PLACEMENT OPTIONS FOR IN-STREET PEDESTRIAN CROSSING SIGNS

Final Report

SPR 870

Oregon Department of Transportation

PLACEMENT OPTIONS FOR IN-STREET PEDESTRIAN CROSSING SIGNS

Final Report

SPR 870

By

Sirisha Kothuri, Ph.D., Senior Research Associate
Chris Monsere, Ph.D., P.E. Professor
Elizabeth Yates, Graduate Research Assistant
Portland State University
P.O. Box 751
Portland, OR 97207

for

Oregon Department of Transportation
Research Section
555 13th Street NE, Suite 1
Salem OR 97301

and

Federal Highway Administration
1200 New Jersey Avenue SE
Washington, DC 20590

June 2026

Technical Report Documentation Page

<table>
<tr><td colspan="2">1. Report No.
FHWA-OR-RD-26-13</td><td colspan="2">2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="4" rowspan="2">4. Title and Subtitle
Placement Options for In-Street Pedestrian Crossing Signs</td><td colspan="2">5. Report Date
June 2026</td></tr>
<tr><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="4">7. Author(s)
Sirisha Kothuri, Chris Monsere, Elizabeth Yates</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="4" rowspan="2">9. Performing Organization Name and Address
Portland State University
P.O. Box 751
Portland, OR 97207</td><td colspan="2">10. Work Unit No. (TRAIS)</td></tr>
<tr><td colspan="2">11. Contract or Grant No.</td></tr>
<tr><td colspan="4" rowspan="2">12. Sponsoring Agency Name and Address
Oregon Dept. of Transportation
Research Section and Federal Highway Admin.
555 13th Street NE, Suite 1 — 1200 New Jersey Avenue SE
Salem, OR 97301 — Washington, DC 20590</td><td colspan="2">13. Type of Report and Period Covered
Final Report</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="6">15. Supplementary Notes</td></tr>
<tr><td colspan="6">16. Abstract This study evaluated the effects of R1-6a pedestrian crossing signs, installed in various configurations, on driver yielding behavior at uncontrolled marked crosswalks across six Oregon locations. The research analyzed both staged and naturalistic crossings under different experimental conditions, including baseline, tubular markers, single and multiple R1-6a signs, and gateway installations. Video data were coded to assess crossing volumes and yielding rates for over 5,900 pedestrians. Baseline yielding was already high, averaging 85% nearside and 89% farside, but increased further with sign treatments. The gateway configuration achieved the highest yielding rates of 92% (nearside) and 97% (farside), while curb-top edge sign placement produced 87% nearside yielding and 99% farside yielding. These findings demonstrate that R1-6a signs, particularly in gateway configurations, enhance driver yielding even when baseline compliance is high, though variations across sites highlight the influence of differing roadway contexts and pedestrian environments.</td></tr>
<tr><td colspan="3">17. Key Words
Pedestrian Safety, In-Street Crossing Signs, Gateway Configuration</td><td colspan="3">18. Distribution Statement
Copies available from NTIS, and online at http://www.oregon.gov/ODOT/TD/TP_RES/</td></tr>
<tr><td colspan="2">19. Security Classification (of this report)
Unclassified</td><td colspan="2">20. Security Classification (of this page)
Unclassified</td><td>21. No. of Pages
133</td><td>22. Price</td></tr>
</table>

Technical Report Form DOT F 1700.7 (8-72) Reproduction of completed page authorized Printed on recycled paper

SI* (Modern Metric) Conversion Factors
Approximate Conversions to SI Units

Physical Quantity	Symbol	When You Know	Multiply By	To Find	Symbol
Length	n	inches	25.4	millimeters	mm
Length	ft	feet	0.305	meters	m
Length	yd	yards	0.914	meters	m
Length	mi	miles	1.61	kilometers	km
Area	in2	square inches	645.2	square millimeters	mm2
Area	ft2	square feet	0.093	square meters	m2
Area	yd2	square yard	0.836	square meters	m2
Area	ac	acres	0.405	hectares	ha
Area	mi2	square miles	2.59	square kilometers	km2
Volume	fl oz	fluid ounces	29.57	milliliters	mL
Volume	gal	gallons	3.785	liters **	L
Volume	ft3	cubic feet	0.028	cubic meters	m3
Volume	yd3	cubic yards	0.765	cubic meters	m3
Mass	oz	ounces	28.35	grams	g
Mass	lb	pounds	0.454	kilograms	kg
Mass	T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
Temperature (exact degrees)	oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	oC
Illumination	fc	foot-candles	10.76	lux	lx
Illumination	fl	foot-Lamberts	3.426	candela/m2	cd/m2
Force and Pressure or Stress	lbf	poundforce	4.45	newtons	N
Force and Pressure or Stress	lbf/in2	poundforce per square inch	6.89	kilopascals	kPa

*SI is the symbol for the International System of Measurement

** Volumes greater than 1000 L shall be shown in m^3

SI* (Modern Metric) Conversion Factors
Approximate Conversions from SI Units

Physical Quantity	Symbol	When You Know	Multiply By	To Find	Symbol
Length	mm	millimeters	0.039	inches	in
Length	m	meters	3.28	feet	ft
Length	m	meters	1.09	yards	yd
Length	km	kilometers	0.621	miles	mi
Area	mm2	square millimeters	0.0016	square inches	in2
Area	m2	square meters	10.764	square feet	ft2
Area	m2	square meters	1.195	square yards	yd2
Area	ha	hectares	2.47	acres	ac
Area	km2	square kilometers	0.386	square miles	mi2
Volume	mL	milliliters	0.034	fluid ounces	fl oz
Volume	L	liters	0.264	gallons	gal
Volume	m3	cubic meters	35.314	cubic feet	ft3
Volume	m3	cubic meters	1.307	cubic yards	yd3
Mass	g	grams	0.035	ounces	oz
Mass	kg	kilograms	2.202	pounds	lb
Mass	Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
Temperature (exact degrees)	oC	Celsius	1.8C+32	Fahrenheit	oF
Illumination	lx	lux	0.0929	foot-candles	fc
Illumination	cd/m2	candela/m2	0.2919	foot-Lamberts	fl
Force and Pressure or Stress	N	newtons	0.225	poundforce	lbf
Force and Pressure or Stress	kPa	kilopascals	0.145	poundforce per square inch	lbf/in2

For More Information see: https://www.fhwa.dot.gov/publications/convtabl.cfm

ACKNOWLEDGEMENTS

We would like to thank Josh Roll, ODOT's research coordinator, for expertly managing the study. We extend our gratitude to Gary Obery for this assistance throughout the study. We would also like to thank the members of the Technical Advisory Committee, whose valuable guidance and feedback ensured the success of this project. We also greatly appreciate the efforts of the Portland State University students - Alison Kirkpatrick, Isa Swain, Delaney Burkett, who performed the staged crossings at the various sites and Steven Lowe and Stefan Fricke, who helped with the video data reduction.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Approximately, 7,148 pedestrians were killed in the US in 2024, which decreased 4.3% from 2023 and represent a second annual decline in a row, but is still 20% higher than 2016 levels (GHSA, 2025). Specifically, in Oregon, there were 99 pedestrian fatalities in 2024, which represented an 8.3% decrease since 2023, but an increase of 32% since 2016 (GHSA, 2025). An analysis of U.S. pedestrian fatality trends between 1977 to 2016 found that pedestrian fatalities are more common in urban areas on arterial roadways, where vehicles are traveling at higher speeds and drivers fail to yield to pedestrians (Schneider, 2020). To achieve a safe transportation system, it is critical to improve pedestrian safety by installing treatments that encourage greater rates of drivers yielding to people walking.

One such treatment is the R1-6a in-street pedestrian crossing signs installed in a gateway configuration. FHWA has identified the R1-6a sign as a highly effective, low-cost engineering countermeasure that can be used to improve pedestrian safety in a proactive and systemic manner. Previous research by Western Michigan University (WMU) evaluated factors related to the efficacy of the gateway treatment, determined the long-term effects of permanent installations, and examined configurations that contribute to the effectiveness of the treatment (Van Houten and Hochmuth, 2016). The study found that the position of the sign is a critical factor influencing driver yielding behavior (Van Houten and Hochmuth, 2016). Signs placed on the white lane line resulted in higher yielding than signs placed at the edge of the roadway and both these configurations resulted in less yielding than the full gateway configuration (Hochmuth et al., 2023). Analysis of speed data showed that the gateway treatment was associated with large speed reductions even when pedestrians were not present at the crosswalk (Van Houten and Hochmuth, 2017).

The 2009 version of the MUTCD did not support installing in-street pedestrian crossing signs in a gateway configuration or using more than one R1-6a sign at a crosswalk (FHWA, 2009). A new version of the MUTCD was released after this study commenced in 2023 including a supplemental summary of dispositions for final rule changes (FHWA, 2023). New clarification was added to the language to allow for placement of more than one sign, including placement on the edge line when beneficial. Additionally, the new MUTCD also offers flexibilities for the use of channelizing devices at midblock pedestrian crossings in conjunction with the in-street pedestrian crossing signs and suggests that when tubular markers are used to supplement a R1-6 series sign that is either on the center line, lane line, or median island, they should not be used on the same pavement marking line where the R1-6 series sign is installed (FHWA, 2023).

Carefully executed comparisons of MUTCD-compliant installations of the R1-6a signs including the use of tubular markers and R1-6a signs in either a single (one tubular marker or sign) or multiconfiguration (multiple signs with or without tubular markers in gateway-style installations) are needed to update national, state, and local guidance on these signs to determine which placements are most effective especially in the Oregon context.

1.1 RESEARCH OBJECTIVES

The objective of this research was to evaluate various R1-6a installation configurations at multiple sites to determine the differences in driver yielding behavior. The research aimed to provide guidance on which configurations are more effective with respect to driver yielding. Additional objectives include evaluation of maintenance costs and durability of the signs over time as well as how signs handle winter maintenance.

1.2 ORGANIZATION OF FINAL REPORT

The remainder of this report contains the following. Chapter 2 presents a review of pedestrian crossing treatments at uncontrolled locations, specifically those focused on improving driver yielding and their safety effectiveness. Chapter 3 describes the data collection process including assembling an inventory of locations, site selection, data collection protocol, data extraction, validation, integration and metrics. Chapter 4 presents the data analysis process, results and a discussion of the findings. Chapter 5 concludes the report with a summary of the study's key findings, recommendations and opportunities for future work.

2.0 LITERATURE REVIEW AND PRACTICE SURVEY

This chapter presents a review of pedestrian crossing treatments at uncontrolled locations, specifically those focused on improving driver yielding and their safety effectiveness. Treatments reviewed include crosswalk markings, in-street pedestrian signs, rectangular rapid flashing beacons (RRFBs) and pedestrian hybrid beacons (PHBs).

This literature review includes peer reviewed journal articles, conference papers, technical reports, and guidebooks produced by state and federal transportation agencies. These documents were obtained from searching journal archives such as those maintained by the Transportation Research Board (i.e. TRID) and Google (i.e. Scholar), general search engines (i.e. Google), Transportation Agency websites (i.e. ODOT), and the reference lists of those identified documents.

2.1 UNCONTROLLED LOCATIONS

Uncontrolled pedestrian crossing locations are where sidewalks or walkways intersect a roadway at a location with no traffic control (Blackburn et al., 2018). These can occur either at intersections or midblock locations. Research has shown that uncontrolled pedestrian crossing locations correspond to higher pedestrian crash rate (Blackburn et al., 2018). Various countermeasures have been deployed to improve pedestrian safety at uncontrolled locations such as crosswalk visibility enhancements (e.g., high visibility crosswalk markings), In-street pedestrian crossing signs, Pedestrian Hybrid Beacons (PHBs), Rectangular Rapid Flashing Beacons (RRFBs), raised crosswalk, pedestrian refuge islands and road diets. Federal Highway Administration's Guide for Improving Pedestrian Safety at Uncontrolled Locations provides guidance on selecting an appropriate countermeasure based on roadway configuration, posted speed limit and Annual Average Daily Traffic (AADT) as shown in Figure 2.1 from Blackburn et al., 2018. Selected countermeasures i.e., crosswalk markings, In-street pedestrian crossing signs, PHBs and RRFBs are reviewed in the following sections.

Roadway Configuration	Posted Speed Limit and AADT								
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 lanes (1 lane in each direction)	❶ 2 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6 7 9	① 5 6 7 9	① 5 6 ❾
3 lanes with raised median (1 lane in each direction)	❶ 2 3 4 5	❶ ❸ 5 7 9	① ❸ 5 ❼ ❾	① 3 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① ❸ 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❾
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 ❾	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 ❾	① ❸ 4 5 6 7 9	① ❸ 5 6 ❾	① ❸ 5 6 ❾
4+ lanes with raised median (2 or more lanes in each direction)	❶ ❸ 5 7 8 9	❶ ❸ 5 7 8 9	① ❸ 5 8 ❾	① ❸ 5 7 8 9	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 8 ❾
4+ lanes w/o raised median (2 or more lanes in each direction)	❶ ❸ 5 6 7 8 9	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 8 ❾

Given the set of conditions in a cell,

- \# Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1. High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2. Raised crosswalk
3. Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4. In-Street Pedestrian Crossing sign
5. Curb extension
6. Pedestrian refuge island
7. Rectangular Rapid-Flashing Beacon (RRFB)**
8. Road Diet
9. Pedestrian Hybrid Beacon (PHB)**

Figure 2.1: Pedestrian Crash Countermeasure by Roadway Feature (FHWA, 2018)

2.2 CROSSWALK MARKINGS

According to the MUTCD, crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops (FHWA, 2009). At uncontrolled intersections, crosswalk markings also alert the drivers of pedestrian presence. In the U.S. crosswalk markings are typically either standard parallel, continental, ladder or zebra as shown in Figure 2.2 below. Several studies have explored the safety effects between marked and unmarked crosswalks. Most studies conducted between 1972 and 2000 found that pedestrian crashes were higher in marked crosswalks than unmarked crosswalks (Herms 1972; Gurnett 1974; Gibby et al., 1994; Jones and Tomcheck 2000), while one study found lower pedestrian crashes at marked crosswalks than unmarked crosswalks (Tobey et al., 1983). However, these studies combined all sites with marked crosswalks and unmarked crosswalks and did not conduct a separate analysis for different cross-sections, traffic volumes, and other roadway features (Mead et al., 2014).

The most comprehensive study was conducted by Zegeer et al., who analyzed data from 1,000 marked and 1,000 unmarked crosswalks at uncontrolled locations in 30 cities (Zegeer et al., 2002). The study did not find any statistically significant differences in pedestrian crash risk for the various crosswalk markings, area type and speed limit (Zegeer et al., 2002). Factors that were related to pedestrian crashes included pedestrian Average Daily Traffic (ADT), vehicle ADT, number of lanes, median type, and region of the United States (Zegeer et al., 2002). Findings from Poisson and binomial regression models revealed that at uncontrolled locations on two-lane roads and multi-lane roads with low traffic volumes (ADT below 12,000 vehicles per day), a marked crosswalk alone compared with an unmarked crosswalk did not result in statistically significant difference in pedestrian crash rate (Zegeer et al., 2002). However, on multi-lane roads with an ADT greater than 12,000 vehicles per day, a marked crosswalk in the absence of other substantial improvements was associated with a statistically significant higher pedestrian crash rate compared to sites with an unmarked crosswalk (Zegeer et al., 2002). Zegeer et al. theorized that the higher crash rates seen at higher volume locations was due to higher observed older pedestrian crashes and the propensity of older pedestrians to cross at marked crosswalks than at unmarked crosswalks (Zegeer et al., 2002). Additionally, on multi-lane roads, the potential for multiple threat crashes is higher, which can also result in a higher crash rate (Zegeer et al., 2002). On multi-lane roads, the presence of raised medians in marked or unmarked crosswalks provided statistically significant lower crash rates than no raised median (Zegeer et al., 2002).

Other studies have analyzed the effect of crosswalk markings on driver and pedestrian behavior (Knoblauch et al., 2000, 2001). The first study evaluated driver and pedestrian behavior at 11 unsignalized locations in four U.S. cities, with all the sites situated on two or three lane roadways with speed limits between 35 and 40 mph. The findings revealed that marked pedestrian crosswalks did not have a negative effect on pedestrian or motorist behavior. The second study evaluated driver speed at six marked crosswalk locations in Maryland, Virginia, and Arizona. The study collected speed under three conditions – no pedestrian present, pedestrian looking, and pedestrian not looking. The study found a small reduction in vehicle approach speeds at some crosswalks, after the markings were installed and a significant reduction in speed when pedestrians were either not present or not looking (Knoblauch et al., 2001). Another study evaluating pedestrian and driver behavior at uncontrolled locations with marked and unmarked crosswalks found that drivers were more likely to yield to pedestrians in marked crosswalks than in unmarked crosswalks (Mitman et al., 2008).

2.2.1 High Visibility Crosswalks

High visibility markings (e.g., continental, bar pair or ladder) are used at special emphasis locations where vulnerable populations (children, older adults) are crossing, or where drivers are less likely to expect pedestrians (O'Brien et al., 2022). The various types of high visibility markings are shown in .

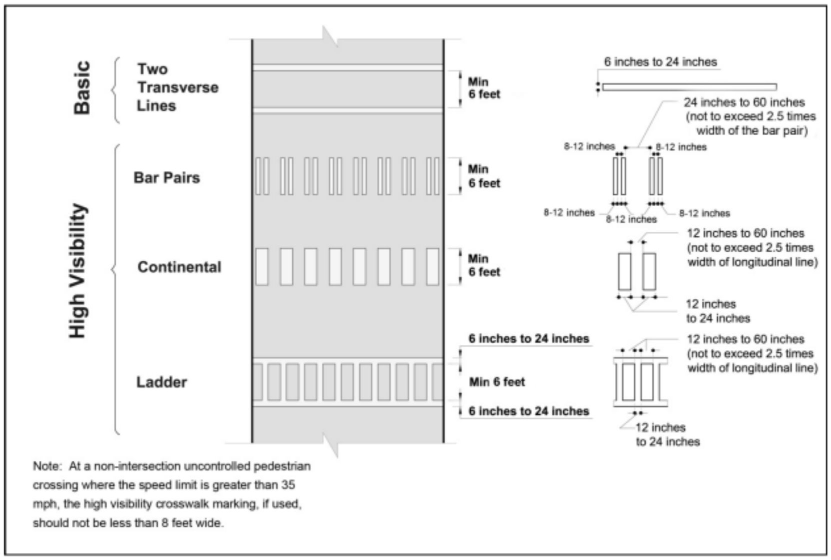


Figure 2.2: Types of Crosswalk Markings (NCUTCD, 2012)

An early study in 2001 by Nitzburg and Knoblauch studied the effectiveness of high-visibility crosswalk markings used along with an illuminated overhead crossing sign at two sites in Florida (Nitzburg and Knoblauch, 2001). The study compared motorist and pedestrian behavior at these two sites with two control sites, one of which had basic crosswalk markings and the other which had no crosswalk markings. Their results revealed statistically significant increase in yielding during day (30%-40%) at the locations with the high visibility crosswalk markings and a smaller insignificant increase in driver yielding at night (8%). They also observed a significant increase in pedestrian using the crosswalks at the treatment sites (Nitzburg and Knoblauch, 2001). While the impact of the high visibility crosswalk markings could not be separated from the overhead sign, the authors concluded that the treatments improved pedestrian safety. NCHRP 562 explored the effect of crossing treatments on driver yielding rates and found that compliance varied between 10% to 61% at three sites with high visibility markings (Fitzpatrick et al., 2006).

Another study conducted an Empirical Bayes analysis of high visibility crosswalks at 54 sites near schools in San Francisco to predict the number of crashes that could be expected in the absence of these markings (Feldman et al., 2010). The study found a statistically significant reduction in crashes by 37 percent (Feldman et al., 2010). Another study evaluated the relative visibility of the different crosswalk markings (transverse, continental, and bar pair) under day and night conditions (Fitzpatrick et al., 2011). The study recruited 78 participants to drive an instrumented vehicle on a route in College Station, TX. The participants were asked to identify crosswalks when they first identified them and these distances were recorded by the researchers (Fitzpatrick et al., 2011). They found that detection distances for continental and bar pair markings to be statistically similar and significantly longer than transverse markings during both day and night. The researchers recommended the addition of bar pair markings to the MUTCD and suggested making the bar pair or continental markings the default crosswalk marking at uncontrolled approaches (Fitzpatrick et al., 2011). Another study evaluated high-visibility crosswalks either installed individually or in combination with other countermeasures (median refuge, offset, and pedestrian channelization) at 8 sites in Las Vegas, NV (Pulugurtha et al., 2012). They found that at sites where the high visibility crosswalks were installed individually, a statistically significant increase in the proportion of pedestrians who looked for vehicles before beginning to cross, a significant increase in the distance at which drivers yielded to pedestrians, and a statistically significant decrease in the number of pedestrians trapped in the middle of the street was observed (Pulugurtha et al., 2012).

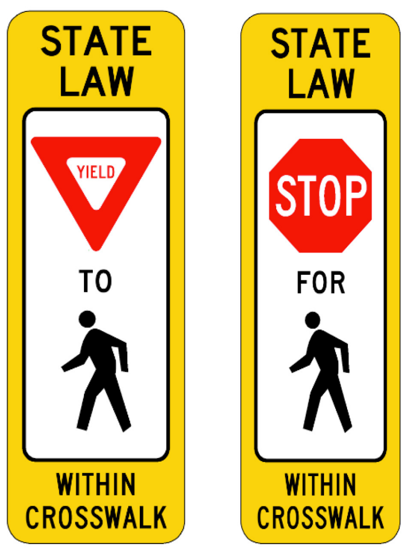
A recent study explored the impacts of crosswalk marking style on driver yielding and pedestrian compliance and studied the effectiveness at existing high visibility crosswalk locations at 65 sites in North Carolina (O'Brien et al., 2022). The findings revealed that driver yielding increased by 22% at sites that were converted to high visibility crosswalk markings, which was significantly different from the change in yield rate observed as sites where crosswalk markings did not change (O'Brien et al., 2022). The highest increase in driver yielding rates was observed at sites that were converted from unmarked crossings to high visibility crosswalk markings, however sites that were converted from transverse to high visibility markings also saw an increase in driver yielding rates (O'Brien et al., 2022). Pedestrian compliance was also observed to increase at sites with high visibility crosswalk markings. The authors found locations with high visibility markings increased from 11.3% to 29% in the before period to 35.7% in the after period. The authors concluded that at the current saturation rates of 40%, the increase in saturation of high visibility markings did not adversely impact the effectiveness of these markings (O'Brien et al., 2022).

2.3 IN-STREET PEDESTRIAN SIGNS

In-street pedestrian signs were first tested in 2000 by Huang et al. for FHWA (Huang et al., 2000). The evaluation consisted of safety cones with a message as shown in Figure 2-3. These signs were tested at 6 sites in New York State and one site in Portland, OR. The study collected pre- and post-treatment data and found that driver yielding increased from 69.8% to 81.2% post treatment across the sites, and the increase in yielding was statistically significant (Huang et al., 2000). The proportion of pedestrians who ran, hesitated, or aborted the crossing decreased but the decrease was not statistically significant.

Figure 2.3: Early Version of the In-Street Pedestrian Signs (Huang et al., 2000)

The in-street pedestrian crossing signs (R1-6) were first included in the 2003 edition of the MUTCD. Two versions of this sign exist including the text YIELD TO (R1-6) or STOP FOR (R1-6a) pedestrians in crosswalk depending on the location where they are used and the prevailing laws. MUTCD stipulates that these signs shall not be used at signalized intersections (FHWA, 2009). Oregon law requires that drivers stop and remain stopped at any crosswalk (marked or unmarked) until the pedestrian has cleared the lane the driver is in plus the next lane. Thus, the R1-6a sign is applicable for Oregon. Figure 2-4 shows the R1-6 and R1-6a signs.



R1-6 R1-6a

Figure 2.4: In-Street Pedestrian Crossing Signs (FHWA, 2009)

Other studies since then have tested the efficacy of in-street pedestrian crossing signs in Madison, WI and Cedar Rapids, IA (City of Madison, 1999; Kannel et al., 2003). Although the results showed statistically significant increases in yielding, however, these results were not consistent across all sites due to site differences. Kamyab et al. installed a removable pedestrian island and pedestrian crossing signs on a two-lane highway in Minnesota and found a statistically significant reduction in average speed and increase in speed limit compliance both in short and long-term (Kamyab et al., 2003).

Ellis et al. explored the placement of the in-street pedestrian signs at varying distances upstream of selected crosswalks in Miami Beach, FL (Ellis et al., 2007). The distances tested were at the crosswalk itself (i.e., 0 ft), 20 ft and 40 ft in advance of the crosswalk. The results revealed that the signs alone were effective in increasing driver yielding and the installation of the sign at the crosswalk was as effective or more effective than installation of the signs either at 20 or 40 ft upstream of the crosswalk. The study also showed that placement of signs at all three locations simultaneously (at the crosswalk, 20 ft, and 40 ft in advance of the crosswalk) was not more effective than placement of the sign at the crosswalk line. The authors also recommended installing the signs on median islands where possible to extend their life (Ellis et al., 2007).

Bennett et al. examined the effectiveness of in-street signs (R1-6) placed in a gateway configuration, which consisted of 1 sign installed between 2 travel lanes in each direction and one on both edges of the roadway in each direction on multi-lane roads (Bennett et al., 2014). Three experiments were conducted as a part of this study. For the first experiment, driver yielding rates were compared between the baseline condition (no signs), one in-street sign and gateway configuration. The results from this experiment conducted at two sites in Michigan showed that yielding rates increased from the baseline condition (23% - 25%) to when one in-street sign was present (45% - 56%) and was the highest for the gateway configuration (79% - 82%) indicating that the gateway configuration was most effective in improving driver yielding rates (Bennett et al., 2014). The second experiment compared the yielding rates obtained with the gateway configuration in conjunction with PHBs to yielding obtained when using PHBs alone. The baseline condition consisted of crossings with PHBs where the PHB was inactivated and there were no in-street signs (1% -10% yielding). The one sign condition had one in-street sign that was placed in between the travel lanes and the PHB was not activated (44%). The PHB alone condition, had the PHB activated but there were no in-street signs present (62% - 85% yielding). The sign plus PHB condition had the PHB active and one in-street sign present between the travel lanes (85% - 94.5% yielding). The gateway configuration had three in-street signs in each direction with the PHB not active (72% yielding). The results show that the addition of an in-street sign to the PHB at both sites increased yielding to higher levels than the PHB alone. The gateway in-street signs were as effective as PHB alone (Bennett et al., 2014). The third experiment involved studying the effects of combining a single in-street sign and the gateway in-street sign configuration with the RRFB. The results show that the gateway in-street signs (80% yielding) produced effects that were similar to RRFB (69% yielding) and that the combination of gateway in-street signs and RRFB (85% yielding) produced yielding rates that were similar to the gateway in-street signs alone. The study also noted two disadvantages with in-street signs namely that these cannot be left in place during winter months (due to plowing), and they need to be replaced more frequently than PHBs and RRFBs due to damage.

Another study compared the R1-6 gateway treatment with the sign message either present or absent (Bennett and Van Houten, 2016). The results from this study showed that the use of yellow-green blanks without the sign message resulted in an increase in yielding rate from 7% to 33%, while the addition of the message increased yielding rate to 78% (Bennett and Van Houten, 2016). Different sign configurations were also tested, and the results revealed that the gateway configuration was the most effective in improving yielding rates. The study also tested the placement of edge signs in the gutter pan and found that it was only slightly more effective than placement on the curb face, however installing the signs on the curb face will increase the life of the signs as they are less likely to get hit by vehicles (Bennett and Van Houten, 2016). The study also tested the substitution of a flexible delineator post instead of the lane line signs which resulted in a decrease in yielding compared to the original gateway configuration with the in-street signs (88% vs. 65%; 76% vs. 55%).

Van Houten and Hochmuth conducted a longer-term evaluation of the yielding associated with the in-street pedestrian crossing signs placed in a gateway configuration and found increase in yielding from 15% to 70% post gateway sign installation and these increases held steady over the course of a few months (Van Houten and Hochmuth, 2016). They also collected speed data at the treated sites and found 4 to 5 mph reduction in average speeds in the absence of pedestrians in the crosswalk (Van Houten and Hochmuth, 2016). The study also tested the placement of signs at 5, 10, 20, 30, and 50 ft in advance of the crosswalk. The results showed that advance placement of the signs produced a significant increase in the likelihood of drivers yielding in advance of the crosswalk (i.e., they are yielding earlier) when compared to the crosswalk placement of signs, although the overall yielding rates were similar across both placements. The study results also revealed that signs mounted on a curb type mount with a flexible rubber attachment all survived, whereas only 58% of the flush mounted signs with a pivoting base survived (Van Houten and Hochmuth, 2016). The study results also revealed that signs mounted on the top of the edge of the curb on a refuge island or median island, curb extension or curb on the edge of the roadway did not get damaged (Van Houten and Hochmuth, 2016).

A study conducted in Florida by the Florida Department of Transportation evaluated partial and full gateway treatment at multiple sites (El-Urfali and Van Houten, 2021). The sites included roadways with two-lanes, four-lane divided and undivided facilities with and without median islands, and six-lane roadways with median island. Overall, the full gateway treatment produced the highest yielding rates, followed by the partial gateway and the single sign. Location of the signs was critical in determining sign durability. Signs placed on the median island were durable, whereas signs placed on the lane lines and centerline did not survive. To improve survivability, the centerline and the lane line signs were substituted with flexible delineators. However, the flexible delineators also showed poor survival rates when placed on lane lines and centerlines. The gateway treatment with R1-6 signs and flexible delineators was found to be less effective in increasing driver yielding than using curb mounted signs at each location. Curb top placement of signs and placement of signs in the gutter pan, or on the road immediately adjacent to the curb increased sign survivability. Full gateway treatments also produced a marked reduction in vehicle speed, while the partial gateway treatment produced a significant shift in the speed distribution by reducing higher speeds.

A recent study evaluated the R1-6 signs in combination with marked crosswalks, flexpost refuge islands, and concrete refuge islands (Baumanis and Machemehl, 2022). Overall, the R1-6 sign increased yielding compliance by 8% assuming no interaction between R1-6 sign and crossing type. When interaction is considered, the probability of yielding increased by 50% at concrete refuge islands, for flexpost islands the sign improves yielding probability by 4% and by 3% at marked crosswalks (Baumanis and Machemehl, 2022). The gateway configuration of the R1-6 signs was not tested in this study.

2.4 RECTANGULAR RAPID FLASHING BEACONS

RRFBs are used at uncontrolled locations to enhance pedestrian safety by incorporating a flash pattern to alert drivers to the presence of pedestrians. RRFBs were first granted interim approval by FHWA in 2008. These are typically activated by pedestrian pushbuttons. shows a RRFB situated at Rock Creek Trail Crossing on NW West Union Rd.

Figure 2.5: RRFB at Rock Creek Trail Crossing on NW West Union Rd.

Many studies explored the impacts of RRFBs on driver yielding behavior and found increases in yielding rates (Van Houten et al., 2008; Pecheux et al., 2009; Hua et al.,2009; Hunter et al. 2009; Shurbutt et al. 2010; Ross et al. 2011; Domarad et al. 2013; Foster et al. 2014, Al-Kaisy et al., 2018). These studies also found significant decrease in the number of pedestrian-vehicle conflicts and the number of trapped pedestrians in the roadway. One study explored the differences in driver yielding rates and pedestrian behavior at midblock crossings on three-lane roadways with RRFBs with and without median refuge islands and center beacon and found overall high yielding rates at the 23 selected sites (Kothuri et al., 2021). Although the high yielding rates and sample size precluded any conclusive observations, generally yielding rates increased with the addition of median beacons and median refuge islands with beacons, with the increase being statistically significant on roadways with ADT between 12,000 to 15,000 (Kothuri et al., 2021). Driver yielding rates were also higher on the far side than the near side (Fitzpatrick et al., 2016; Kothuri et al., 2021). One study also reported that crosswalks equipped with RRFBs attracted more pedestrians despite the presence of other crosswalks nearby (Foster et al., 2014).

A NCHRP study developed crash modification factors for four treatment types -RRFBs, PHBs, refuge island, and advance yield or stop markings and signs using 975 treatment and comparison sites from 14 cities in the US (Zegeer et al., 2017). Cross-sectional regression models and before-after empirical Bayes methods were used determine the crash effects of each treatment type. While all treatment types were associated with reduction in pedestrian-vehicle crash risk, RRFB sites were associated with a 47% reduction in crash risk (Zegeer et al., 2017). The authors did state that due to low sample sizes, the RRFB Crash Modification Factors (CMFs) should be used with caution.

2.5 PEDESTRIAN HYBRID BEACONS

Pedestrian hybrid beacons, also known as High-Intensity Activated CrossWalK (HAWK) were first used in Tucson, AZ in 2000 to enable safe crossings at locations where minor streets intersected with major arterials (Nassi and Barton, 2008). PHBs were included for the first time in the MUTCD in 2009 (FHWA, 2009). Since then, they have been used widely and have been the focus of many research studies evaluating their safety impacts. Fitzpatrick et al. studied motorist and pedestrian behavior at 5 PHB sites in Tucson, AZ using a mixture of staged and naturalistic pedestrians (Fitzpatrick et al., 2006). Their results showed an average yielding rate of 97%, which is in line with yielding rates seen with traffic signals and other beacons as seen in Figure 2-6 (Fitzpatrick et al., 2006).

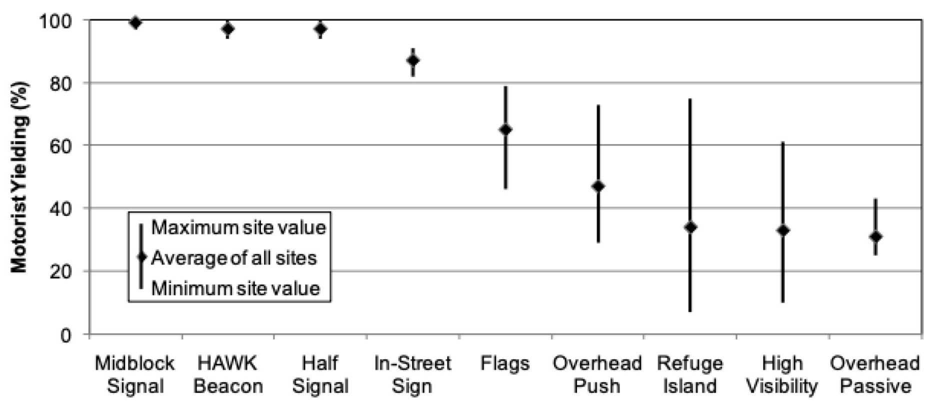


Figure 2.6: Driver Yielding Rates by Countermeasure (FHWA, 2010)

A later study by Fitzpatrick and Park evaluated pre- and post-crash data from treated (PHB) and untreated (comparison) sites to evaluate the safety impacts (Fitzpatrick and Park, 2010). Using an empirical Bayes analysis, the researchers found a 29% reduction in total crashes and 69% reduction in pedestrian crashes, both of which were statistically significant, leading to the conclusion that PHB was an effective pedestrian safety countermeasure (Fitzpatrick and Park, 2010). Other studies have also demonstrated increase in driver yielding rates and explored factors associated with driver yielding (Fitzpatrick et al., 2013; Fitzpatrick et al., 2016). Another study evaluated the safety impacts of PHBs at three sites in Charlotte, NC and found increase in driver yielding, decrease in percentage of trapped pedestrians and a decrease in pedestrian-vehicle conflicts and all three sites, with significant differences observed at one site (Pulugurtha et al., 2015). The study also found an increase in average vehicle speed at one site (Pulugurtha et al., 2015). Crash data analysis did not show any significant changes in pedestrian -vehicle crashes, probably due to the small sample size (Pulugurtha et al., 2015). NCHRP 841 used crash data to develop CMFs for crossing treatments including PHBs using cross-sectional models and before/after Empirical Bayes methods (Zegeer et al., 2017). Their findings revealed that PHBs were associated with reduction in pedestrian crash risk and that PHBs (CMF 0.453) and PHBs with advance YIELD or STOP signs and marking (CMF of 0.432) showed the greatest safety benefit among the countermeasures that were studied (Zegeer et al., 2017).A more recent study evaluated the impacts of PHBs on higher speed roadways in Arizona by selecting 10 sites with operating speeds between 44 and 54 mph (Fitzpatrick et al., 2019). The findings revealed an overall yielding rate of 97 percent, 25% crash reduction for severe crashes, 46% reduction in pedestrian crashes and 29% reduction in severe rear-end crashes (Fitzpatrick et al., 2019).

The research findings all point to PHBs as an effective countermeasure to improve pedestrian safety by improving driver yielding and reducing pedestrian-vehicle crashes. PHBs appear to be suitable for multi-lane roadways with posted speed limits up to 50 mph.

2.6 PRACTICE SURVEY

An online survey was designed and administered to transportation professionals to better understand their experiences with using and maintaining the R1-6a signs. The survey consisted of a mix of open-ended and multiple-choice questions that were developed to elicit agency practices and responses regarding sign usage and maintenance practices.

2.6.1 Design

The survey was designed and administered in Qualtrics, an online survey platform that the research team had access to. The survey was designed to be fairly short, and questions were presented neutrally, allowing respondents to provide answers that reflected their agency's practices. Several rounds of review and refinement followed the internal development of the survey questions. Transportation graduate students at PSU and members of the research team tested a pilot survey and provided feedback for further improvements on the format and content of the survey questions. Once the project team was satisfied with the survey design, the survey was finalized. The project team shared the finalized survey with PSU's Institutional Review Board (IRB) and it was determined to be exempt.

2.6.2 Instrument

The survey consisted of 14 questions in total, which included a mix of open-ended and multiple-choice questions. The survey flow incorporated logic to allow certain questions to be skipped, depending on the answers provided for prior questions by the respondents, especially if they were not applicable. Before being shown the questions, all respondents had to provide informed consent for the survey. The questions asked the respondents about their agency's history with sign usage, types of signs used, site selection criteria, types of sign configurations being used, estimated cost and time for replacement, sign management policies for restriping, and winter maintenance.

2.6.3 Administration

The survey was distributed to the Association of Pedestrian & Bicycle Professionals (APBP) through the member email list and to the Institute of Transportation Engineers (ITE) through their newsletter. The survey was active between January – April 2025. Within this period, multiple reminder emails were sent to encourage professionals to take the survey.

2.6.4 Results

Fourteen respondents agreed to take the survey; however, two respondents did not provide responses to any other questions. Of the twelve, ten (83%) replied that they used the sign while two (17%) respondents stated that they did not use them. One of the two respondents who indicated that they did not use the signs, stated that their reason for not using them anymore was that the signs were being struck too often, and the maintenance costs grew too expensive. Therefore, their agency donated several signs to the local university. The other respondent gave no reason as to why they do not use the R1-6a signs.

Of the twelve respondents who responded positively regarding the usage of signs, only five respondents provided an answer to the duration of usage question (between 5 – 15 years). Two agency representatives gave information about the models in use, with one specifying the Qwick Kurb slender base as the preferred model and the bullnose version as a secondary choice. The other representative stated that they (the state) almost always used a weighted base not affixed to the roadway.

Three respondents using the signs, gave information about site characteristics where the R1-6a sign was chosen for deployment. Two respondents said they used the signs only in two-way traffic while the third indicated that one-way or two-way traffic was not a consideration for them, however they mostly used it in downtown areas with higher pedestrian traffic. One respondent stated they used R1-6a signs only on two-lane roads, one on two to three-lanes, and the third on two to four-lane roads. Only two respondents provided information about Annual Average Daily Traffic (AADT) estimates for roadways where these signs were used. One respondent stated that roadways over 6,000 AADT were not considered, while the other respondent stated that roadways over 10,000 AADT were not considered but site selection also depended on number of lanes and other crossing treatments. Posted speeds varied, with one agency reporting usage at 25 to 30 mph locations, another at 30 mph and under locations, and the third using the signs at 35 mph locations. Two agency respondents stated that signs were used at crossings without median islands, however one noted using the signs at crossings with a median island in place. Finally, when asked about special considerations for locating the signs, two respondents said R1-6a signs were used in school crossings, one stated that they were also used near public attractions, one other said that they used the signs primarily in their downtown area and at midblock crossings with high volumes. When asked about the configuration of R1-6a signs used by their jurisdictions, three respondents provided feedback. All three indicated that they used the single sign at the centerline configuration. One respondent indicated they also use the single sign at the centerline with delineators at the edge lines configuration. No agency that responded to the survey reported using the signs in a gateway configuration.

When asked about the cost of installation and replacement of the signs, one respondent indicated that the sign typically costs $400 for each brand-new installation. One respondent also expressed that an investment of time amounting to 15 minutes of labor and 15 minutes of equipment changes is required for installation. This respondent also stated that when replacement is required (i.e., signs are hit by vehicles), usually the base is still functional, limiting replacement to only the upright sign. The respondents were asked about the frequency of sign replacement, opined that location greatly impacted the life expectancy of the R1-6a signs. While installations along a straight segment or midblock can last an entire season (removed during winter), those near curves or intersections need sign replacement once every five times a sign is struck (sign needs replacement, while base is generally intact). When asked about agency management practices of the sign installations for instances of restriping, the agency that uses weighted bases indicated that they just moved their signs out of the way. The other responding agency said that they contracted out their striping and had not thought about it; their best guess is that the contractor must skip over the signs as they are striping.

Finally, when asked if their agency uses snowplows, three respondents indicated that they did plow, with one agency plowing rarely and two plowing regularly over the winter season. The respondent with the agency that rarely plowed, stated that signs are placed outside the plowing area and sometimes on a concrete median. Of the two agencies that plowed regularly, one removes and stores the signs for winter and the other has a parking schedule in neighborhoods limiting parking to one side of the street or the other depending on the date from November 1st through April 1st to accommodate plowing. They remove and reinstall their signs using the same schedule.

When asked if they would like to share any other thoughts, one respondent emphasized the difficulty in finding the "sweet spot" for sign placement before an intersection crossing. They stated that signs get damaged most often, when they are placed too close to a turning radius, which is where most crosswalks typically are. The respondent stated that the ideal spot for sign placement is where the pedestrian feels adequately protected and drivers yield, it is placed close enough but not too far from the crosswalk for drivers to understand and for turning vehicles from the side street to have enough room to maneuver around it. The other respondent felt that these signs can be effective, particularly with delineators on the edge lines, but are most effective when used in the right place contextually i.e., downtown or other high pedestrian volume locations, where slow speeds and pedestrians are expected.

2.6.5 Interview

We also conducted an interview with Carissa McQuiston, a safety manager at the Michigan Department of Transportation (MDOT), who previously oversaw a series of research projects studying the installation, varying configurations and maintenance of R1-6a signs in Michigan. To help with maintenance, a few suggestions were provided.

- Curb top placement was preferred and MDOT had to submit a RTE request to FHWA for approval. However, no database keeps track of where these changes were made.
- Installing the signs setback (30-50 ft) from the crosswalk, also helped with maintenance issues, while not affecting the yielding compliance.
- MDOT replaced certain signs that were getting hit with flexible delineators, which are hardier. The yielding rates were lower than those observed with the signs, but they still worked.
- Signs are removed in winter.

The success of R1-6a signs increases when it is part of a suite of treatments used to communicate to drivers that they are in a shared space. In Michigan, they have been mainly used on roadways with speed limits of 25 mph and downtown setting, with 35 mph being the highest. Yielding was found to increase when the signs are used with RRFBs or curb extensions. Another situation that improves success is community-wide usage, which sets the expectation that drivers share space with pedestrians and other vulnerable road users. Educational campaign was not conducted, as these are pretty common signs especially around schools.

Finally, the research team asked if there was any evidence of drivers stopping short or increasing rear-end crashes at locations where the R1-6a treatment was installed. While MDOT had heard anecdotally about this concern, there is no data to support that rear-end crashes have increased due to this treatment.

2.7 SUMMARY

This chapter presented the findings of a literature review, a state of practice survey and an interview to understand the usage and impact of R1-6a signs. The literature review considered previously conducted studies relevant to the safety of pedestrians at uncontrolled locations. The review provided a synthesis of pedestrian treatments to improve safety at uncontrolled locations including crosswalk markings, in-street signs, RRFBs and PHBs. Some of the key literature review findings include:

- At uncontrolled locations on two-lane roads and multi-lane roadways with low traffic volumes (ADT < 12,000), there was no difference in crash rate between locations with marked crosswalks and unmarked crosswalks.
- On multi-lane roads with ADT >12,000 vehicles per day, a marked crosswalk in the absence of other substantial improvements was associated with a statistically higher pedestrian crash rate compared to sites with an unmarked crosswalk.
- High-visibility markings led to increase in driving yielding rates compared to transverse markings.
- In-street pedestrian signs increased driver yielding rates compared to the baseline condition with no signs and yielding rates were highest when the signs were installed in a gateway configuration.
- The addition of an in-street sign to the PHB increased yielding to higher levels than the PHB alone. The gateway in-street signs were as effective as PHB alone.
- Gateway in-street signs produced yielding rates that were similar to RRFB and the combination of gateway in-street signs and RRFB produced results that were similar to the gateway in-street signs alone.
- Advance placement of the in-street signs produced a significant increase in the likelihood of drivers yielding in advance of the crosswalk when compared to the crosswalk placement of signs, although the overall yielding rates were similar across both placements.
- Signs mounted on a curb type mount with a flexible rubber attachment lasted longer than flush mounted signs with a pivoting base. Signs mounted on the top of the edge of the curb on a median island, curb extension or curb on the edge of the roadway did not suffer any damage.
- RRFBs increased driver yielding rates and resulted in significant decrease in the frequency of pedestrian-vehicle conflicts and crashes, and number of trapped pedestrians in the roadway.

- PHBs are associated with high yielding rates similar to those seen with traffic signals and other beacons.
- PHBs also resulted in significant decrease in pedestrian-vehicle crashes.

The findings from the survey revealed that optimal placement for R1-6a signs is key for improved yielding and reduced maintenance. The signs were generally installed on one-three lane roadways and in areas where higher pedestrian volumes were expected. Respondents also revealed that they remove the signs in the winter for snowplowing. An interview with MDOT revealed that curb top placement, setting back the signs (30-50 ft) from the crosswalk and replacing the signs that were frequently struck with flexible delineators and removing the signs during winter were some of the best practices that they follow.

Although, many studies have showed an increase in driver yielding rates with the gateway configuration of the in-street pedestrian signs, there are currently no studies that have been undertaken in Oregon. This research aims to evaluate various R1-6a installation configurations to understand which configurations work best in the Oregon context.

3.0 DATA COLLECTION

This chapter describes the data collection process including assembling an inventory of locations, site selection, data collection protocol, data extraction, validation, integration and metrics.

3.1 INVENTORY OF LOCATIONS

To compile an inventory of locations, the research team obtained a file containing marked crosswalks from the Oregon Department of Transportation (ODOT). This file contained 4,487 rows, including 205 rows where crosswalks previously existed but were later removed. These 205 rows were removed from the dataset to yield 4,282 locations which currently have marked crosswalks. These included both uncontrolled and controlled locations. From this dataset, the controlled locations were removed, resulting in a potential sample of 1,144 marked crosswalks at uncontrolled locations. These locations were further filtered to include only crosswalks in ODOT Regions 1, 2 and 4 based on conversations with region and district staff from ODOT regarding their willingness and resource (staff and budget) availability to install the treatments across the various stages. This resulted in a potential sample of 413 locations, shown in Figure 3.1.

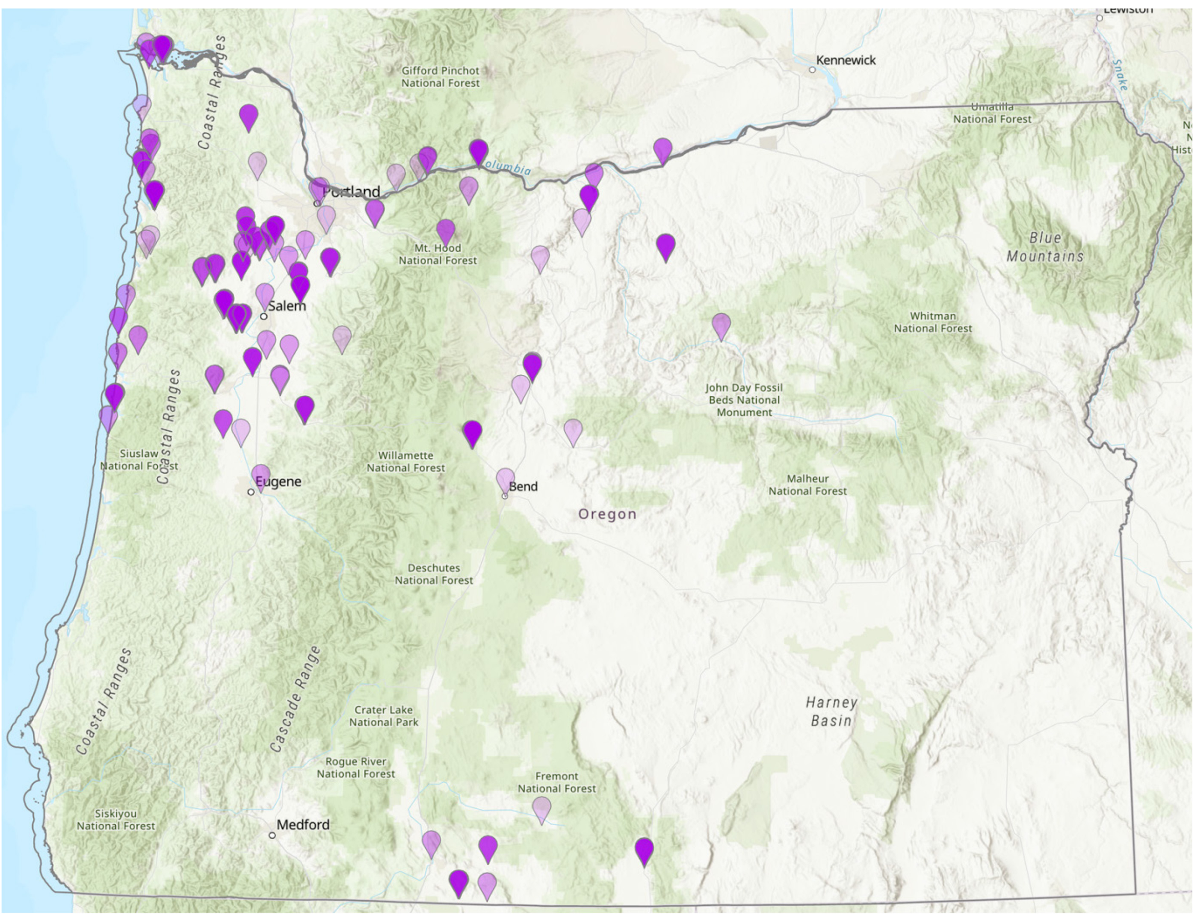


Figure 3.1: Map of potential study locations

3.2 SITE SELECTION

The objective of the site selection process was to select a variety of locations to study, to ensure various configurations of the signs can be tested. The following criteria were identified to be desirable at the selected sites.

- Uncontrolled location (i.e., no traffic signals, RRFBs or PHBs)
- Presence of a marked crosswalk
- One-way or two-way
- 2-4 travel lanes
- Speed limit $\leq$ 30 mph
- AADT $\leq$ 20,000
- Moderate pedestrian volume

The 413 locations were further filtered based on the criteria listed above and conversations with ODOT district staff and maintenance crew. Ultimately, six locations were selected as candidate sites for testing the various configurations of R1-6a signs. These selected sites are listed in Table 3.1. A map of these selected sites is shown in Figure 3.2 and each of the sites is further described below.

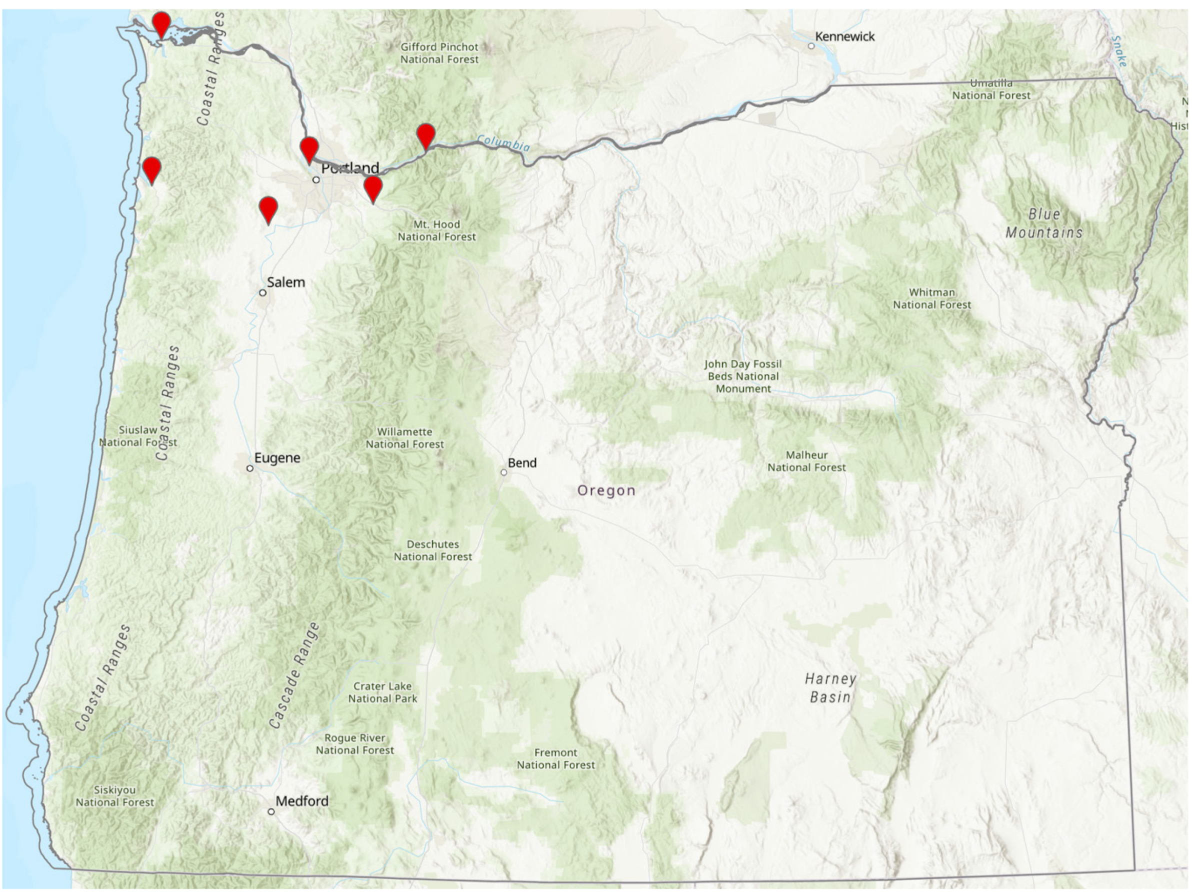


Figure 3.2: Map of selected study locations

Table 3.1: List of Selected Study Locations

Location	Direction	Median Island	Location of Crosswalk	Crossing Width (ft)	Num. of Lanes	Speed Limit (mph)	AADT
Proctor Blvd. and Beers Ave, Sandy	One-way	No	East	31	2	25	15,159
Marine Dr. and 15th St., Astoria	One-way	No	West	33	2	20	7,979
Wa Na Pa St. and Regulator St., Cascade Locks	Two-way	No	South	44	2	30	4,634
3rd St. and Adventist Health, Tillamook	Two-way	No	Midblock	35	2	30	5,249
N Lombard St. and N Fortune St., Portland	Two-way	Yes	Eastern	37	2	30	15,539
OR 99W and 7th St., Dundee	Two-way	Yes	North	39	2	30	21,328

3.3 SELECTED SITES

At each of the selected sites, various stages were proposed for experimentation. The stages at each site varied between four to six stages and are shown in Table 3.2. Each site and the stages tested at the site are individually described below.

Table 3.2: Description of Stages

Stage	Description	Abbreviation
1	Baseline	Base
2	Post on centerline	Post on CL
3	R1-6 on centerline or median	R1-6
4	R1-6 on centerline or median, post on edge line	R1-6 + Post
5	R1-6 on centerline or median, R1-6 on each edge line (Gateway)	R1-6 GTWY
6	R1-6 on centerline or median, R1-6 on top of left and right curb (Gateway Curb-top)	R1-6 GTWY CT

3.3.1 One-way Sites

Two one way-sites were selected for this study, and these are further described below.

3.3.1.1 Proctor Blvd. and Beers Ave.

The marked crosswalk at Proctor Blvd. and Beers Ave. was chosen as a site for testing the installation of R1-6a signs. At this location, Proctor Blvd. is a one-way street with two travel lanes and a bike lane. At the crosswalk, two W11-2 Pedestrian Crossing warning signs along with an advanced stop bar was present prior to any installations. At this location, five stages for R1-6a signs were developed as shown in Figure 3.3. The first stage at this site is the baseline stage, without any R1-6 signs or tubular markers/posts. The second stage consists of a tubular marker/post installed on the center line. The third stage consist of a single R1-6a sign installed on the center line. The fourth stage consists of a R1-6a sign installed on the center line and tubular markers installed on the edge lines. The fifth and final stage consists of the full gateway configuration with three R1-6a signs installed on each center line, lane line, or edge line.

3.3.1.2 Marine Dr. and 15th St.

The marked crosswalk at Marine Dr. and 15th St. was chosen as a site for testing the installation of R1-6a signs. At this location, Marine Dr. is a one-way street with two travel lanes and on-street parking present on both sides of the street west of the crosswalk. At the crosswalk, two W11-2 Pedestrian Crossing warning signs were present prior to any installations. At this location, five stages for R1-6a signs were developed as shown in Figure 3.4. The first stage at this site is the baseline stage, without any R1-6 signs or tubular markers/posts. The second stage consists of a tubular marker/post installed on the center line. The third stage consist of a single R1-6a sign installed on the center line. The fourth stage consists of a R1-6a sign installed on the center line and tubular markers/posts installed on the edge lines. The fifth and final stage consists of the full gateway configuration with three R1-6a signs installed on each center line, lane line, or edge line.

Stage 1 - Baseline condition

(b) Stage 2 – One tubular marker

(c) Stage 3 – One R1-6a sign

(d) Stage 4 – One R1-6a sign and two tubular markers

(e) Stage 5 - Three R1-6a signs

Figure 3.3: Tested Configurations at Proctor Boulevard and Beers Avenue (Sandy)

Stage 1 - Baseline condition

(b) Stage 2 – One tubular marker

(c) Stage 3 – One R1-6a sign

(d) Stage 4 – One R1-6a sign and two tubular markers

(e) Stage 5 - Three R1-6a signs

Figure 3.4: Tested Configurations at Marine Drive and 15th Street (Astoria)

3.3.2 Two-way Sites

Four two-way sites were chosen for this study. These are further described below.

3.3.2.1 Wa Na Pa St. and Regulator St.

The marked crosswalk at Wa Na Pa St. and Regulator St. in Cascade Locks was chosen as a site for testing the installation of R1-6a signs. At this location, Wa Na Pa St. is a two-way street with one travel lane in each direction. At this location, six stages for R1-6a signs were developed as shown in Figure 3.5. The first stage at this site is the baseline stage, without any R1-6 signs or tubular markers/posts. The second stage consists of two tubular markers/posts installed on the center line. The third stage consist of a single R1-6a sign installed on the center line. The fourth stage consists of a R1-6a sign installed on the center line and tubular markers/posts installed on the edge lines. The fifth stage consists of the full gateway configuration with three R1-6a signs installed on each center line, lane line, or edge line. An additional phase (Stage 6) was proposed at this site where the left and right side R1-6 signs are placed atop the curb.

3.3.2.1 3rd St. and Adventist Health

The marked crosswalk at 3rd St. and Adventist Health in Tillamook was chosen as a site for testing the installation of R1-6a signs. At this location, 3rd St. is a two-way street with one travel lane in each direction. At this location, five stages for R1-6a signs were developed as shown in Figure 3.5. The first stage at this site is the baseline stage, without any R1-6 signs or tubular markers. The second stage consists of two tubular markers/posts installed on the center line. The third stage consist of a single R1-6a sign installed on the center line. The fourth stage consists of a R1-6a sign installed on the center line and tubular markers/posts installed on the edge lines. The fifth and final stage consists of the full gateway configuration with three R1-6a signs installed on each center line, lane line, or edge line.

3.3.2.2 N Lombard St. and N Fortune Ave

The marked crosswalk at N Lombard St. and N Fortune Ave in Portland was chosen as a site for testing the installation of R1-6a signs. At this location, N Lombard St. is a two-way street with one travel lane in each direction. At the crosswalk, two W11-2 Pedestrian Crossing warning signs and a median island were present prior to any installations. At this location, four stages for R1-6a signs were developed as shown in Figure 3.5. The first stage at this site is the baseline stage, without any R1-6 signs or tubular markers/posts. The second stage consists of a single R1-6a sign installed on the median island. The third stage consists of a R1-6a sign installed on the center line and tubular markers/posts installed on the edge lines. The fourth and final stage consists of the full gateway configuration with three R1-6a signs installed on each center line, lane line, or edge line.

3.3.2.3 OR 99W and 7th St.

The marked crosswalk at OR 99W and 7th St. in Dundee was chosen as a site for testing the installation of R1-6a signs. At this location, OR 99W is a two-way street with one travel lane in each direction. At the crosswalk, two W11-2 Pedestrian Crossing warning signs and a median island were present prior to any installations. At this location, five stages for R1-6a signs were developed as shown in Figure 3.5. The first stage at this site is the baseline stage, without any R1-6 signs or tubular markers/posts. The second stage consists of a single R1-6a sign installed on the median island. The third stage consists of a R1-6a sign installed on the median island and tubular markers/posts installed on the edge lines. The fourth stage consists of the full gateway configuration with three R1-6a signs installed one each on the median island, and lane lines, or edge lines. An additional phase (Stage 5) was proposed at this site where the R1-6 signs placed on the edge or lane lines are placed atop the curb.

3.4 REQUEST TO EXPERIMENT

While FHWA has identified the R1-6a sign as a highly effective, low-cost engineering countermeasure that can be used to improve pedestrian safety in a proactive and systemic manner, their use with certain configurations is not allowed. The MUTCD does not offer support for the installation of the sign in a gateway configuration on an edge line or right-side curb line, nor does it offer support for the use of more than one R1-6a sign at a crosswalk.

In this study, the following configurations were proposed to be tested. These represent deviations from Section 2B.12 of the 2009 MUTCD and Section 2B.20 of the 2023 MUTCD.

- Placement of more than one R1-6a sign at a crosswalk;
- Placement of the R1-6a sign on an edge line, and,
- Placement of the R1-6a sign on a curb.

To enable this testing, a request to experiment (RTE) was created and sent to FHWA for approval. Once approval was received, data collection commenced.

Stage 1 - Baseline condition

(b) Stage 2 – Two tubular markers/posts

(c) Stage 3 – One R1-6a sign

(d) Stage 4 – One R1-6a sign and two tubular markers/posts

(e) Stage 5 - Three R1-6a signs

(f) Stage 6 - Three R1-6a signs (2 on top of curb)

Figure 3.5: Tested Configurations at Wa Na Pa Street and Regulator Street (Cascade Locks)

Stage 1 - Baseline condition

(b) Stage 2 – Two tubular markers/posts

(c) Stage 3 – One R1-6a sign

(d) Stage 4 – One R1-6a sign and two tubular markers/posts

(e) Stage 5 - Three R1-6a signs

Figure 3.6: Tested Configurations at 3rd Street and Adventist Health (Tillamook)

Stage 1 - Baseline condition

(b) Stage 2 – One R1-6a sign

(c) Stage 3 – One R1-6a sign and two tubular markers/posts

(d) Stage 4 - Three R1-6a signs

Figure 3.7: Tested Configurations at N. Lombard Street and N. Fortune Avenue (Portland)

Stage 1 - Baseline condition

(b) Stage 2 – One in-street sign

(c) Stage 3 – One in-street sign and two tubular markers/posts

(d) Stage 4 - Three in-street signs

(e) Stage 5 - Three R1-6a signs (2 on top of curb)

Figure 3.8: Tested Configurations at OR 99W and 7th Street (Dundee)

3.5 DATA COLLECTION PROTOCOL

At all the selected sites, video data were collected for 24 hours, for each stage. Table 3.3 shows the data collection timeline. Field data were collected using two video cameras at each location, usually on a typical weekday during clear weather conditions. The dates of the video data collection for each stage are noted at two of the sites (Marine Dr. and 15th St., 3rd St. and Adventist Health), video for the baseline stage (Stage 1) was collected at the end of the data collection due to a scheduling error. At the Marine Dr. and 15th St. site in Astoria, data collection was halted after Stage 3. At this site, several complaints were received regarding the tubular markers on the edge lines of the crosswalk. The north side tubular marker was impeding the freight movement for the right turn, while the south side tubular marker was causing issues for the 15th Street traffic going south to north. Due to these complaints, ODOT decided to remove those installations.

Table 3.3: Data Collection Timeline

Location	Base	Post on CL	R1-6a Stage 3	R1-6a + Post	R1-6a GTWY	R1-6a GTWY CT
Marine Dr. and 15th St., Astoria	10/9/24	6/14/24	7/19/24	NA	NA	NA
Wa Na Pa St. and Regulator St., Cascade Locks	5/31/24	6/28/24	7/26/24	8/16/24	9/13/24	10/2/24
OR 99W and 7th St., Dundee	5/17/24	N/A	6/18/24	7/22/24	8/21/24	9/27/24
N Lombard St. and N Fortune St., Portland	5/24/24	N/A	6/21/24	7/31/24	8/14/24	NA
Proctor Blvd. and Beers Ave , Sandy	5/31/24	6/28/24	7/26/24	8/16/24	9/13/24	NA
3rd St. and Adventist Health, Tillamook	10/9/24	6/14/24	7/19/24	8/23/24	9/6/24	NA

A vendor was used to assist with the video data collection. The research team worked with the vendor to ensure that camera angles and placement facilitated clear views of pedestrian crossings at each location. Once the video recordings were obtained, relevant data (e.g., pedestrian counts by time of day) were extracted from the videos as described in the following section.

3.5.1 Staged Pedestrian Crossings

The research team used a staged pedestrian protocol to collect driver yielding data to ensure that oncoming drivers receive a consistent presentation of approaching pedestrians (Fitzpatrick et al., 2016). These staged pedestrian crossings were performed at each stage, on the same day that the video cameras were set up for data collection. A member of the project team approached the crosswalk as a pedestrian intending to cross. Each staged pedestrian was uniformly clothed and crossed the roadway, in the same manner, every time. The protocol prescribed by Fitzpatrick et al. required that the stopping sight distance (SSD) on each roadway be marked with cones or markers. The SSDs for each site are shown in Table 3.4.

Table 3.4: Stopping Sight Distance

Location	Speed Limit (mph)	Stopping Sight Distance (ft)

Marine Dr. and 15th St., Astoria	20	112
Wa Na Pa St. and Regulator St., Cascade Locks	30	197
OR 99W and 7th St., Dundee	30	197
N Lombard St. and N Fortune St., Portland	30	197
Proctor Blvd. and Beers Ave , Sandy	25	152
3rd St. and Adventist Health, Tillamook	30	197

As vehicles approached the SSD marker, the staged pedestrian approached the crosswalk and waited on the curb, signaling their intent to cross. The staged pedestrian waited to cross until the approaching drivers yielded or until all the drivers traveled through the crosswalk. Data collection crews obtained a minimum of 60 (30 each direction) staged pedestrian interactions at each site for each stage during daytime light conditions. After each staged crossing, the project team member walked away from the crosswalk so as not to confuse the other approaching drivers. The project team collected the staged pedestrian data during daylight and in good weather conditions.

3.6 DATA EXTRACTION

Once the videos were obtained from the vendor, researchers developed an extraction plan to review the footage and manually transcribe timestamped pedestrian crossing events, record pedestrian volumes, and collect data on driver yielding rates across the various stages.

A standardized data collection form was created in Excel to document the crossing events. For each location, the form included a unique figure featuring a screenshot annotated with pedestrian directional information and vehicle Stopping Sight Distance (SSD) to assist student coders during data collection.

Figure 3.9: Reference Figure for Data Collection

Additionally, each form was pre-filled with the location name, date of collection, event number, and information on median island availability. Calculations for crossing time, user delay, and time gap for nearside/farside were also pre-entered, enabling student coders to verify the accuracy of their timestamp entries as they input them. For data collection, nearside was defined as the lane closest to the pedestrian as they started crossing while farside was the lane farthest to them.

For each crossing event, student coders were required to extract and input the following information:

- Crosswalk user type (pedestrian, bicyclist, wheelchair user, skateboard, scooter, other)
- Staged or Naturalistic crossing
- Number of users crossing
- Direction of travel (N→S, S→N, E→W, W→E)
- Arrival Time (when the pedestrian arrives at the crossing, indicating intent to cross)
- Start Time (when the pedestrian steps off the curb to begin crossing)
- Driver Yielding - Near Side/Far Side (Y if a vehicle at/near/behind the SSD stops or slows to allow crossing; N if such a vehicle does not; NA if no vehicle is present or if no adjustment is needed for the pedestrian to cross safely)
- Number of vehicles in the queue - Near Side/Far Side (vehicles that stop or slow to yield, including the first to do so; left blank if none)
- Number of vehicles that failed to yield – Near Side/Far Side (vehicles that should have yielded based on their position relative to SSD at pedestrian arrival, but did not; left blank if none)
- Time prior Near Side/Far Side vehicle arrives (timestamp of the vehicle preceding the yielding vehicle's arrival at the SSD)
- Time Near Side/Far Side yielding vehicle arrives (timestamp of the yielding vehicle’s arrival at the SSD)
- If a median is present:
- Pedestrian arrival time (timestamp when the pedestrian’s rear foot leaves the roadway onto the median)
- Pedestrian departure time (timestamp when the pedestrian’s lead foot leaves the median island to reenter the roadway)
- Notes (any significant or unusual observations about the crossing)

Where applicable, data entry options were provided via dropdown lists. In other cases, data validation and formatting rules were applied to ensure the correct data types were entered. After completing data entry for each stage at a site, coders uploaded the finalized spreadsheet to a secure drive for validation.

Location	Date Collected	Observation ID	Crossing User Type	Staged Ped (Y/N)	Number of Peds Crossing	Direction Of Crossing	Time Ped Arrived at C/W	Time Ped Started Crossing	Driver Yielding Near Side (Y/N)--If Y fill only I, if N fill columns I & J	Number of vehicles in queue on near side (incl. the first car that yielded)	Number of vehicles that failed to yield	Time Near Side Prior Vehicle Arrives	Time Near Side Yielding Vehicle Arrives
Tillamook	10/9/2024	1											
Tillamook	10/9/2024	2											
Tillamook	10/9/2024	3											
Tillamook	10/9/2024	4											
Tillamook	10/9/2024	5											
Tillamook	10/9/2024	6											
Tillamook	10/9/2024	7											
Tillamook	10/9/2024	8											
Tillamook	10/9/2024	9											
Tillamook	10/9/2024	10											
Tillamook	10/9/2024	11											
Tillamook	10/9/2024	12											
Tillamook	10/9/2024	13											
Tillamook	10/9/2024	14											

If Median Present, Time Ped Reached Median	If Present, Time Ped Started Crossing from Median	Driver Yielding Far Side (Y/N)	Number of vehicles in queue on far side (incl. the first car that yielded)	Number of vehicles that failed to yield	Time Ped Finished Crossing	Time Far Side Prior Vehicle Arrives	Time Far Side Yielding Vehicle Arrives	Notes	Crossing Time	User Delay	Time Gap for Near Side Vehicles	Time Gap for Far Side Vehicles
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00
									00:00	00:00	00:00	00:00

Figure 3.10: Video Data Extraction Form

3.7 DATA VALIDATION

Once the video data were fully transcribed for each location, a trained researcher (not the original student coder) conducted a validation check. The researcher randomly selected at least 5% of all recorded crossing events at each location (with a minimum of 10 events) and cross-referenced them against the original video footage. If any systemic issues were identified, they were corrected, and additional entries were reviewed as needed. Figure 3.6 shows an example of the video validation form. Entries highlighted in blue indicate those that were checked, while entries with red text represent errors, such as incorrect or missing timestamps or vehicle queue counts.

Location	Date Collected	Observation ID	Crossing User Type	Staged Ped (Y/N)	Number of Peds Crossing	Direction Of Crossing	Time Ped Arrived at C/W	Time Ped Started Crossing	Driver Yielding Near Side (Y/N)--If Y fill only I, if N fill columns I & J	Number of vehicles in queue on near side (incl. the first car that yielded)	Number of vehicles that failed to yield	Time Prior Vehicle Arrives	Time Yielding Vehicle Arrives
Tillamook	6/14/2024	84	Pedestrian	Y	1	N-->S	10:52:23	10:52:28	Y	1	0		
Tillamook	6/14/2024	85	Pedestrian	Y	1	S-->N	10:53:28	10:53:29	Y	2	0		
Tillamook	6/14/2024	86	Pedestrian	Y	1	S-->N	10:54:24	10:54:26	Y	4	0		
Tillamook	6/14/2024	87	Pedestrian	Y	1	N-->S	10:55:30	10:55:32	Y	1	0		
Tillamook	6/14/2024	88	Pedestrian	Y	1	N-->S	10:56:20	10:56:23	Y	1	0		
Tillamook	6/14/2024	89	Pedestrian	Y	1	S-->N	10:57:09	10:57:11	Y	2	0		
Tillamook	6/14/2024	90	Pedestrian	Y	1	S-->N	10:57:32	10:57:34	Y	2	0		
Tillamook	6/14/2024	91	Pedestrian	Y	1	N-->S	10:58:40	10:58:42	Y	1	0		
Tillamook	6/14/2024	92	Pedestrian	Y	1	N-->S	10:59:01	10:59:09	Y	2	0		
Tillamook	6/14/2024	93	Pedestrian	Y	1	S-->N	11:01:07	11:01:11	Y	1	0		
Tillamook	6/14/2024	94	Pedestrian	Y	1	S-->N	11:01:32	11:01:32	NA				
Tillamook	6/14/2024	95	Pedestrian	Y	1	N-->S	11:02:27	11:02:30	Y	1	0		
Tillamook	6/14/2024	96	Pedestrian	Y	1	N-->S	11:03:22	11:03:22	NA				
Tillamook	6/14/2024	97	Pedestrian	N	1	S-->N	11:09:26	11:09:26	NA				
Tillamook	6/14/2024	98	Pedestrian	N	1	S-->N	11:29:07	11:29:11	Y	1	0	11:28:50	11:29:12
Tillamook	6/14/2024	99	Pedestrian	N	1	N-->S	11:41:49	11:41:51	Y	3	0	11:41:37	11:41:46
Tillamook	6/14/2024	100	Pedestrian	N	1	N-->S	11:47:02	11:47:02	NA				
Tillamook	6/14/2024	101	Pedestrian	N	2	S-->N	11:56:28	11:56:28	NA				
Tillamook	6/14/2024	102	Pedestrian	N	1	S-->N	11:58:02	11:58:06	Y	1	0	11:57:47	11:58:06
Tillamook	6/14/2024	103	Pedestrian	N	1	N-->S	12:05:11	12:05:20	Y	1	0	12:04:40	12:05:14
Tillamook	6/14/2024	104	Pedestrian	N	1	N-->S	12:14:49	12:14:56	Y	2	0	12:14:39	12:14:54
Tillamook	6/14/2024	105	Pedestrian	N	1	S-->N	12:23:39	12:23:39	NA				
Tillamook	6/14/2024	106	Pedestrian	N	1	N-->S	12:37:07	12:37:07	NA				
Tillamook	6/14/2024	107	Pedestrian	N	1	N-->S	12:39:08	12:39:12	Y	1	0	12:38:45	12:39:14
Tillamook	6/14/2024	108	Pedestrian	N	1	N-->S	12:39:54	12:40:00	N	0	1		
Tillamook	6/14/2024	109	Pedestrian	N	1	N-->S	12:40:27	12:40:27	NA				
Tillamook	6/14/2024	110	Pedestrian	N	2	S-->N	12:48:01	12:48:02	Y	1	0	12:47:58	12:48:06
Tillamook	6/14/2024	111	Pedestrian	N	1	S-->N	12:58:15	12:58:20	NA				
Tillamook	6/14/2024	112	Pedestrian	N	1	S-->N	12:59:21	12:59:26	Y	1	0	12:59:07	12:59:27
Tillamook	6/14/2024	113	Pedestrian	N	1	N-->S	13:07:12	13:07:31	N	1	2	10:07:23	10:07:32

Figure 3.11: Video Data Validation

During data collection, student coders were encouraged to note any unusual behaviors or actions that did not fit the standard input fields in the data collection spreadsheet. These notes were reviewed during validation, and the research team made changes when appropriate. In some cases, the notes led to edits; in others, they resulted in the removal of the entry from the final dataset. Examples include:

- Editing a record:
- If users crossed simultaneously but used different modes (e.g., a pedestrian and a bicyclist), some coders combined these into one entry, such as “Pedestrian/Bicycle.” These were separated into two distinct entries—one for each user type.
- Removing a record:
- In some cases, the crosswalk also served as a school bus stop. When a bus stopped and deployed its stop sign for students to deboard and cross, it altered the experimental environment, potentially skewing yielding behavior. These entries were excluded from analysis.

The research team also conducted several primary checks to identify and address erroneous or missing data:

- Checking for missing or extra data in key columns:

- Identified and corrected missing or incorrectly entered values in critical fields, including crossing type (staged vs. naturalistic), number of users, driver yielding behavior, vehicles in queue, vehicles that failed to yield, and all associated timestamps (seven or nine, depending on the presence of a median).
- Checking for problematic timestamps:
- Verified that timestamps were consistent and logical. Corrections were made to any records showing zero or negative crossing time, negative user delay, or time gap. The team also flagged and corrected records where any of these durations exceeded two minutes.

3.8 DATA INTEGRATION

Once all the data for each location and stage was validated, the spreadsheets for each stage at a particular location were combined to produce a master spreadsheet. These master spreadsheets were then used for further analysis.

3.9 SUMMARY

This chapter summarized the data collection process including assembling an inventory, criteria for selecting sites, and methods for data collection, extraction, validation and integration. Overall, video data was extracted from 6 locations, with each location having a mix of 4-6 stages. At one location, data collection was terminated due to concerns arising from the placement of the R1-6a installations. where video data was collected for this study. Data from all the stages at each site were merged to generate a combined data set for analysis. The next chapter details the data analysis process.

4.0 DATA ANALYSIS

This chapter presents the yielding analysis across the six sites and the various stages. The chapter includes a descriptive summary, a comparison of yielding rates by various groupings, and a statistical analysis of the yielding rates.

4.1 METRICS

Section 3.6 lists all the metrics that were coded during the data collection process. Although video was collected for 24 hours, the research team only coded data from 7AM – 7PM at each location for each stage, due to the number of stages and videos at each site. Pedestrian volumes were also likely to be at their maximum levels during the chosen time period. The coded data were used to calculate the following metrics.

$$\textbf{Crossing time} = \textbf{Time ped finished crossing} - \textbf{Time ped started crossing}$$

(4-1)

$$\textbf{User delay} = (\textbf{Time ped stated crossing} - \textbf{Time ped arrived at crosswalk}) + (\textbf{Time ped started crossing from median} - \textbf{Time ped reached median})$$

(4-2)

$$\textbf{Time gap for near(far)side vehicles} = \textbf{Time near(far)side yielding vehicle arrives} - \textbf{Time prior near(far)side vehicle arrives} \ldots$$

(4-3)

$$\textbf{Yielding Proportion} = \frac{\textbf{Total number of vehicles yielding}}{(\textbf{Total number of vehicles yielding} + \textbf{Total number of vehicles not yielding})}$$

(4-4)

To compare the yielding proportions across different stages, a z-test for comparing two proportions was used. The z-test compares whether the proportion of a certain characteristics differs significantly between two independent samples. The null and alternative hypothesis for the test is as follows:

- Null hypothesis (H_0): The proportions in the two populations are equal, i.e., $p_1 = p_2$
- Alternative hypothesis (H_1): The proportions in the two populations are not equal, i.e., $p_1 \neq p_2$ (two-tailed)

The z-statistic for comparing two proportions is calculated as

$$z = \frac{\widehat{p_1} - \widehat{p_2}}{\sqrt{\hat{p}\,(1-\hat{p}\,)\,(\frac{1}{n_1}+\frac{1}{n_2})}}$$

(4-5)

Where,

$\widehat{p_1}$ = sample proportion in the first sample

$\widehat{p_2}$ = sample proportion in the second sample.

n_1 = size of first sample

n_2 = size of second sample

$\hat{p}$ = pooled proportion, calculated as $\hat{p} = \frac{x_1+x_2}{n_1+n_2}$, where x_1, x_2 are the counts of successes in the two samples.

The z-test determines statistical significance by comparing the calculated z-statistic to a critical value. For 95% confidence, $\alpha = 0.05$, the null hypothesis is rejected if $|z| > 1.96$ for a two-tailed test.

4.2 PEDESTRIAN VOLUMES

Table 4.1 shows the overall pedestrian volumes observed across all stages at all six locations. Overall, 6,151 users were observed crossing at the locations. From this set, only pedestrians were extracted. These included people walking, on scooters, skateboards, and wheelchairs. Overall, 5,992 pedestrians were observed with 4,063 (68%) naturalistic and 1,929 (32%) staged crossings. Figure 4.1 shows the hourly distribution of naturalistic volumes. The highest naturalistic volumes (1,706) were observed at Wa Na Pa St. and Regulator St. in Cascade Locks, while the lowest volumes (117) were observed at OR 99W and 7th St. in Dundee. At most locations, naturalistic pedestrian crossings were higher than staged crossings except at OR 99W and 7th St crosswalk in Dundee. Naturalistic pedestrian volumes were generally steady across the stages at all locations except for two notable exceptions. The naturalistic volume observed during stage 4 (R16a sign+post) at Wa Na Pa St. and Regulator St. in Cascade Locks was significantly higher than the volumes observed during the other stages. This was due to the closure of the Pacific Crest Trail due to fire during the stage 4 data collection period and hikers were observed to be camping at the Marine Park which was close to the crosswalk and led to increased crosswalk usage. Stage 3 (R1-6a sign) crossings at Marine Dr. and 15th St. in Astoria were also higher due to the favorable weather (sunny/warm day on the coast).

4.3 CROSSING TIME

Table 4.2 shows the average crossing time for all pedestrians. The crossing time was calculated as the time the pedestrian finished crossing minus the time the pedestrian started crossing. If a median was present (e.g., at Dundee and Lombard), the waiting time at the median was subtracted from the overall crossing time to only reflect the time spent in the crosswalk. Overall the average crossing time across all locations and stages was 9.44 sec. The average crossing time at most locations was below 10 sec except at Astoria and Cascade Locks locations. Average crossing times for the staged pedestrians were lower than those for naturalistic pedestrians. This was most likely because the staged pedestrian was a trained researcher who was aware of the risks in the roadway and was instructed to expediently complete their crossing.

Table 4.1: Pedestrian Volumes by Location and Stage for 12 Hours

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + Post	R1-6a + Post	R1-6a GT WY	R1-6a GT WY	R1-6a GT WY CT	R1-6a GT WY CT	Tot	Tot	Tot
	Nat	Sta	Nat	Sta	Nat	Sta	Nat	Sta	Nat	Sta	Nat	Sta	Nat	Sta	Tot
Marine Dr. and 15th St., Astoria	142	66	186	70	360	63	--	--	--	--	--	--	688 78%	199 22%	887 100%
Wa Na Pa St. and Regulator St., Cascade Locks	118	79	285	67	284	66	745	52	231	71	43	64	1706 81%	399 19%	2105 100%
OR 99W and 7th St., Dundee	21	75	--	--	22	85	12	68	31	66	31	63	117 25%	357 75%	474 100%
N Lombard St. and N Fortune St., Portland	183	70	--	--	193	97	175	61	190	64	--	--	741 72%	292 28%	1033 100%
Proctor Blvd. and Beers Ave , Sandy	109	68	59	64	119	66	93	69	72	67	--	--	452 58%	334 42%	786 100%
3rd St. and Adventist Health, Tillamook	84	72	67	74	78	67	75	68	55	67	--	--	359 51%	348 49%	707 100%
Total	656	430	812	457	1028	391	1134	319	389	268	43	64	4062 68%	1929 32%	5992 100%

Table 4.2: Average Pedestrian Crossing Time by Location and Stage

	Base	Base	Base	Post on CL	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a	R1-6a+post	R1-6a+post	R1-6a+post	R1-6a GTWY	R1-6a GTWY	R1-6a GTWY	R1-6a GTWY CT	R1-6a GTWYCT	R1-6a GTWY CT	Total	Total	Total
Location	**Mi**	**Av**	**Ma**	**Mi**	**Av**	**Ma**	**Mi**	**Av**	**Ma**	**Mi**	**Av**	**Ma**	**Mi**	**Av**	**Ma**	**Mi**	**Av**	**Ma**	**Mi**	**Av**	**Ma**
Astoria	0	11	20	0	8	17	0	11	71										0	10	71
Cascade Locks	0	10	21	0	11	23	0	11	26	0	12	24	0	11	38	0	10	16	0	11	38
Dundee	0	9	12	0	8	14	0	8	15	0	8	11	0	9	51				0	8	51
Portland	0	10	18	0	8	17	0	9	16	0	9	22							0	9	22
Sandy	0	7	14	0	7	13	0	7	44	0	8	15	0	7	12				0	7	44
Tillamook	0	8	14	0	8	12	0	8	17	0	9	25	0	8	14				0	8	25

4.4 DELAY

Table 4.3 shows the average pedestrian delay. The delay was calculated as the difference between the time the pedestrian arrived at the crosswalk and when they started crossing. If a median was present, the delay at the median was also taken into account. Overall, pedestrian delays were short with an average of 3.83 sec across all locations and stages. Among the locations, higher delays were observed at Dundee and Lombard likely due to the presence of a median. In contrast to crossing time, delays for staged pedestrians were higher than those for naturalistic pedestrians (4.81 sec vs. 3.14 sec). This was most likely because the staged pedestrians were instructed to not start crossing until the approaching vehicle yielded (stopped or slowed), which may have caused additional delays.

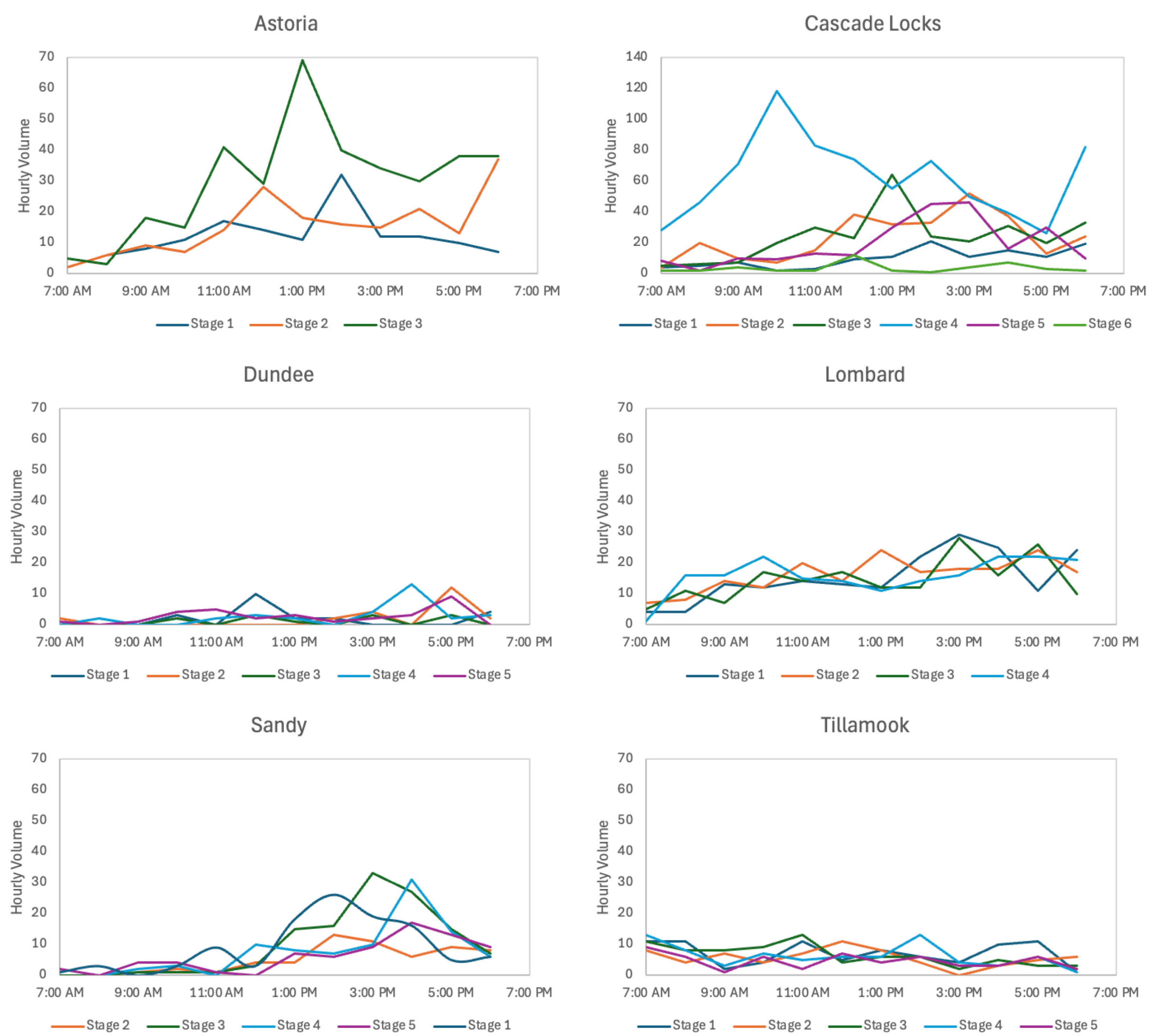


Figure 4.1: Naturalistic Hourly Volumes

Table 4.3: Average Pedestrian Delay by Location and Stage

Location	Base	Post on CL	R1-6a	R1-6a + Post	R1-6a GTWY	R1-6a GTWY CT	Total
Marine Dr. and 15th St., Astoria	3.28	3.85	2.43	--	--	--	3.10
Wa Na Pa St. and Regulator St., Cascade Locks	3.33	3.61	3.18	1.72	2.60	2.37	2.60
OR 99W and 7th St., Dundee	7.63	--	6.05	7.22	6.33	6.69	6.76
N Lombard St. and N Fortune St., Portland	5.46	--	6.17	5.55	4.75	--	5.50
Proctor Blvd. and Beers Ave , Sandy	4.04	4.48	4.47	3.93	2.90	--	3.97
3rd St. and Adventist Health, Tillamook	3.80	2.80	2.22	2.76	2.12	--	2.77

4.5 DRIVER YIELDING

Driver yielding proportions were calculated for both nearside and farside crossings. For data collection, nearside was defined as the lane closest to the pedestrian as they started crossing while farside was the lane farthest to them. As outlined earlier, driver yielding was calculated as the number of vehicles that yielded either nearside or farside divided by the number of vehicles that yielded plus the number of vehicles that did not yield.

4.5.1 Nearside

4.5.1.1 All Pedestrian Crossings

Overall, there were 4,634 nearside crossing events observed for pedestrians crossing at the six locations. These included instances where the drivers yielded, did not yield or where the pedestrians had no interaction with a vehicle while crossing. The no interaction events were removed, which resulted in a total of 3,054 crossing events for analysis, which included both staged and naturalistic pedestrians. Table 4.4 shows the yielding proportions for nearside crossings for all pedestrians. Overall across all stages, yielding rates were high (i.e., greater than 90%), except at two locations (Lombard and Dundee). Figure 4.2 and Figure 4.3 show the yielding rates by stage at each location.

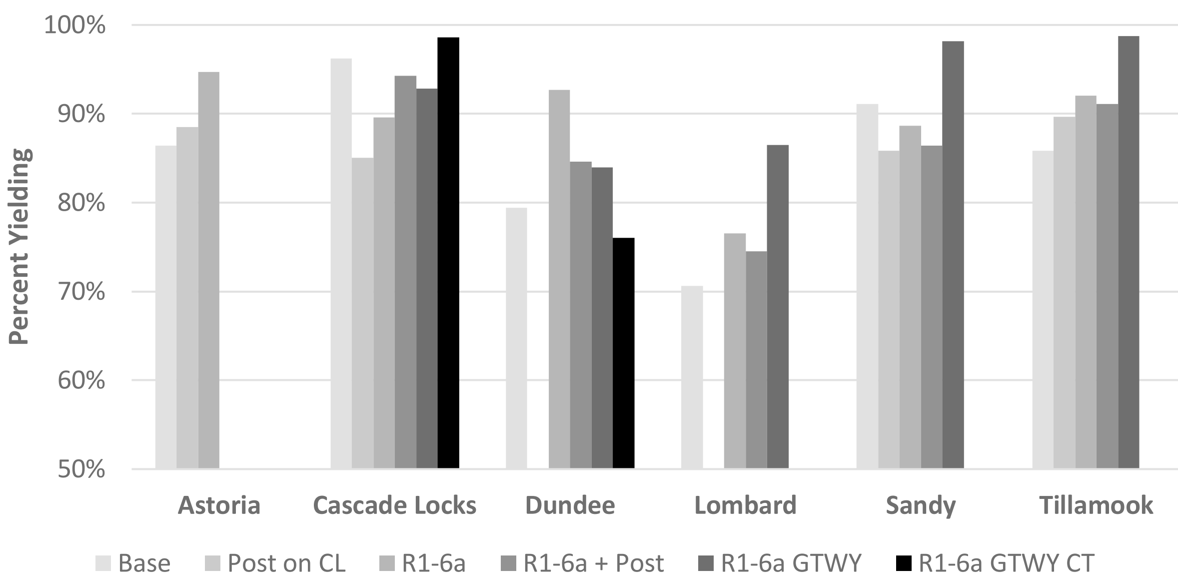


Figure 4.2: Nearside Yielding

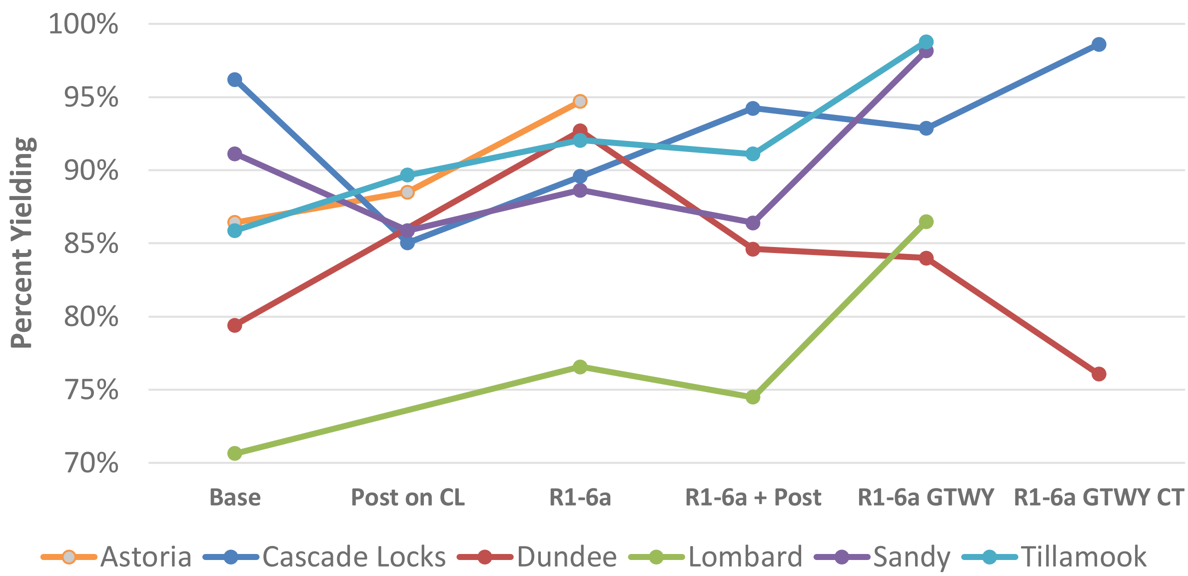


Figure 4.3: Nearside Yielding for All Pedestrian Crossings

Table 4.5 shows the percent difference in yielding rates and the computed z-values in parentheses by stage compared to the base condition. The bolded percentage differences are statistically significantly different. At the two one-way sites (Astoria and Sandy), generally, the yielding rates also increased for the higher stages (with signs and tubular markers) compared to the base condition (Stage 1). At Astoria, there was a 2% increase in yielding when a tubular marker was added and 9% increase in yielding when one R1-6a sign was added. No further testing was done at the Astoria site, due to concerns as outlined earlier. At the Sandy site, it was observed that yielding rates decreased when a tubular marker/post (5%), one R1-6a sign (2%), and one R1-6a sign with tubular markers/posts was added (5%) when compared to the base condition. However, with the addition of three R1-6a signs in a gateway configuration (Stage 5), yielding rate increased by 7% compared to the base condition. At the two two-way sites (Cascade Locks and Tillamook), the individual stage trends were mixed. At Cascade Locks, yielding decreased when tubular markers/posts, one R1-6a sign with tubular markers/posts and three R1-6a signs were added in a gateway configuration, but increased by 2% when the edge R1-6a signs were placed on curb top position. At the Tillamook, an increase in yielding rate was seen with the addition to tubular markers/posts and R1-6a signs and highest yielding rates (13% increase) were observed for the three R1-6a signs in gateway configuration. At the two-way locations with median (Dundee, Lombard), yielding rate trends were generally positive with the addition of tubular markers and R106a signs. At the Dundee location, the addition of one R1-6a sign produced the greatest increase in yielding rate, while the gateway configuration of R1-6a signs produced modest increase (5%). At the Lombard location, a 16% increase in yielding rates was seen with the addition of three R1-6a signs in the gateway configuration.

Table 4.4: Nearside Driver Yielding by Location and Stage for all Pedestrians

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + Post	R1-6a + Post	R1-6a GT WY	R1-6a GT WY	R1-6a GT WY CT	R1-6a GT WY CT	Tot	Tot	Tot
	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Tot
Marine Dr. and 15th St., Astoria	70	11	100	13	125	7	--	--	--	--	--	--	295	31	326
Marine Dr. and 15th St., Astoria	86%	14%	88%	12%	95%	5%	--	--	--	--	--	--	90%	10%	100%
Wa Na Pa St. and Regulator St., Cascade Locks	101	4	108	19	103	12	180	11	117	9	71	1	680	56	736
Wa Na Pa St. and Regulator St., Cascade Locks	96%	4%	85%	15%	90%	10%	94%	6%	93%	7%	99%	1%	92%	8%	100%
OR 99W and 7th St., Dundee	54	14	--	--	76	6	55	10	63	12	54	17	302	59	361
OR 99W and 7th St., Dundee	79%	21%	--	--	93%	7%	85%	15%	84%	16%	76%	24 %	84%	16%	100%
N Lombard St. and N Fortune St., Lombard	101	42	--	--	134	41	108	37	147	23	--	--	490	143	633
N Lombard St. and N Fortune St., Lombard	71%	29%	--	--	77%	23%	74%	26%	86%	14%	--	--	77%	23%	100%
Proctor Blvd. and Beers Ave , Sandy	113	11	79	13	117	15	89	14	106	2	--	--	504	55	559
Proctor Blvd. and Beers Ave , Sandy	91%	9%	86%	14%	89%	11%	86%	14%	98%	2%	--	--	90%	10%	100%
3rd St. and Adventist Health, Tillamook	79	13	78	9	81	7	82	8	81	1	--	--	401	38	439

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + Post	R1-6a + Post	R1-6a GT WY	R1-6a GT WY	R1-6a GT WY CT	R1-6a GT WY CT	Tot	Tot	Tot
3rd St. and Adventist Health, Tillamook	86%	14%	90%	10%	92%	8%	91%	9%	99%	1%	--	--	91%	9%	100%

Table 4.5: Percent Difference in Nearside Driver Yielding Rate for all Pedestrians

Location	Base	Post on CL	R1-6a	R1-6a + Post	R1-6a GTWY	R1-6a GTWY CT
Marine Dr. and 15th St., Astoria	--	2% (0.43)	8% **(2.11)**	--	--	--
Wa Na Pa St. and Regulator St., Cascade Locks	--	**-11% (2.83)**	-7% (1.89)	-2% (0.73)	-3% (1.09)	2% (0.95)
OR 99W and 7th St., Dundee	--	--	**13% (2.38)**	5% (0.78)	5% (0.71)	-3% (0.48)
N Lombard St. and N Fortune St., Lombard	--	--	6% (1.20)	4% (0.73)	**16% (3.44)**	--
Proctor Blvd. and Beers Ave , Sandy	--	-5% (1.22)	-2% (0.66)	-5% (1.13)	**7% (2.32)**	--
3rd St. and Adventist Health, Tillamook	--	4% (0.77)	6% (1.32)	5% (1.11)	**13% (3.13)**	--

*Bolded figures are statistically significantly different at the 95% confidence level

4.5.1.1 Staged Pedestrian Crossings

Overall, there were 1,718 crossing events which involved a staged pedestrian interacting with a vehicle (yield, no yield) at the six locations. Table 4.6 shows the yielding rates for staged pedestrian crossing nearside. These yielding rates closely mirrored the overall yielding rates seen for all pedestrian crossings. At four locations (Astoria, Cascade Locks, Sandy, Tillamook), overall yielding rates across all stages for staged pedestrians were greater than 90%. Similar to the trend seen for all pedestrian crossings, yielding rates for Lombard and Dundee locations were lower compared to the other sites. Figure 4.4 shows the nearside yielding rates for staged pedestrian crossings at all sites.

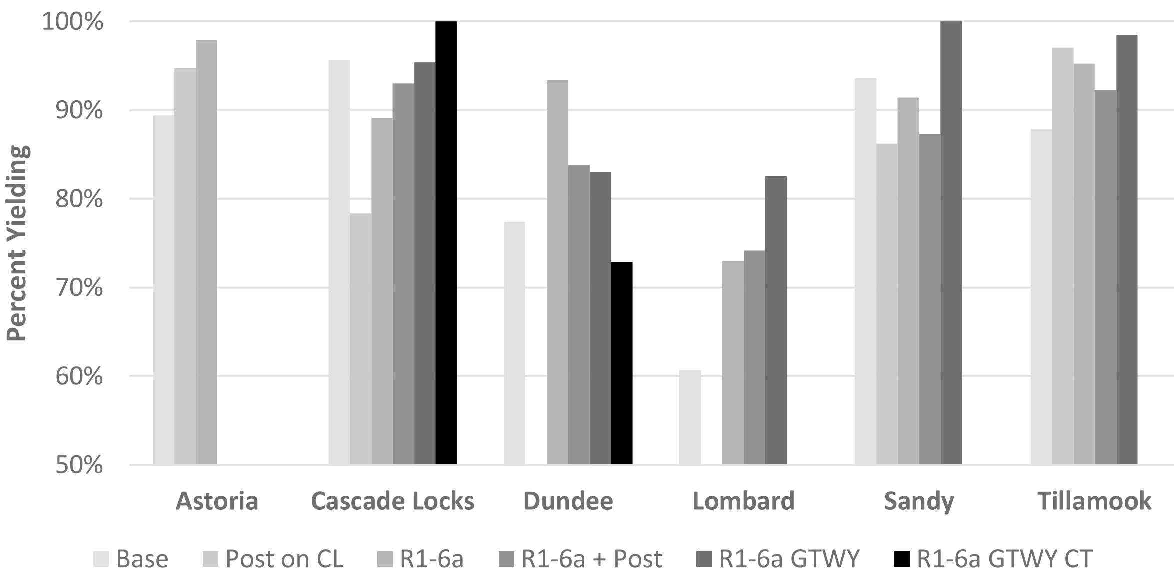


Figure 4.4: Nearside Yielding for Staged Pedestrian Crossings

Table 4.7 shows the percent difference in yielding rates and the computed z-values in parentheses by stage compared to the base condition. The bolded percentage differences are statistically significantly different. At the two one-way sites (Astoria and Sandy), the trend regarding yielding rates were mixed when considered stage by stage. At Astoria, there was a 5% increase in yielding when a tubular marker/post was added and 9% increase in yielding when one R1-6a sign was added. At the Sandy site, it was observed that yielding rates decreased when a tubular marker/post (-7%), one R1-6a sign (-2%), and one R1-6a sign with tubular markers/posts was added (-6%) when compared to the base condition. However, with the addition of three R1-6a signs in a gateway configuration (Stage 5), yielding rate increased by +6% compared to the base condition. At the two two-way sites (Cascade Locks and Tillamook), the individual stage trends were mixed. At Cascade Locks, yielding decreased when tubular markers/posts (-17%), one R1-6a sign (-7%), one R1-6a sign with tubular markers/posts (-3%), remained the same when three R1-6a signs were added in a gateway configuration (0%), but increased by +4% when the edge R1-6a signs were placed on curb top position. At the Tillamook, an increase in yielding rate was seen with the addition to tubular markers/posts and R1-6a signs and highest yielding rates (11% increase) were observed for the three R1-6a signs in gateway configuration. At the two-way locations with median (Dundee, Lombard), yielding rate trends were generally positive with the addition of tubular markers/posts and R1-6a signs. At the Dundee location, the addition of one R1-6a sign produced the greatest increase in yielding rate (16%), while the gateway configuration of R1-6a signs produced modest increase (6%). At the Lombard location, a 22% increase in yielding rates was seen with the addition of three R1-6a signs in the gateway configuration.

Table 4.6: Nearside Driver Yielding Proportions for Staged Pedestrian Crossings

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + Post	R1-6a + Post	R1-6a GT WY	R1-6a GT WY	R1-6a GT WY CT	R1-6a GT WY CT	Tot	Tot	Tot
	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Tot
Marine Dr. and 15th St., Astoria	42	5	54	3	46	1	--	--	--	--	--	--	142	9	151
Marine Dr. and 15th St., Astoria	89%	11%	95%	5%	98%	2%	--	--	--	--	--	--	94%	6%	100%
Wa Na Pa St. and Regulator St., Cascade Locks	66	3	47	13	49	6	40	3	62	3	58	0	322	28	350
Wa Na Pa St. and Regulator St., Cascade Locks	96%	4%	78%	22%	89%	11%	93%	7%	95%	5%	100 %	0%	92%	8%	100%
OR 99W and 7th St., Dundee	48	14	--	--	70	5	52	10	54	11	43	16	267	56	323
OR 99W and 7th St., Dundee	77%	23%	--	--	93%	7%	84%	16%	83%	17%	73%	27%	83%	17%	100%
N Lombard St. and N Fortune St., Lombard	37	24	--	--	65	24	43	15	52	11	--	--	197	74	271
N Lombard St. and N Fortune St., Lombard	61%	39%	--	--	73%	27%	74%	26%	83%	17%	--	--	73%	27%	100%
Proctor Blvd. and Beers Ave , Sandy	58	4	50	8	53	5	48	7	64	0	--	--	273	24	297
Proctor Blvd. and Beers Ave , Sandy	94%	6%	86%	14%	91%	9%	87%	13%	100 %	0%	--	--	92%	8%	100%
3rd St. and Adventist Health, Tillamook	58	8	65	2	60	3	60	5	64	1	--	--	307	19	326

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + Post	R1-6a + Post	R1-6a GT WY	R1-6a GT WY	R1-6a GT WY CT	R1-6a GT WY CT	Tot	Tot	Tot
3rd St. and Adventist Health, Tillamook	88%	12%	97%	3%	95%	5%	92%	8%	98%	2%	--	--	94%	6%	100%

Table 4.7: Percent Difference in Nearside Driver Yielding Rate for Staged Pedestrian Crossings

Location	Base	Post on CL	R1-6a	R1-6a + Post	R1-6a GTWY	R1-6a GTWY CT
Marine Dr. and 15th St., Astoria	-	5% (1.02)	9% (1.69)	--	--	--
Wa Na Pa St. and Regulator St., Cascade Locks	-	**-17% (2.98)**	-7% (1.40)	-3% (0.60)	0% (0.07)	4% (1.61)
OR 99W and 7th St., Dundee	-	--	**16% (2.68)**	6% (0.91)	6% (0.80)	-5% (0.58)
N Lombard St. and N Fortune St., Lombard	-	--	12% (1.60)	13% (1.57)	**22% (2.71)**	--
Proctor Blvd. and Beers Ave , Sandy	-	-7% (1.34)	-2% (0.45)	-6% (1.16)	**6% (2.07)**	--
3rd St. and Adventist Health, Tillamook	-	**9% (2.00)**	7% (1.50)	4% (0.85)	**11% (2.39)**	--

*Bolded figures are statistically significantly different at the 95% confidence level

4.5.1.1 Naturalistic Pedestrian Crossings

Overall, there were 1,336 nearside crossing interactions observed for naturalistic pedestrian crossings at the six locations. These included instances where the drivers yielded and did not yield. Table 4.8 shows the yielding proportions for nearside crossings for naturalistic pedestrian crossings. In general, the overall yielding rates observed for naturalistic crossings were lower at four locations (Astoria, Cascade Locks, Sandy, Tillamook) than for staged crossings and higher at two locations (Lombard, Dundee). Figure 4.5 shows the yielding rates by stage at each location.

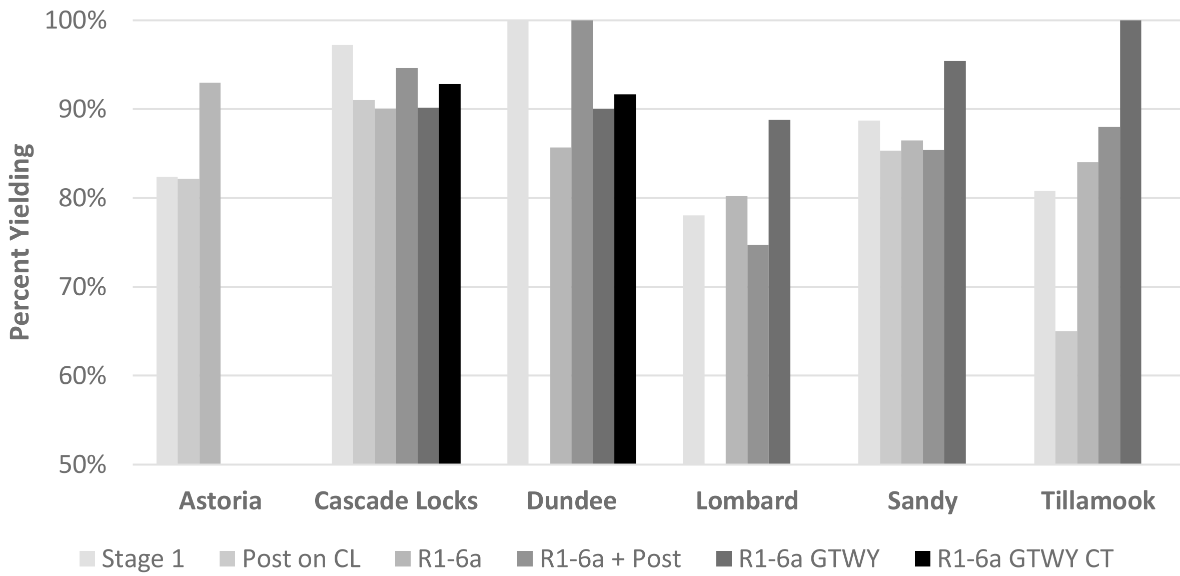


Figure 4.5: Nearside Yielding for Naturalistic Pedestrian Crossings

Table 4.9 shows the percent difference in yielding rates and the computed z-values in parentheses by stage compared to the base condition. The bolded percentage differences are statistically significantly different. At the two one-way sites (Astoria and Sandy), the trend regarding yielding rates were mixed when considered stage by stage. At Astoria, there was no increase in yielding (0%) when a tubular marker/post was added and 11% increase in yielding when one R1-6a sign was added. No further testing was done at the Astoria site. At the Sandy site, it was observed that yielding rates decreased when a tubular marker/post (-3%), one R1-6a sign (-2%), and one R1-6a sign with tubular markers/posts were added (-3%) when compared to the base condition. However, with the addition of three R1-6a signs in a gateway configuration (Stage 5), yielding rate increased by +7% compared to the base condition. At the two two-way sites (Cascade Locks and Tillamook), the individual stage trends were also mixed. At Cascade Locks, yielding decreased across all stages for naturalistic crossings compared to the base case. Decreases were observed with the installation of tubular markers/posts (-6%), one R1-6a sign (-7%), one R1-6a sign with tubular markers/posts (-3%), three R1-6a signs were added in a gateway configuration (-7%), and when the edge R1-6a signs were placed on curb top position (-4%). At the Tillamook location, a decrease in yielding rate was seen with the addition to tubular markers/posts (-16%) and increase was seen with the addition of R1-6a signs and highest yielding rates (19% increase) were observed for the three R1-6a signs in gateway configuration. At the two-way locations with median (Dundee, Lombard), yielding rate trends were mixed with the addition of tubular markers/posts and R1-6a signs. At the Dundee location, the addition of either one R1-6a sign (-14%) or multiple R1-6a signs in gateway configuration (-10%, -8%) were all observed to produce a decrease in yielding rates. At the Dundee location, the volume of naturalistic crossings observed were very low, hence a small change may have skewed the proportions. At the Lombard location, a 11% increase in yielding rates was seen with the addition of three R1-6a signs in the gateway configuration. Overall, the researchers noticed that the naturalistic pedestrians were not waiting at a consistent location unlike the staged pedestrians, which in turn made it hard for the drivers sometimes to see the pedestrians and yield, which can explain the higher non-yielding rate for naturalistic pedestrian crossings.

Table 4.8: Nearside Driver Yielding Proportions for Naturalistic Pedestrian Crossings

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + post	R1-6a + post	R1-6a GTWY	R1-6a GTWY	R1-6a GTWY CT	R1-6a GTWY CT	Tot	Tot	Tot
	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Tot
Marine Dr. and 15th St., Astoria	28	6	46	10	79	6	--	--	--	--	--	--	153	22	175
Marine Dr. and 15th St., Astoria	82%	18%	82%	18%	93%	7%	--	--	--	--	--	--	87%	13%	100%
Wa Na Pa St. and Regulator St., Cascade Locks	35	1	61	6	54	6	140	8	55	6	13	1	358	28	386
Wa Na Pa St. and Regulator St., Cascade Locks	97%	3%	91%	9%	90%	10%	95%	5%	90%	10%	93%	7%	93%	7%	100%
OR 99W and 7th St., Dundee	6	0			6	1	3	0	9	1	11	1	35	3	38
OR 99W and 7th St., Dundee	100%	0%			86%	14%	100%	0%	90%	10%	92%	8%	92%	8%	100%
N Lombard St. and N Fortune St., Lombard	64	18			69	17	65	22	95	12	--	--	293	69	362
N Lombard St. and N Fortune St., Lombard	78%	22%			80%	20%	75%	25%	89%	11%	--	--	81%	19%	100%
Proctor Blvd. and Beers Ave , Sandy	55	7	29	5	64	10	41	7	42	2	--	--	231	31	262
Proctor Blvd. and Beers Ave , Sandy	89%	11%	85%	15%	86%	14%	85%	15%	95%	5%	--	--	88%	12%	100%
3rd St. and Adventist Health, Tillamook	21	5	13	7	21	4	22	3	17	0	--	--	94	19	113

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + post	R1-6a + post	R1-6a GTWY	R1-6a GTWY	R1-6a GTWY CT	R1-6a GTWY CT	Tot	Tot	Tot
3rd St. and Adventist Health, Tillamook	81%	19%	65%	35%	84%	16%	88%	12%	100%	0%	--	--	83%	17%	100%

Table 4.9: Percent Difference in Nearside Driver Yielding Rate for Naturalistic Pedestrian Crossings

Location	Base	Post on CL	R1-6a	R1-6a + Post	R1-6a GTWY	R1-6a GTWY CT
Marine Dr. and 15th St., Astoria	-	0% (0.03)	11% (1.73)	--	--	--
Wa Na Pa St. and Regulator St., Cascade Locks	-	-6% (1.19)	-7% (1.32)	-3% (0.66)	-7% (1.30)	-4% (0.71)
OR 99W and 7th St., Dundee	-	--	-14% (0.96)	0%	-10% (0.80)	-8% (0.73)
N Lombard St. and N Fortune St., Lombard	-	--	2% (0.35)	-3% (0.51)	**11% (2.00)**	--
Proctor Blvd. and Beers Ave , Sandy	-	-3% (0.48)	-2% (0.39)	-3% (0.51)	7% (1.23)	--
3rd St. and Adventist Health, Tillamook	-	-16% (1.21)	3% (0.30)	7% (0.71)	19% (1.92)	--

*Bolded figures are statistically significantly different at the 95% confidence level

4.5.1 Farside

4.5.1.1 All Pedestrian Crossings

Overall, there were 4,631 farside crossing events observed for pedestrians crossing at the six locations. These included instances where the drivers yielded, did not yield or where the pedestrians had no interaction with a vehicle while crossing. The no interaction events were removed, which resulted in a total of 2,702 crossing events for analysis, which included both staged and naturalistic pedestrians. Table 4.10 shows the yielding proportions for farside crossings for all pedestrians. Overall, yielding rates were high. Figure 4.6 and Figure 4.7 show the yielding rates by stage at each location.

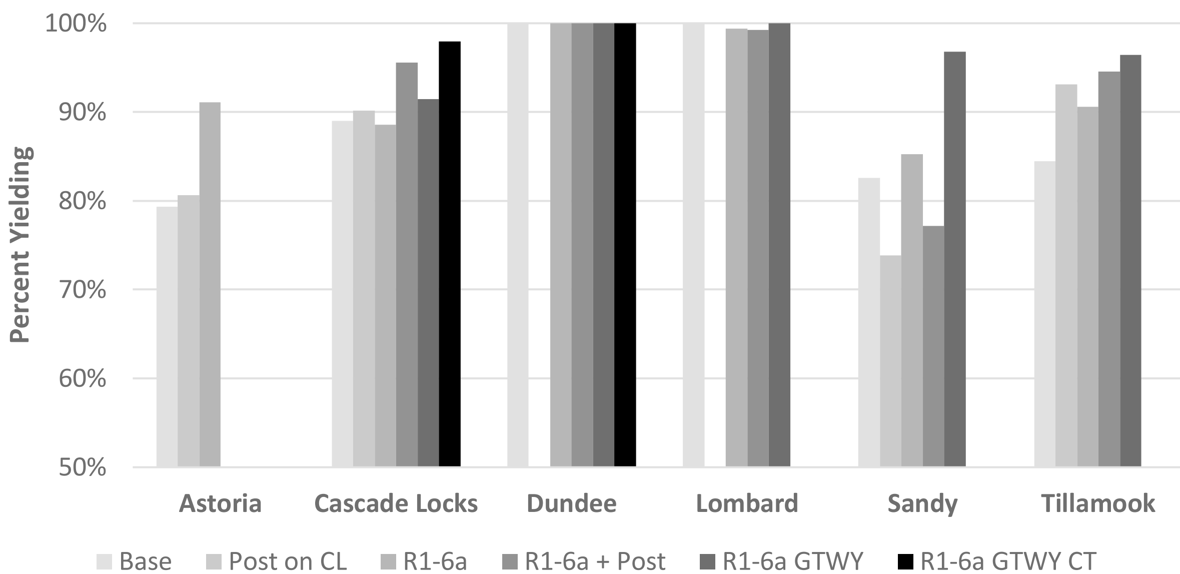


Figure 4.6: Farside Yielding

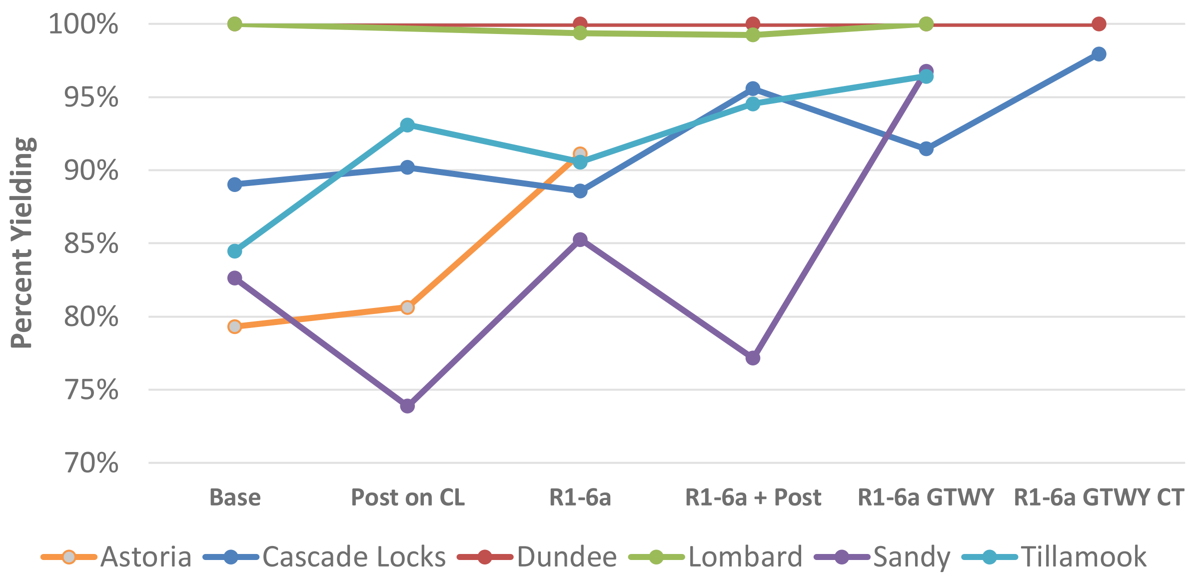


Figure 4.7: Farside Yielding for All Pedestrian Crossings

Table 4.11 shows the percent difference in yielding rates and the computed z-values in parentheses by stage compared to the base condition. The bolded percentage differences are statistically significantly different. At the two one-way sites (Astoria and Sandy), the trend regarding yielding rates were mixed when considered stage by stage. At Astoria, there was an increase in yielding (1%) when a tubular marker/post was added and 12% increase in yielding when one R1-6a sign was added. No further testing was done at the Astoria site, due to reasons as outlined earlier. At the Sandy site, it was observed that yielding rates decreased when a tubular marker/post (-9%) but increased when one R1-6a sign (+3%), and one R1-6a sign with tubular markers/posts were added (-5%) when compared to the base condition. However, with the addition of three R1-6a signs in a gateway configuration (Stage 5), yielding rate increased by +14% compared to the base condition. At the two two-way sites (Cascade Locks and Tillamook), farside yielding increased with the addition of tubular markers/posts and signs. At Cascade Locks, yielding either increased or there was no change across all stages for all pedestrian crossings compared to the base case. Increase in yielding was observed with the installation of tubular markers/posts (+1%), one R1-6a sign with tubular markers/posts (+7%), three R1-6a signs were added in a gateway configuration (+2%), and when the edge R1-6a signs were placed on curb top position (+9%). At the Tillamook, similar increases in yielding proportion was seen with the addition of tubular markers/posts (+9%), one R1-6a sign (+6%), one R1-6a sign with tubular markers/posts (+10%) and highest yielding proportions (12% increase) were observed for the three R1-6a signs in gateway configuration. At the two-way locations with median (Dundee, Lombard), little to no change was observed with yielding proportions as they were high even in the base condition. At these sites, a median was present which probably allowed greater visibility of the crossing pedestrian to the farside driver thus leading to higher yielding rates. At the Dundee location, yielding proportions were 100% irrespective of the stage. At Lombard, yielding decreased slightly (-1%) with the addition of a R1-6a sign and tubular markers/posts but showed no change with the three R1-6a signs in a gateway configuration (100% yielding).

Table 4.10: Farside Driver Yielding by Location and Stage for All Pedestrian Crossings

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + Post	R1-6a + Post	R1-6a GT WY	R1-6a GT WY	R1-6a GT WY CT	R1-6a GT WY CT	Tot	Tot	Tot
	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Tot
Marine Dr. and 15th St., Astoria	69	18	104	25	154	15	--	--	--	--	--	--	327	58	385
Marine Dr. and 15th St., Astoria	79%	21%	81%	19%	91%	9%	--	--	--	--	--	--	85%	15%	100%
Wa Na Pa St. and Regulator St., Cascade Locks	73	9	101	11	93	12	172	8	107	10	48	1	594	51	645
Wa Na Pa St. and Regulator St., Cascade Locks	89%	11%	90%	10%	89%	11%	96%	4%	91%	9%	98%	2%	92%	8%	100%
OR 99W and 7th St., Dundee	62	0	--	--	58	0	56	0	60	0	55	0	291	0	291
OR 99W and 7th St., Dundee	100%	0%	--	--	100 %	0%	100%	0%	100 %	0%	100 %	0%	100%	0%	100%
N Lombard St. and N Fortune St., Lombard	123	0	--	--	158	1	130	1	158	0	--	--	569	2	571
N Lombard St. and N Fortune St., Lombard	100%	0%	--	--	99%	1%	99%	1%	100 %	0%	--	--	99%	1%	100%
Proctor Blvd. and Beers Ave , Sandy	95	20	65	23	110	19	81	24	90	3	--	--	441	89	530
Proctor Blvd. and Beers Ave , Sandy	83%	17%	74%	26%	85%	15%	77%	23%	97%	3%	--	--	83%	17%	100%
3rd St. and Adventist Health, Tillamook	49	9	54	4	48	5	52	3	54	2	--	--	257	23	280

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + Post	R1-6a + Post	R1-6a GT WY	R1-6a GT WY	R1-6a GT WY CT	R1-6a GT WY CT	Tot	Tot	Tot
3rd St. and Adventist Health, Tillamook	84%	16%	93%	7%	91%	9%	95%	5%	96%	4%	--	--	92%	8%	100%

Table 4.11: Percent Difference in Farside Driver Yielding Rate for All Pedestrian Crossings

Location	Base	Post on CL	R1-6a	R1-6a + Post	R1-6a GTWY	R1-6a GTWY CT
Marine Dr. and 15th St., Astoria	--	1% (0.24)	**12% (2.67)**	--	--	--
Wa Na Pa St. and Regulator St., Cascade Locks	--	1% (0.26)	0% (0.10)	**7% (1.99)**	2% (0.57)	9% (1.86)
OR 99W and 7th St., Dundee	--	--	0%	0%	0%	0%
N Lombard St. and N Fortune St., Lombard	--	--	-1% (0.88)	-1% (0.97)	0%	--
Proctor Blvd. and Beers Ave , Sandy	--	-9% (1.51)	3% (0.57)	-5% (1.01)	**14% (3.24)**	--
3rd St. and Adventist Health, Tillamook	--	9% (1.47)	6% (0.96)	10% (1.74)	**12% (2.16)**	--

*Bolded figures are statistically significantly different at the 95% confidence level

4.5.1.1 Staged Pedestrian Crossings

Overall, there were 1,249 crossing events which involved a staged pedestrian interacting with a vehicle (yield, no yield) at the six locations. Table 4.12 shows the yielding rates for staged pedestrian crossings nearside. These yielding rates closely mirrored the overall yielding rates seen for all pedestrian crossings. At four locations (Astoria, Cascade Locks, Sandy, Tillamook), overall yielding rates across all stages for staged pedestrians were greater than 90%. Figure 4.8 shows the nearside yielding rates for staged pedestrian crossings at all sites.

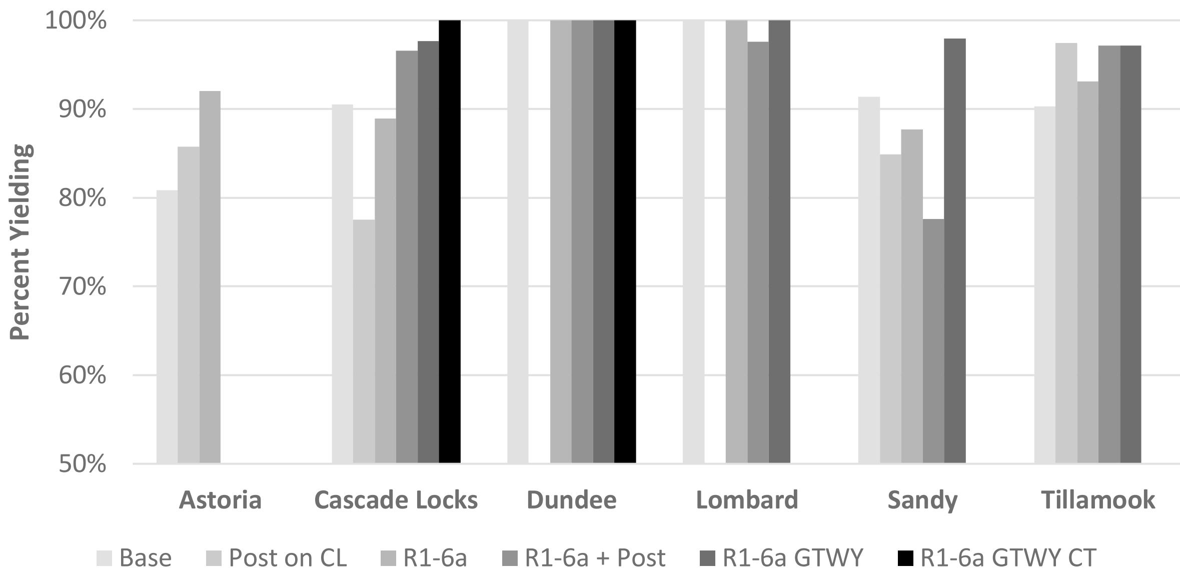


Figure 4.8: Farside Yielding for Staged Pedestrian Crossings

Table 4.13 shows the percent difference in yielding rates and the computed z-values in parentheses by stage compared to the base condition. The bolded percentage differences are statistically significantly different. At the two one-way sites (Astoria and Sandy), the trend regarding yielding rates were mixed when considered stage by stage. At Astoria, there was an increase in yielding (5%) when a tubular marker/post was added and 11% increase in yielding when one R1-6a sign was added. At the Sandy site, it was observed that yielding rates decreased with a tubular marker/post (-6%), one R1-6a sign (-4%), and one R1-6a sign with tubular markers/posts were added (-14%) when compared to the base condition. However, with the addition of three R1-6a signs in a gateway configuration (Stage 5), yielding rate increased by +7% compared to the base condition. At the two two-way sites (Cascade Locks and Tillamook), individual yielding rates were mixed with the addition of tubular markers/posts and signs. At Cascade Locks, yielding either increased or decreased across all stages for all pedestrian crossings compared to the base case. Decrease in yielding was observed with the installation of tubular markers/posts (-13%), one R1-6a sign (-2%), but increase in yielding was observed with one R1-6a sign with tubular markers/posts (+6%), three R1-6a signs were added in a gateway configuration (+7%), and when the edge R1-6a signs were placed on curb top position (+10%). At the Tillamook, similar increases in yielding proportion were seen with the addition of tubular markers/posts (+7%), one R1-6a sign (+3%), one R1-6a sign with tubular markers/posts (+7%) and three R1-6a signs in gateway configuration (+7%). At the two-way locations with median (Dundee, Lombard), little to no change was observed with yielding proportions as they were high even in the base condition. At these sites, a median was present which probably allowed greater visibility of the crossing pedestrian to the farside driver thus leading to higher yielding rates. At the Dundee location, yielding proportions were 100% irrespective of the stage. At Lombard, yielding did not change with the addition of a R1-6a sign (0%) but decreased slightly with a R1-6a sign with tubular markers/posts (-2%) but showed no change with the three R1-6a signs in a gateway configuration (100% yielding).

Table 4.12: Farside Driver Yielding by Location and Stage for Staged Pedestrian Crossings

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + Post	R1-6a + Post	R1-6a GT WY	R1-6a GT WY	R1-6a GT WY CT	R1-6a GT WY CT	Tot	Tot	Tot
	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Tot
Marine Dr. and 15th St., Astoria	38	9	48	8	46	4	--	--	--	--	--	--	132	21	153
Marine Dr. and 15th St., Astoria	81%	19%	86%	14%	92%	8%	--	--	--	--	--	--	86%	14%	100%
Wa Na Pa St. and Regulator St., Cascade Locks	38	4	31	9	32	4	28	1	42	1	33	0	204	19	223
Wa Na Pa St. and Regulator St., Cascade Locks	90%	10%	78%	22%	89%	11%	97%	3%	98%	2%	100 %	0%	91%	9%	100%
OR 99W and 7th St., Dundee	56	0	--	--	51	0	51	0	49	0	46	0	253	0	253
OR 99W and 7th St., Dundee	100%	0%	--	--	100%	0%	100%	0%	100 %	0%	100 %	0%	100 %	0%	100%
N Lombard St. and N Fortune St., Portland	38	0	--	--	51	0	40	1	47	0	--	--	176	1	177
N Lombard St. and N Fortune St., Portland	100%	0%	--	--	100%	0%	98%	2%	100 %	0%	--	--	99%	1%	100%
Proctor Blvd. and Beers Ave , Sandy	53	5	45	8	50	7	45	13	47	1	--	--	240	34	274
Proctor Blvd. and Beers Ave , Sandy	91%	9%	85%	15%	88%	12%	78%	22%	98%	2%	--	--	88%	12%	100%
3rd St. and Adventist Health, Tillamook	28	3	38	1	27	2	34	1	34	1	--	--	161	8	169
3rd St. and Adventist Health, Tillamook	90%	10%	97%	3%	93%	7%	97%	3%	97%	3%	--	--	95%	5%	100%

Table 4.13: Percent Difference in Farside Driver Yielding Rate for Staged Pedestrian Crossings

Location	Base	Post on CL	R1-6a	R1-6a + Post	R1-6a GTWY	R1-6a GTWY CT
Marine Dr. and 15th St., Astoria	-	5% (0.66)	11% (1.61)	--	--	--
Wa Na Pa St. and Regulator St., Cascade Locks	-	-13% (1.61)	-2% (0.23)	6% (0.98)	7% (1.41)	10% (1.82)
OR 99W and 7th St., Dundee	-	--	0%	0%	0%	0%
N Lombard St. and N Fortune St., Lombard	-	--	0%	-2% (0.97)	0%	--
Proctor Blvd. and Beers Ave , Sandy	-	-6% (1.06)	-4% (0.64)	**-14% (2.05)**	7% (1.45)	--
3rd St. and Adventist Health, Tillamook	-	7% (1.27)	3% (0.39)	7% (1.16)	7% (1.16)	--

*Bolded figures are statistically significantly different at the 95% confidence level

4.5.1.1 *Naturalistic Pedestrian Crossings*

Overall, there were 1,453 crossing events which involved a naturalistic pedestrian interacting with a vehicle (yield, no yield) at the six locations. Table 4.14 shows the yielding proportions for naturalistic pedestrian crossings farside. These yielding rates were either equal to or lower than the proportions seen with staged pedestrian crossings. Figure 4.9 shows the nearside yielding rates for naturalistic pedestrian crossings at all sites.

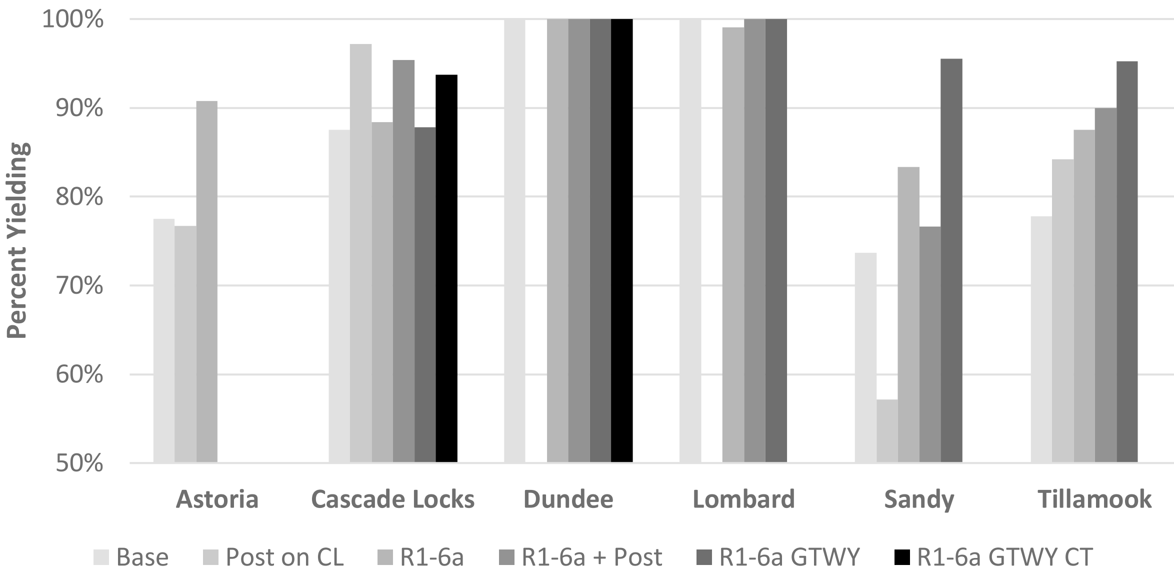


Figure 4.9: Farside Yielding for Naturalistic Pedestrian Crossings

Table 4.15 shows the percent difference in yielding rates and the computed z-values in parentheses by stage compared to the base condition. The bolded percentage differences are statistically significantly different. At the two one-way sites (Astoria and Sandy), the trend regarding yielding rates were mixed when considered stage by stage. At Astoria, there was a slight decrease in yielding (-1%) when a tubular marker/post was added but a 13% increase in yielding when one R1-6a sign was added. At the Sandy site, it was observed that yielding rates decreased with a tubular marker/post (-17%) but increased with one R1-6a sign (+10%), and one R1-6a sign with tubular markers/posts were added (+3%) when compared to the base condition. However, with the addition of three R1-6a signs in a gateway configuration (Stage 5), yielding rate increased by +22% compared to the base condition. At the two two-way sites (Cascade Locks and Tillamook), individual yielding rates increased with the addition of tubular markers/posts and signs. At Cascade Locks, an increase in yielding was observed with the installation of tubular markers/posts (+10%), one R1-6a sign (+1%), with one R1-6a sign with tubular markers/posts (+8%), no change in yielding with three R1-6a signs were added in a gateway configuration (+0%), and when the edge R1-6a signs were placed on curb top position (+6%). At the Tillamook, similar increases in yielding proportion were seen with the addition of tubular markers/posts (+6%), one R1-6a sign (+10%), one R1-6a sign with tubular markers/posts (+12%) and three R1-6a signs in gateway configuration (+17%). At the two-way locations with median (Dundee, Lombard), little to no change was observed with yielding proportions as they were high even in the base condition. At these sites, a median was present which probably allowed greater visibility of the crossing pedestrian to the farside driver thus leading to higher yielding rates. At the Dundee location, farside yielding proportions were 100% irrespective of the stage. At Lombard, yielding decreased slightly with the addition of a R1-6a sign (-1%) and did not change with the addition of a R1-6a sign with tubular markers/posts (0%) or with the three R1-6a signs in a gateway configuration (0%).

Table 4.14: Farside Driver Yielding by Location and Stage for Naturalistic Pedestrian Crossings

Location	Base	Base	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + Post	R1-6a + Post	R1-6a GTWY	R1-6a GTWY	R1-6a GTWY CT	R1-6a GTWY CT	Tot	Tot	Tot
	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Y	NY	Tot
Marine Dr. and 15th St., Astoria	31	9	56	17	108	11	--	--	--	--	--	--	195	37	232
Marine Dr. and 15th St., Astoria	78%	22%	77%	23%	91%	9%	--	--	--	--	--	--	84 %	16 %	100 %
Wa Na Pa St. and Regulator St., Cascade Locks	35	5	70	2	61	8	144	7	65	9	15	1	390	32	422
Wa Na Pa St. and Regulator St., Cascade Locks	88%	12%	97%	3%	88%	12%	95%	5%	88%	12%	94%	6%	92 %	8%	100 %
OR 99W and 7th St., Dundee	6	0	--	--	7	0	5	0	11	0	9	0	38	0	38
OR 99W and 7th St., Dundee	100%	0%	--	--	100%	0%	100%	0%	100%	0%	100%	0%	100 %	0%	100 %
N Lombard St. and N Fortune St., Portland	85	0	--	--	107	1	90	0	111	0	--	--	393	1	394
N Lombard St. and N Fortune St., Portland	100%	0%	--	--	99%	1%	100%	0%	100%	0%	--	--	100 %	0%	100 %
Proctor Blvd. and Beers Ave , Sandy	42	15	20	15	60	12	36	11	43	2	--	--	201	55	256
Proctor Blvd. and Beers Ave , Sandy	74%	26%	57%	43%	83%	17%	77%	23%	96%	4%	--	--	78 %	22 %	100 %
3rd St. and Adventist Health, Tillamook	21	6	16	3	21	3	18	2	20	1	--	--	96	15	111
3rd St. and Adventist Health, Tillamook	78%	22%	84%	16%	88%	12%	90%	10%	95%	5%	--	--	86 %	14 %	100 %

Table 4.15: Percent Difference in Farside Driver Yielding Rate for Naturalistic Pedestrian Crossings

Location	Base	Post on CL	R1-6a	R1-6a + Post	R1-6a GTWY	R1-6a GTWY CT
Marine Dr. and 15th St., Astoria	-	-1% (0.10)	**13% (2.19)**	--	--	--
Wa Na Pa St. and Regulator St., Cascade Locks	-	**10% (2.04)**	1% (0.14)	8% (1.82)	0% (0.05)	6% (0.68)
OR 99W and 7th St., Dundee	-	--	0%	0%	0%	0%
N Lombard St. and N Fortune St., Lombard	-	--	-1% (0.89)	0%	0%	--
Proctor Blvd. and Beers Ave , Sandy	-	-17% (1.64)	10% (1.34)	3% (0.34)	**22% (2.94)**	--
3rd St. and Adventist Health, Tillamook	-	6% (0.54)	10% (0.91)	12% (1.10)	17% (1.70)	--

*Bolded figures are statistically significantly different at the 95% confidence level

4.6 DISCUSSION OF RESULTS

Table 4.16 shows the summary of the nearside and farside yielding behavior of drivers towards all pedestrians with the various configurations of tubular markers/posts and signs. The “+” sign represents increase in yielding and “-“ represents a decrease in yielding compared to the base case (Stage 1). No change is represented by “•”. The addition of one tubular marker/post shows mixed results with some locations showing increase in yielding, while others showing a decrease in yielding. Similar mixed trends were observed for one R1-6a sign and one R1-6a sign with two tubular markers/posts. However, for the three R1-6a signs in the gateway configuration, yielding generally increased except for one instance (nearside yielding at Cascade Locks) and was statistically significantly different at the three locations. At the Cascade Locks location, nearside yielding increased with three R1-6a signs with two signs placed on the curb top.

Table 4.16: Summary of Nearside/Farside Yielding Behavior

Location	Post on CL	Post on CL	R1-6a	R1-6a	R1-6a + Post	R1-6a + Post	R1-6a GTWY	R1-6a GTWY .	R1-6a GTWY CT	R1-6a GTWY CT
	NS	FS	NS	FS	NS	FS	NS	FS	NS	FS
Marine Dr. and 15th St., Astoria	↑	↑	↑	↑	--	--	--	--	--	--
Wa Na Pa St. and Regulator St., Cascade Locks	↓	↑	↓	•	↓	↑	↓	↑	↑	↑
OR 99W and 7th St., Dundee	--	--	↑	•	↑	•	↑	•	↓	•
N Lombard St. and N Fortune St., Lombard	--	--	↑	↓	↑	↓	↑	•	--	--
Proctor Blvd. and Beers Ave , Sandy	↓	↓	↓	↑	↓	↓	↑	↑	--	--
3rd St. and Adventist Health, Tillamook	↑	↑	↑	↑	↑	↑	↑	↑	--	--

"↑" Increase in yielding; "↓" Decrease in yielding; Shaded – Statistically significantly different from base condition.

These results indicate that the gateway configuration increased yielding on both the nearside and the farside, replicating previous research findings (Bennett and Van Houten, 2016; Van Houten and Hochmuth, 2016). A previous study found that yielding with these signs in a gateway configuration on multi-lane roads is comparable to that with a PHB or RRFB alone (Bennett and Van Houten, 2016). These signs are less expensive than PHBs or RRFBs and relatively easy to install. These signs also don't require special outreach efforts to educate the public, as they are easy to understand. They also do not require a pushbutton to be activated prior to crossing.

Table 4.17 Average Yielding Proportions by Treatment Type

Location	Post on CL	R1-6a	R1-6a + Post	R1-6a GTWY	R1-6a GTWY CT
Nearside	87%	89%	86%	92%	87%
Farside	84%	92%	93%	97%	99%

Table 4.17 shows the average yielding proportions by treatment type across all locations for nearside and farside crossings. The use of tubular markers/posts alone produced 87% and 84% yielding for nearside and farside crossings respectively. Note that the tubular markers/posts alone were not used at the locations with a median island (Dundee, Lombard). Introducing one R1-6a sign increased the average yielding proportions to 89% and 92% for nearside and farside crossings respectively. This indicates that the addition of a single in-street crossing sign is favorable for yielding and produces higher yielding rates than the tubular marker/post alone. The addition of tubular markers/posts on the edge lines to supplement the existing center R1-6a sign produced some mixed results with yielding decreasing nearside and increasing slightly farside when compared to proportions seen with just the one R1-6a sign alone, indicating that the addition of the tubular markers/posts is not beneficial in increasing the yielding proportions. A previous study found that when the most vulnerable signs in the gateway configuration (i.e., the sign in the center) was replaced by a fluorescent traffic post or tubular marker, average yielding decreased compared to the gateway using only R1-6 signs (Bennett and Van Houten, 2015). The highest average yielding proportions across all locations were observed when three R1-6a signs were used in the gateway configuration, mirroring previous research findings (Bennet et al., 2014). When the edge signs were placed on the curb top, results were mixed with yielding lower nearside and higher farside when compared to the rates observed when all three signs were placed in the roadway. However, the yielding rates with this configuration were still similar or higher than the other treatments studied (tubular marker/post alone, one R1-6 sign, one R1-6 sign with tubular markers/posts in a gateway configuration) except for the stage when the gateway configuration included all three signs.

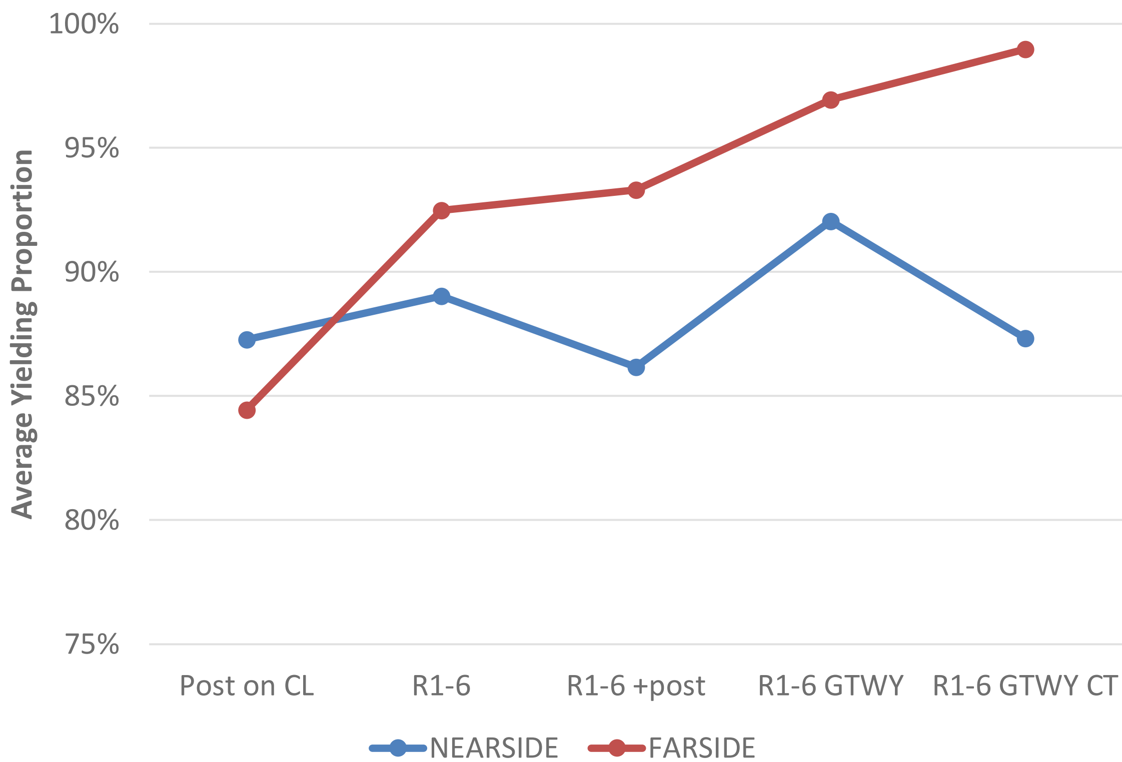


Figure 4.10: Average Yielding Proportion by Treatment for Nearside and Farside Crossings

Figure 4.10 shows the average yielding proportion by treatment for nearside and farside across all sites. When comparing yielding proportions for nearside and farside, the placement of R1-6a signs in a gateway configuration produced the highest yielding proportions nearside, while on the farside the placement of R1-6a signs in a curb top presentation produced the highest yielding rates. For nearside crossings, the in-street signs placed in a gateway configuration likely provide stronger visual framing and advance cueing as drivers approach the crosswalk, reinforcing yielding expectations earlier in the decision process, while curb top signs may be perceived too late to change behavior. For farside crossings, curb top presentations may provide higher visibility by placing the sign closer to the driver's focal area. Differences in sight distance and vehicle speed profiles may also have caused the observed differences in yielding performance.

4.7 MAINTENANCE

Previous research conducted in Michigan found some key factors that contributed to the survival of the gateway installation (Van Houten and Bennett, 2018). The guide recommends removal of in-street signs before the winter plowing season and reinstallation in spring in snowy climates. Specifically in the Oregon context, this may be applicable to higher elevations of Region 3 Region 4, and Region 5. Placing the signs in the gutter pan, on top of the median refuge island or curb top increase their lifespan than when placed on the edge line (Van Houten and Bennett. 2018). Results from this study showed that the yielding rates with curb top placement were slightly lower than those achieved with in-street gateway signs, however they were still higher than the other tested configurations, indicating that placing the edge signs on curb top where available might be a good solution to increase their longevity. Installing the signs with a removable curb type base improved survivability compared to those bolted to a flush base. In this study, none of the signs or tubular markers needed to be replaced during the testing phase. One sign at the Sandy location needed replacement because of improper installation but worked fine henceforth.

4.8 SUMMARY

This chapter presented the results of the data analysis at the six selected locations. Metrics such as pedestrian crossing time, delay and driver yielding rates were analyzed. The findings revealed that the gateway treatment with three signs placed in-street was most effective followed closely by the gateway treatment with the edge signs placed on the curb top position.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This research explored the impacts of adding R1-6a pedestrian crossing signs in various configurations on driver yielding behavior both nearside and farside for staged and naturalistic pedestrian crossings. To accomplish these goals, 6 locations in Oregon with uncontrolled marked crosswalks were selected, representing locations with diverse pedestrian volumes, land uses and roadway configurations. At each of these sites, the experimentation protocol involved multiple stages with and without tubular markers and R1-6a signs placed in various configurations including gateway and testing in-street vs. curb-top placement for the edge signs. Staged pedestrian crossings were conducted, and videos were recorded at these sites for each stage. The videos from these sites were coded to extract the counts of pedestrians, bicyclists, scooter users, skateboarders, wheelchair users, and other crosswalk users and observe driver yielding behavior.

At the 6 locations, 6, 151 users were observed crossing at the marked crosswalks. From this set, only pedestrians were extracted. These included people walking, on scooters, skateboards, and wheelchairs. Overall, 5,992 pedestrians were observed with 4,063 (68%) naturalistic and 1,929 (32%) staged crossings. Filtering out bicyclists and other crosswalk users and the crossings where pedestrians had no interactions with vehicles yielded a dataset of 3,054 crossings nearside and 2,702 crossings farside for staged and naturalistic crossings. The highest naturalistic volumes (1,706) were observed at Wa Na Pa St. and Regulator St. in Cascade Locks, while the lowest volumes (117) were observed at OR 99W and 7th St. in Dundee. At most locations, naturalistic pedestrian crossings were higher than staged crossings except at OR 99W and 7th St crosswalk in Dundee.

At all six locations, stage 1 was the baseline condition. Overall yielding rates were high even in the baseline condition for both nearside (average 85%) and farside (average 89%) yielding. Yielding rates remained high with the addition of tubular markers/posts with 87% yielding nearside and 84% farside. The addition of one R1-6a sign increased yielding rates to 89% nearside and 92% farside. Adding two tubular markers/posts to the R1-6a sign resulted in average yielding rates of 86% nearside and 93% farside. Installing three R1-6a signs in the gateway configuration produced highest yielding rates of 92% and 97% at the nearside and farside respectively. Adding the edge signs onto the curb top resulted in yielding rates of 87% and 99% nearside and farside respectively.

Notable increase in yielding rates was observed with the addition of signs and in particular with the gateway treatment, which is particularly meaningful given that baseline yielding was already quite high, making additional improvements difficult to achieve. Achieving improvements in yielding with the signs underscores their effectiveness, even under conditions when driver yielding is already high. It is likely that if the base yielding rates were lower, larger increases may have been observed. At the same time, site diversity remains a challenge and despite installing similar treatments, variations in roadway context, driver behavior, and context naturally lead to some differences in the outcomes.

5.1 RECOMMENDATIONS

Drawing from the findings of this study and past research, below are some recommendations for ODOT to consider for the use and placement of in-street pedestrian crossing signs.

5.1.1 Location

The R1-6a signs in a gateway configuration have shown to be most effective in increasing yielding rates at uncontrolled locations with marked crosswalks compared to other tested configurations. This treatment may be most suited for roadways with speed limits of 30 mph or less as they provide a strong visual cue in the driver's line of sight. Previous research recommends using them on roadways with speed limit of 35 mph only when the AADT is below 12,000. When installing multiple signs along a corridor, ensure consistent placement to avoid driver confusion. Prior research has also shown that the effectiveness of the gateway treatment is inversely proportional to the gap between the sizes, with narrower gap being more effective.

5.1.2 Maintenance

Sign placement is key for survivability. Placing the edge signs on curb top or a median (where available) can help increase the lifespan of the signs especially where street sweeping, snowplowing, or turning movements make in-street placement impractical. However, the MUTCD requires that the in-street signs shall only be placed in the roadway at the crosswalk location on the center line, on a median island, on a lane line, or on an edge line, therefore curb top placement may need additional approval. Installing the signs with a removable curb type base is better than those bolted to a flush base. Previous research recommends installing curb extensions when on-street parking is present to increase the visibility of the signs (Van Houten and Bennett, 2018). Removing the signs before winter and reinstalling in spring can help increase sign longevity. Check for retroreflectivity and vertical alignment regularly. Avoid locations where drainage or bike lanes make placement hazardous.

5.2 LIMITATIONS

Several limitations should be considered when interpreting the findings from this study. First, baseline yielding rates at many sites were already high, which limits the potential magnitude of observed improvements. Second, despite efforts to select comparable sites, contextual differences in roadway geometry, traffic volumes, land use, visibility and driver familiarity introduce variability that cannot be fully controlled which may influence driver yielding behavior. Finally, the study also evaluated limited number of sites and all data was collected during daylight hours only, which prevents the assessment of how gateway treatments with R1-6 signs perform under low-light conditions when driver visibility and behavior may differ from daytime conditions.

5.3 FUTURE WORK

This study explored short-term impacts of the various configurations of R1-6a signs on driver yielding. It would be helpful to see if the yielding improvements persist over the long term. In this study, while some variability was observed with yielding behavior across stages, the results do not appear entirely random or unrelated to treatment effects. In particular, consistent evidence of increased yielding associated with the gateway sign configuration as observed at several sites, suggesting that the treatment can positively influence driver behavior despite contextual noise. However, it must be acknowledged that yielding behavior is sensitive to confounding factors such as traffic volumes, pedestrian presence, visibility, and temporal variation, which can obscure treatment effects in limited samples. Future research could strengthen inference by expanding sample sizes, collecting data across multiple days and times, and employing repeated treatment–baseline sequences similar to those used in previous studies. Such approaches would help isolate treatment effects, assess behavioral stability over time, and improve the reliability of stopping compliance as a primary evaluation metric.

While previous research has shown speed reductions associated with the gateway configuration, it would be helpful to study if the same impacts are seen in the Oregon context. Future research should also explore how site context (e.g., roadway width, speed, ADT, land use, lighting, pedestrian volume) moderates effectiveness. Predictive models can also be developed to estimated expected yielding based on site characteristics, allowing for data-driven selection of R1-6a treatments.

6.0 REFERENCES

Al-Kaisy, A., G.T. Miyake, J. Staszcuk, and D. Scharf. Motorists' Voluntary Yielding of Right-of-Way at Uncontrolled Midblock Crosswalks with Rectangular Rapid Flashing Beacons. Journal of Transportation Safety & Security, 10(4), 2018. https://doi.org/10.1080/19439962.2016.1267827

Baumanis, C. and R. Machemehl. Driver Compliance with Pedestrian Crossings at Non-Signalized Intersections. Interim Report, Center for Advanced Multimodal Mobility Solutions and Education, 2022.

Bennett, M.K., H. Manal, and R. Van Houten. A Comparison of Gateway In-Street Sign Configuration to Other Driver Prompts to Increase Yielding to Pedestrians at Crosswalks. Journal of Applied Behavior Analysis, Vol. 47, 2014, pp. 3-15.

Bennett, M.K., and R. Van Houten. Variables Influencing Efficacy of Gateway In-Street Sign Configuration on Yielding at Crosswalks. Transportation Research Record 2586, Transportation Research Board, Washington, D.C., 2016, pp. 100–105. DOI: 10.3141/2586-11

Blackburn, L., C. Zegeer, and K. Brookshire. Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations. FHWA-SA-17-072, 2018.

City of Madison Traffic Engineering Division. Year 2 Field Evaluation of Experimental 'In-Street' Yield to Pedestrian Signs. City of Madison Department of Transportation, Madison, Wisconsin, 1999.

Domarad, J., P. Grisak, and J. Bolgar. Improving Crosswalk Safety: Rectangular Rapid-Flashing Beacon (RRFB) Trial in Calgary. Institute of Traffic Engineers District 7 Canada, 2013.

Ellis Jr., R. D., R. Van Houten and J.-L. Kim. In-Roadway 'Yield to Pedestrian' Signs: Placement Distance and Motorist Yielding. In Transportation Research Record: Journal of the Transportation Research Board, No. 2002, Transportation Research Board of the National Academies, Washington, D.C., 2007, pp. 84-89.

El-Urfali, A., and R. Van Houten. FHWA Request to Experiment R1-6 Gateway Effect- FDOT. Progress Report, 2021.

Federal Highway Administration. Manual on Uniform Traffic Control Devices, 2009. https://mutcd.fhwa.dot.gov/

Feldman, M., J. G. Manzi and M. Mitman. An Empirical Bayesian Evaluation of the Safety Effects of High-Visibility School (Yellow) Crosswalks in San Francisco. In Transportation Research Record: Journal of the Transportation Research Board, No. 2198, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 8-14.

Fitzpatrick K., Turner S. M., Brewer M., Carlson P. J., Ullman B., Trout N. D., Park E. S., Whitacre J., Lalani N., and Lord D. *TCRP Report 112–NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings.* Transportation Research Board of the National Academies, Washington, D.C., 2006.

Fitzpatrick, K., and E. S. Park. Safety Effectiveness of the HAWK Pedestrian Crossing Treatment. Publication FHWA-HRT-10-042. FHWA, U.S. Department of Transportation, 2010.

Fitzpatrick, K., S. Chrysler, V. Iragavarapu, and E. S. Park. Detection Distances to Crosswalk Markings: Transverse Lines, Continental Markings, and Bar Pairs. In Transportation Research Record: Journal of the Transportation Research Board, No. 2250, Transportation Research Board of the National Academies, Washington, D.C., 2011, pp. 1-10.

Fitzpatrick, K., M. Brewer, and R. Avelar. Driver Yielding at Traffic Control Signals, Pedestrian Hybrid Beacons and Rectangular Rapid Flashing Beacons in Texas. Transportation Research Record 2463, 2014, pp. 46–54.

Fitzpatrick, K. and M. Pratt. Road User Behaviors at Pedestrian Hybrid Beacons. Transportation Research Record 2586 (1), 2016, 9-16.

Fitzpatrick, K., M. Cynecki, M. Pratt, E.S. Park, and M. Beckley. Evaluation of Pedestrian Hybrid Beacons on Arizona Highways. Final Report, Arizona Department of Transportation, 2019.

Foster, N., C. M. Monsere, and K. Carlos. Evaluating Driver and Pedestrian Behaviors at Enhanced Multi- Lane Midblock Pedestrian Crossings: A Case Study in Portland, Oregon. Transportation Research Record, 2464(1), 2014, 59–66. https://doi.org/10.3141/2464-08.

Gibby, A.R., J.L. Stites, G.S. Thurgood, and T.C. Ferrara. Evaluation of Marked and Unmarked Crosswalks at Intersections in California. Chico State University, Report Number FHWA/CA/TO-94/1, June 1994.

Governor's Highway Safety Association. Pedestrian Traffic Fatalities by State, 2025. https://www.ghsa.org/resource-hub/pedestrian-traffic-fatalities-state-2024-preliminary-data-january-december

Gurnett, G. Marked Crosswalk Removal Before and After Study. Los Angeles County Road Department, November 1974.

Herms, B. Pedestrian Crosswalk Study: Accidents in Painted and Unpainted Crosswalks. Highway Research Record Number 406 Pedestrian Protection, Highway Research Board, pp. 1-13, Washington DC, 1972.

Hua, J., N. Gutierrez, I. Banerjee, F. Markowitz, and D. R. Ragland. San Francisco Pedsafe II Project Outcomes and Lessons Learned. Presented at the 88th Annual Meeting of the Transportation Research Board, Washington, D.C., 2009.

Huang, H.F. and M.J. Cynecki. The Effects of Traffic Calming Measures on Pedestrian and Motorist Behavior. Report No. FHWA-RD-00-104, University of North Carolina Highway Safety Research Center, Chapel Hill, NC & City of Phoenix, Street Transportation Dept., Phoenix, AZ, August 2000.

Hunter, W. W., R. Srinivasan, and C. A. Martell. Evaluation of the Rectangular Rapid Flash Beacon at a Pinellas Trail Crossing in St. Petersburg, Florida. Florida Department of Transportation, Tallahassee, Florida, 2009.

Jones, T. L., and P. Tomcheck. Pedestrian Accidents in Marked and Unmarked Crosswalks: A Quantitative Study. ITE Journal, Vol. 70, No. 9, 2000, pp. 42-46.

Kamyab, A., S. Andrie, D. Kroeger, and D. Heyer. Methods to Reduce Traffic Speed in High-Pedestrian Rural Areas. In Transportation Research Record: Journal of the Transportation Research Board, No. 1828, Transportation Research Board of the National Academies, Washington, D.C., 2003, 31-37.

Kannel, E.J., R. R. Souleyrette, and R. Tenges. In-Street Yield to Pedestrian Sign Application in Cedar Rapids, Iowa. Center for Transportation Research and Education, Iowa State University, Ames, Iowa, 2003.

Knoblauch, R. L., and P. D. Raymond. The Effect of Crosswalk Markings on Vehicle Speeds in Maryland, Virginia, and Arizona. Publication FHWA-RD-00-101, FHWA, U.S. Department of Transportation, 2000.

Knoblauch, R. L., M. Nitzburg, and R. F. Seifert. Pedestrian Crosswalk Case Studies: Richmond, Virginia; Buffalo, New York; Stillwater, Minnesota. Publication FHWA-RD-00-103, FHWA, U.S. Department of Transportation, 2001.

Kothuri, S., F.B., Appiah, and C. Monsere. Driver Yielding and Pedestrian Performance at Midblock Crossings on Three-Lane Roadways with Rectangular Rapid Flashing Beacons. Transportation Research Record, 2675(9), 910 – 923, 2021. https://doi.org/10.1177/03611981211004962

Mead, J., C. Zegeer, and M. Bushell. Evaluation of Pedestrian-Related Roadway Measures: A Summary of Available Research, Federal Highway Administration, 2014.

Mitman, M.F., D. R. Ragland, and C. V. Zegeer. The Marked Crosswalk Dilemma: Uncovering Some Missing Links in a 35-Year Debate. Presented at 87th Annual Meeting of the Transportation Research Board, Washington, D.C., 2008.

Nassi, R.B., and M. J. Barton. New Traffic Control for an Old Pedestrian Crossing Safety Problem. APWA Reporter, Vol. 75, No. 6, 2008, pp. 44-49.

National Committee on Uniform Traffic Control Devices (NCUTCD). Crosswalk Markings Application Criteria, 2012. https://ncutcd.org/wp-content/uploads/meetings/2012A/Attach-No.-12-Markings-No.2-Section-3B.18.pdf

Nitzburg, M., and R. Knoblauch. An Evaluation of High-Visibility Crosswalk Treatments—Clearwater, Florida. Publication FHWA-RD-00-105, FHWA, U.S. Department of Transportation, 2001. http://www.fhwa.dot.gov/publications/research/safety/pedbike/0105.pdf

O'Brien, S.W., C.V. Zegeer, I. Ahmed, S. Searcy, B. Kearns, and K. Pyo. Yielding Compliance at High Visibility Crosswalks. Final Report, North Carolina Department of Transportation, 2022.

Oregon Department of Transportation. Annual Crash Summary Books. https://www.oregon.gov/odot/data/pages/crash.aspx

Pecheux, K., J. Bauer, P. McLeod. Pedestrian Safety Engineering and ITS-Based Countermeasures Program for Reducing Pedestrian Fatalities, Injury Conflicts, and Other Surrogate Measures Final System Impact Report. Federal Highway Administration, U.S. Department of Transportation, 2009.

Pulugartha, S. S., V. Vasudevan, S. S. Nambisan, and M. R. Dangeti. Evaluating the Effectiveness on Infrastructure-Based Countermeasures on Pedestrian Safety. In Transportation Research Record: Journal of the Transportation Research Board, No. 2299, Transportation Research Board of the National Academies, Washington, D.C., 2012.

Pulugurtha, S. S., and D. R. Self. Pedestrian and Motorists' Actions at Pedestrian Hybrid Beacon Sites: Findings from a Pilot Study. International Journal of Injury Control and Safety Promotion, 2015, 22, 143-152.

Ross, J., D. Serpico, and R. Lewis. Assessment of Driver Yielding Rates Pre- and Post-RRFB Installation, Bend, Oregon. Oregon Department of Transportation, Salem, Oregon, 2011.

Schneider, R. *United States Pedestrian Fatality Trends, 1977 to 2016*. Transportation Research Record, Journal of the Transportation Research Board, 2020. https://doi.org/10.1177/0361198120933636

Schneider, R., Sanders, R., Proulx, F., and Moayyed, H. United States Fatal Pedestrian Crash Hot Spot Locations and Characteristics. Journal of Transport and Land Use, Vol. 14 (1), 2021. https://www.jtlu.org/index.php/jtlu/article/view/1825

Shurbutt, J. and R. Van Houten. Effects of Yellow Rectangular Rapid-Flashing Beacons on Yielding at Multilane Uncontrolled Crosswalks. Publication FHWA-HRT-10-043, FHWA, U.S. Department of Transportation, 2010.

Tobey, H.N., E.M. Shunamen, and R.L. Knoblauch. Pedestrian Trip Making Characteristics and Exposure Measures, DTFH61-81-C-00020, Federal Highway Administration, 1983.

Van Houten, R.G., R. D. Ellis Jr, and E. Marmolejo. Stutter Flash LED Beacons to Increase Yielding to Pedestrians at Crosswalks. In Transportation Research Record: Journal of the Transportation Research Board, No. 2073, Washington D.C., 2008, pp. 69-78.

Van Houten, R., and Hochmuth, J. Comparison of Alternative Pedestrian Crossing Treatments. Final Report RC-1638, Michigan Department of Transportation, 2016. https://rosap.ntl.bts.gov/view/dot/32247

Knoblauch, C. V., R. Stewart, H. Huang, and P. Lagerwey. *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines*. Publication FHWA-RD-01-075, FHWA, U.S. Department of Transportation, 2002.

Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. *Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments*. National Cooperative Highway Research Program, 2017. http://nap.nationalacademies.org/24627

7.0 APPENDICES

APPENDIX A

STAGED PEDESTRIAN DATA COLLECTION PROTOCOL

Materials: Paint, Traffic cones (2) and measuring wheel

At each location, use the measuring wheel to mark the stopping sight distance (SSD) from the crosswalk. Place a cone on the sidewalk away from the path of the pedestrians at the SSD marker. The SSDs at each site are shown in Table 1 below. If the road is one-way, this will be measured in just one direction (Figure 1). If the road is two-way, measure the SSD in both directions and place the cones at the SSD marker upstream of the direction of travel.

Table 7.1 SSD at Selected Sites

Location	SSD
Marine Dr. and 15th St., Astoria	112
Wa Na Pa St. and Regulator St., Cascade Locks	197
OR 99W and 7th St., Dundee	197
N Lombard St. and N Fortune Ave, Portland	197
Proctor Blvd and Beers Ave, Sandy	152
3rd St. and Adventist Health, Tillamook	197

Figure 7.1. Proctor Blvd. and Beers Ave (One-way)

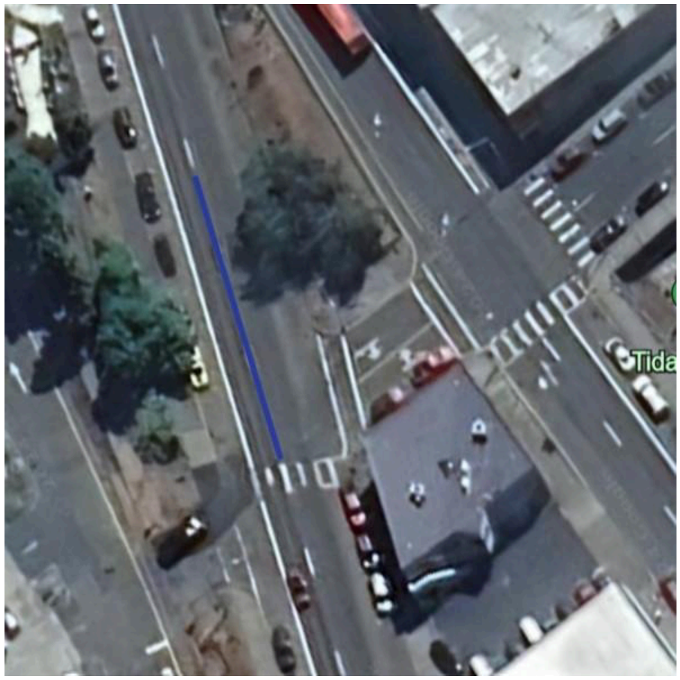


Figure 7.2 Marine Dr. and 15th St.(One-way)

Figure 7.3 Wa Na Pa St. and Regulator St. (Two-way)

Figure 7.4 3rd St. and Adventist Health (Two-way)

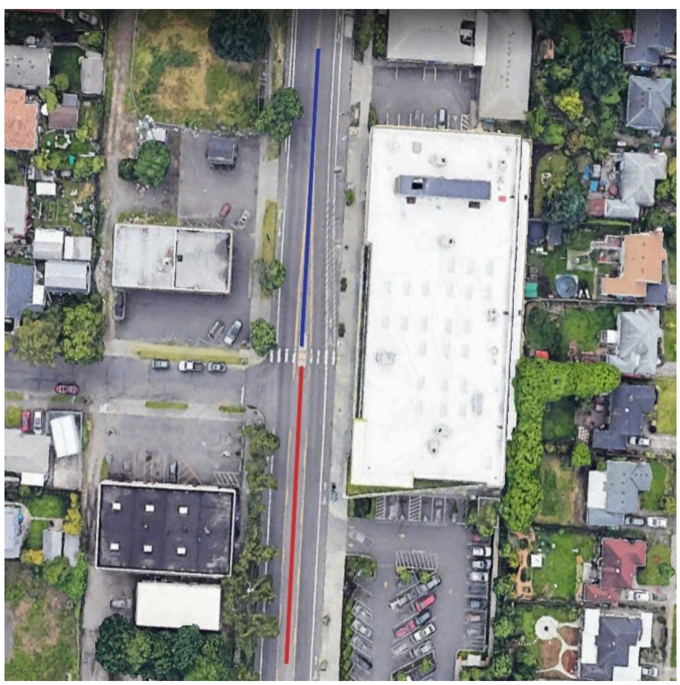


Figure 7.5 N Lombard St. and N Fortune Ave (Two-way)

Figure 7.6 OR 99W and 7th St. (Two-way)

When a vehicle is at or beyond the SSD marker, approach the crosswalk with the intent to cross. Do not use hand signals or try to alert the driver in any way. Wait at the curb and do not begin crossing until the vehicle yields. Once the vehicle yields, begin crossing. If the vehicle does not yield, wait for the vehicle to depart from the crossing before beginning to cross. Complete the crossing and walk away from the curb. Wait for a few minutes and repeat the exercise, crossing from the other direction. If it is a site with a median island, treat the crossing as two crossings. Check the SSD marker and walk from the curb to the median island after the vehicle has yielded. Check for the vehicle yielding on the far side before leaving the median island.

Continue until 30 crossings from each direction have been completed, a total of 60 crossings.

APPENDIX B

Figure 7.7 Marine Dr. and 15th St. Astoria, Stage 1 (Base)

Figure 7.8 Marine Dr. and 15th St. Astoria Stage 2 (Post on CL)

Figure 7.9 Marine Dr. and 15th St. Astoria Stage 3 (R1-6a)

Figure 7.10 Wa Na Pa St. and Regulator St., Cascade Locks Stage 1 (Base)

Figure 7.11 Wa Na Pa St. and Regulator St., Cascade Locks Stage 2 (Post on CL)

Figure 7.12 Wa Na Pa St. and Regulator St., Cascade Locks Stage 3 (R1-6a)

Figure 7.13 Wa Na Pa St. and Regulator St., Cascade Locks Stage 4 (R1-6a + Post)

Figure 7.14 Wa Na Pa St. and Regulator St., Cascade Locks Stage 5 (R1-6a GTWY)

Figure 7.15 Wa Na Pa St. and Regulator St., Cascade Locks Stage 6 (R1-6a GTWY CT)

Figure 7.16 OR 99W and 7th St,, Dundee Stage 1(Base)

Figure 7.17 OR 99W and 7th St,, Dundee Stage 2 (R1-6a)

Figure 7.18 OR 99W and 7th St,, Dundee Stage 3 (R1-6a + Post)

Figure 7.19 OR 99W and 7th St,, Dundee Stage 4 (R1-6a GTWY)

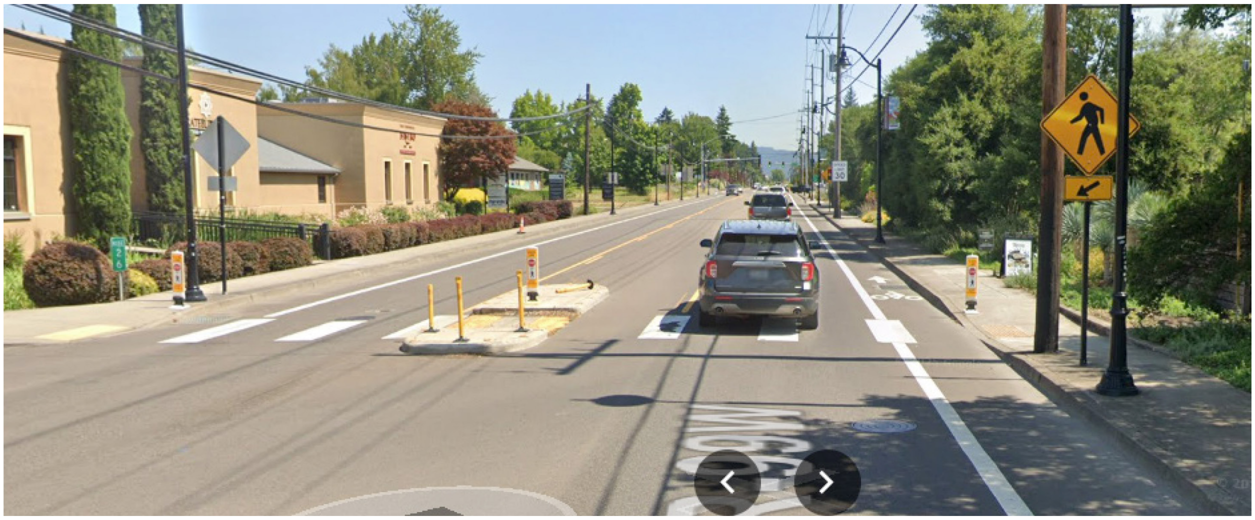


Figure 7.20 OR 99W and 7th St,, Dundee Stage 5 (R1-6a GTWY CT)

Figure 7.21 **N Lombard St and N Fortune St, Portland Stage 1 (Base)**

Figure 7.22 **N Lombard St and N Fortune St, Portland Stage 2 (R1-6a)**

Figure 7.23 N Lombard St and N Fortune St, Portland Stage 3 (R1-6a + Post)

Figure 7.24 N Lombard St and N Fortune St, Portland Stage 4 (R1-6a GTWY)

Figure 7.25 Proctor Blvd. and Beers Ave, Sandy Stage 1 (Base)

Figure 7.26 Proctor Blvd. and Beers Ave, Sandy Stage 2 (Post on CL)

Figure 7.27 Proctor Blvd. and Beers Ave, Sandy Stage 3 (R1-6a)

Figure 7.28 Proctor Blvd. and Beers Ave, Sandy Stage 4 (R1-6a + Post)

Figure 7.29 **Proctor Blvd. and Beers Ave, Sandy Stage 5 (R1-6a GTWY)**

Figure 7.30 3rd St. and Adventist Health, Tillamook Stage 1 (Base)

Figure 7.31 3rd St. and Adventist Health, Tillamook Stage 2 (Post on CL)

Figure 7.32 3rd St. and Adventist Health, Tillamook Stage 3 (R1-6a)

Figure 7.33 3rd St. and Adventist Health, Tillamook Stage 4 (R1-6a + Post)

Figure 7.34 3rd St. and Adventist Health, Tillamook Stage 5 (R1-6a GTWY)