PEDESTRIAN SAFETY IMPACTS OF CURB EXTENSIONS: A CASE STUDY

Final Report

SPR 304-321

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by

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16. Abstract

This report documents a case study evaluating motorist yielding behavior at a crosswalk in Albany, Oregon. In 2003 the City of Albany installed curb extensions, continental markings and advance stop bars at several uncontrolled intersections along the U.S. Highway 20 one-way couplet. The City of Albany requested that an evaluation be conducted to determine if the pedestrian safety improvements functioned as intended. Since the installation in 2003, there had been no data collection effort on the operation of these features.

The focus of this study was the intersection of 4th Avenue and Lyon Street because the nearside crosswalk had a curb extension on only one side of the street, thus allowing for an analysis of motorist behavior toward pedestrians crossing from either the side with the curb extension or the side without. Specifically, this study examined the average number of vehicles that passed between the time a pedestrian arrived at the crosswalk to the time they were able to cross, the percent of vehicles that yielded at the advance stop bar, and the percent of pedestrian crossings in which a vehicle yielded.

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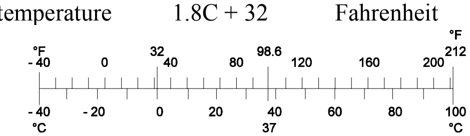
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	Inches	25.4	Millimeters	Mm
Ft	Feet	0.305	Meters	M
Yd	Yards	0.914	Meters	M
Mi	Miles	1.61	Kilometers	Km
		AREA		
In^2	square inches	645.2	Millimeters squared	mm^2
ft^2	square feet	0.093	Meters squared	m^2
Yd^2	square yards	0.836	Meters squared	m^2
Ac	Acres	0.405	Hectares	Ha
Mi^2	square miles	2.59	Kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	Milliliters	mL
Gal	Gallons	3.785	Liters	L
ft^3	cubic feet	0.028	Meters cubed	m^3
Yd^3	cubic yards	0.765	Meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
Oz	Ounces	28.35	Grams	G
Lb	Pounds	0.454	Kilograms	Kg
T	short tons (2000 lb)	0.907	Megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8C + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

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PEDESTRIAN SAFETY IMPACTS OF CURB EXTENSIONS: A CASE STUDY

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1.0 INTRODUCTION

1.1 BACKGROUND

This study evaluates an intersection with a pedestrian crossing that is treated both with and without curb extensions and advance stop bars and investigates motorist yielding behavior. Curb extensions (Figure 1.0), also known as bulbouts, are an extension of the curb line into the roadway. They are commonly installed along streets with on-street parking and extend to the travel lane. Curb extensions have different intended purposes. They are used for improved pedestrian safety and/or traffic calming. The pedestrian safety benefits include shorter crossing distance and increased visibility for both the driver of the waiting pedestrian and the waiting pedestrian of the approaching vehicles. Curb extensions can also make pedestrian crossings more visible, especially when used in combination with high visibility markings, such as continental markings (Figure 1.1). Continental markings are a series of wide longitudinal stripes that extend the width of the crosswalk.

When the intended purpose of curb extensions is for traffic calming, they typically extend into the travel lane to reduce speeds by narrowing the lanes. A series of curb extensions at intersection or mid-lock locations is typically used to reduce speeds along a corridor. Bulbouts at intersections can reduce the speeds of turning vehicles and still maintain an adequate turning radius.

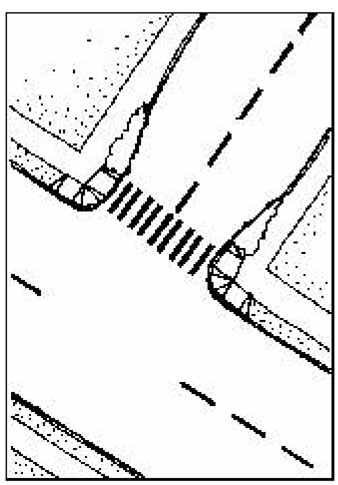

Figure 1.0: Curb extension diagram

The advance stop bars (Figure 1.1) are also evaluated in this study as a pedestrian safety feature. An advance stop bar is a stripe that is placed up to 20 or more feet upstream from the crosswalk.

A common pedestrian safety hazard that occurs on a one-way multi-lane street is when the motorist in the near lane yields at the edge of the crosswalk marking. This blocks the view of the pedestrian already in the crosswalk from the motorist in the far lane, often resulting in a failure to yield and an increase in the potential for a pedestrian-vehicle collision. This type of collision is known as a "multi-threat" collision (*Zegeer, et al. 2001*). The use of advance stop bars encourages the near lane driver to yield farther back from the crosswalk, thus maintaining a safe stopping sight distance for the motorist in the far lane.

Figure 1.1: Crosswalk with continental marking and advance stop bars

In 2003 the City of Albany installed curb extensions, advance stop bars, and striped crosswalks with continental markings on Lyon and Ellsworth Street at 4th and 5th Avenues. These streets are located in the downtown district and are part of a one-way couplet for U.S. Highway 20. The purpose of these improvements was to increase pedestrian safety at these intersection locations.

There were many issues that led to this joint Albany and Oregon Department of Transportation (ODOT) project. The intersections at 4th and 5th Avenues have no stop or yield control on the major street, which carries more than 17,000 trips per day (*Irish 2002*). High traffic volumes in combination with average and 85th percentile speeds well above the posted 25-mph speed limit make pedestrian crossing of these streets difficult and sometimes dangerous. No vehicle/pedestrian accidents had been reported in the last five years, but Albany averages just over 12 vehicle/pedestrian accidents each year for the entire city.

These intersections also provide an important pedestrian link between commercial uses in Albany's historic downtown area, government offices and services, and the residential neighborhoods in the Hackleman Historic District (*Irish 2002*). The curb extensions and striping were designed to improve crossing conditions for pedestrians with little or no impact to traffic.

It is important to note that the curb extensions in Albany were for improved pedestrian safety and not intended as traffic calming features. The design of the curb extensions terminated the edge of the bulbout two feet from the travel lanes and did not narrow the lanes or increase congestion. The benefits for pedestrians were increased visibility and shorter crossing distance.

1.2 PROBLEM STATEMENT

The City of Albany requested that a performance evaluation be conducted to determine if the pedestrian safety improvements functioned as designed. Since the installation in 2003, there had been no data collection effort on the operation of these features. This installation was extremely controversial and generated a lot of intense local debate. Some citizens deemed this project unnecessary and an inappropriate use of funds when other city streets were in disrepair.

Curb extensions are commonly used as traffic calming devices, and most studies have involved the evaluation of curb extensions as such. For example, bulbouts used to narrow travel lanes in the Dutch town of De Meern resulted in a significant reduction of the 85th percentile speeds (*Replogle 1992*). Few studies, however, have evaluated the safety of pedestrian crossings with curb extensions or developed methodologies to evaluate the safety performance beyond improved sight distance and a shorter crossing distance. One study that did evaluate bulbouts for safety in terms of behavior was the Federal Highway Administration's (FHWA) study titled *The Effects of Traffic Calming Measures on Pedestrian and Motorist Behavior* (*Huang and Cynecki 2001*). This study, however, evaluated the effect of *traffic calming* bulbouts on motorist behavior.

1.3 OBJECTIVE OF THE PROJECT

The ODOT design manual states that, "Curb extensions reduce the pedestrian crossing distance and improve the visibility of pedestrians for motorists on streets where parking is allowed." (*ODOT 2003*). These pedestrian safety benefits of curb extensions, as described in the ODOT design manual, are often the justification for their installation. The objective of this study was to further quantify the safety benefits that curb extensions provide to pedestrians by examining motorist behavior.

This study compared motorist yielding behavior of a pedestrian crossing with and without curb extensions that had continental markings and advance stop bars. The methodology used to quantify motorist yielding behavior was intended to allow the City of Albany to determine if the curb extensions, advance stop bars and continental crosswalk striping had increased the safety of pedestrian crossings, thus justifying the expense for this project. This methodology could also be adapted for use by other agencies to evaluate the safety performance of curb extensions.

2.0 METHODOLOGIES USED

2.1 BACKGROUND RESEARCH

Previous research reports were reviewed to determine the extent to which motorist behavior has been evaluated in relation to curb extensions. The most closely related study was the FHWA study titled *The Effects of Traffic Calming Measures on Pedestrian and Motorist Behavior* (*Huang and Cynecki 2001*). Of interest from this study was the effect bulbouts as traffic calming features have on pedestrian and motorist behavior. Huang and Cynecki cited previous studies that evaluated curb extensions as speed reduction measures. One such study was the evaluation of bulbouts used to narrow travel lanes in the Dutch town of De Meern that resulted in a significant reduction of the 85th percentile speeds (*Replogle 1992*). In contrast, a study of bulbouts in the Australian cities of Keilor, Queensland and Eltham, Victoria resulted in little effect on reducing vehicle speeds (*Hawley, et al. 1992*). The many studies on curb extensions as traffic calming features have shown that they can be effective in calming traffic. In their own research, Huang and Cynecki performed before and after studies of bulbouts in Cambridge, MA and Seattle, WA and treatment-and-control studies of bulbouts in Greensboro, NC and Richmond, VA. The measures of effectiveness used to measure the behaviors of pedestrians and motorists were *percentage of pedestrians for whom motorists stopped or yielded, percentage of pedestrians who crossed in the crosswalk,* and *wait time* before crossing.

The study locations in Cambridge, MA were in residential neighborhoods, while the Seattle, WA sites were on arterial streets near downtown Seattle. The percentage of pedestrians for whom motorists yielded in the Cambridge sites showed a large increase with bulbouts, but with very small sample sizes before and after the installation of the bulbout. The Seattle study showed a small decrease from 58% to 52%, but the results were not statistically significant. No explanation was given regarding possible causes for the insignificant results. The differences at the Cambridge site were also statistically insignificant from before and after the bulbout for the percentage of pedestrians who crossed in the crosswalk and wait time. The Seattle results surprisingly showed a significant decrease in the percentage of pedestrians who crossed in the crosswalk and a significant increase in wait time. The insignificant result in the wait time for the Cambridge site was attributed to low traffic volumes, so most pedestrians had little or no wait time. Fluctuations in traffic conditions are given as a possible cause for the significant results in the wrong direction for the Seattle locations.

For the Greensboro, NC and Richmond, VA treatment-and-control study, there were two treatment and two control sites for each city. One Greensboro site was along a major downtown arterial and the other was on a bidirectional two-lane street with on-street parking. Both Richmond sites were along one-way two-lane streets in residential neighborhoods. This treatment-and-control study only observed the percentage of pedestrians for whom motorists yielded and vehicle speeds. The Greensboro site resulted in a significant 1.1 mph decrease for the site with bulbouts compared to the one without. The Richmond site resulted in a significant

2.0 mph increase in the 50^{th} percentile speed. There was no explanation of what may have caused the increase in speed. Both the Greensboro and Richmond sites had very low percentages of pedestrians for whom motorists yielded with no significant difference between the treatment and control.

Another study of importance was the FHWA's *Improving Motorists Yielding at Crosswalks on Multilane Roads with an Uncontrolled Approach* (*Zegeer, et al. 2001*). This FHWA study focused on pedestrian crash data and factors such as pedestrian and vehicle volumes, median type, crossing location, vehicle speed, and lane configuration. In the end, 229 pedestrian crashes at 2000 crossings from a 5-year period were analyzed. Interestingly, factors determined to have no effect on the pedestrian crash rate included speed limit, traffic operation (one- or two-way), marking type (continental, zebra, parallel lines) and crossing location (mid-block or intersection).

Another surprising result was that for multi-lane roads with an average daily traffic (ADT) greater than 15,000 and no raised median, there was a significant difference with a higher pedestrian crash rate for marked crossings when compared to unmarked. One possible explanation for this was that "at risk" pedestrians (children and elderly) could go to the nearest signalized crossing if there was no marked crosswalk available. Results showed that over 70 percent of pedestrians under the age of 12 and over 64 used marked crosswalks (*Zegeer, et al. 2001*).

Another notable result was that "multiple-threat" crashes occurred almost 18 percent of the time in marked crosswalks and did not occur at all with unmarked crossings. The "multiple-threat" crash occurs when there are multiple lanes of travel in the same direction and the vehicle in the near lane yields to the pedestrian and blocks the sight distance of the motorist in the other lane. This situation was present at the Albany curb extension crosswalks, thus making them vulnerable to this type of crash.

For a multi-lane road (4 or more lanes), with no raised median, speed limit of less than 35 mph, and an ADT greater than 15,000, Zegeer, et al. recommended that marked crosswalks alone are insufficient and that additional treatments should be provided. These treatments may include raised medians, traffic signals, roadway narrowing, enhanced overhead lighting, traffic-calming measures, and/or curb extensions. Lyon and Ellsworth Street through downtown Albany do not have 4 lanes, but they do have two lanes of travel in the same direction and meet all other criteria for the recommendation by Zegeer, et al. Based on this study, the curb extensions and advance stop bars installed at the crossings at 4^{th} and 5^{th} Avenues were warranted.

2.2 STUDY AREA DESCRIPTION

The curb extension project includes the intersections of 4^{th} and 5^{th} Avenues along Ellsworth and Lyon Street. (Figure 2.0). Lyon (northbound) and Ellsworth (southbound) comprise a one-way couplet of U.S. Highway 20 through downtown Albany. Both streets have two travel lanes with on-street parking on both sides. All four intersections also have a no parking zone (yellow curb marking) of approximately 40 feet on all nearside approaches. There is no stop control along Highway 20 at these intersections, but there are stop signs on the approaches of 4^{th} and 5^{th}

Avenues. Signalized controls are located in the core downtown area along Highway 20 between 3rd and 1st Avenues. These intersections are all located in mixed retail and commercial land use. The Hackleman Historic District residential neighborhood is located one block east of Lyon Street. Emergency fire signals are located at 6th Avenue on both Lyon and Ellsworth. A school zone also exists just downstream of the study zone on Ellsworth. Fluorescent pedestrian crossing warning signs are located near 6th Avenue, and school zone warning signs are placed at 7th Avenue.

Both directions of this couplet experience over 17,000 vehicles per day. Average speeds are known to exceed the posted speed limit through this corridor. Vehicles typically travel in platoons in both directions. The signal controls downtown set up vehicles traveling south to be in platoons. The majority of the vehicle volume on Lyon stems from westbound traffic on the shared Highway 20/99E through north Albany. Traffic arriving on Lyon from Highway 20/99E typically arrives in platoons created from signals located several miles upstream.

The intersection of 4th Ave. and Ellsworth Street (Figure 2.1) has curb extensions on both the near and far side crosswalk on Ellsworth Street. Continental crosswalks with advance stop bars are located on the major crossings, while the minor crossings only have parallel lines. The close proximity of the government offices makes this intersection an important link to the downtown shopping area. Observations show that this link has the highest pedestrian volume in the study area, although an exact count was not determined.

The 5th Avenue intersections at Ellsworth and Lyon (Figures 2.2 and 2.3) both only have near side marked crossings with curb extensions and advance stop bars. There are no curb extensions or marked crossings for the farside crosswalk. The minor crossings have parallel stripes.

This study focuses the research effort on the intersection of 4th Ave. and Lyon Street (Figure 2.4). The nearside crosswalk of this intersection provides for a unique treatment-and-control study opportunity. A curb extension has been installed at the west side of the crosswalk, but the east side has been left with the original curb line because a driveway is nearby. Similar to the intersections at 5th Avenue, the minor streets have parallel stripe markings with no curb extensions. There is also no marked farside crosswalk on Lyon Street. Pedestrian attractors for this crosswalk include the Old Armory Building, which serves as a meeting hall, located at the west end of the crosswalk and a liquor store and bank, located east of 4th and Lyon. This intersection also provides a link between the Hackleman Historic District and the downtown sector.

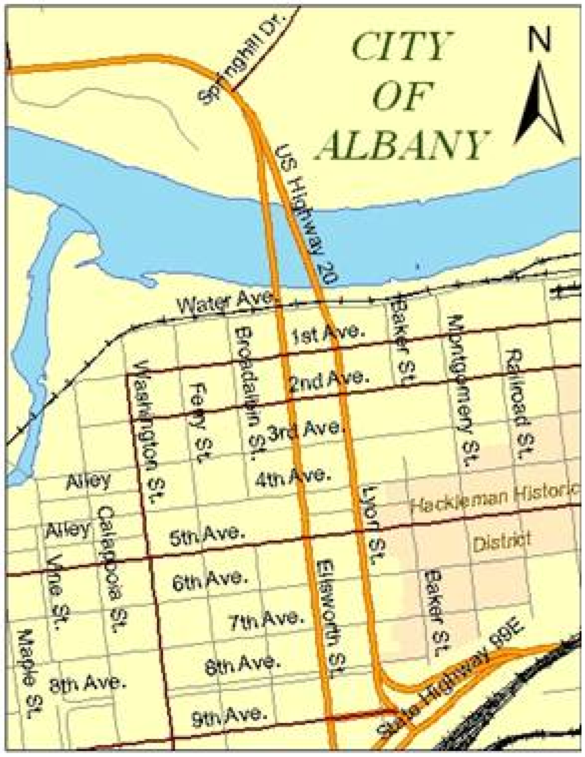

Figure 2.0: Study area: Albany, Oregon

Figure 2.1: 4th Ave./Ellsworth St. facing south

Figure 2.2: 5^{th} Ave./Ellsworth St. facing north

Figure 2.3: 5^{th} Ave./Lyon St. facing north

Figure 2.4: 4th Ave./Lyon St. facing south

2.3 RESEARCH DESIGN

No data had been collected prior to the installation of the pedestrian improvement features, so a before-and-after study was not possible. A treatment-and-control study was considered between the curb extension locations and the uncontrolled, unimproved crosswalks downstream on Ellsworth Street and upstream on Lyon Street. Such a design, however, would have had too many confounding variables that could have a substantial impact on the data. These variables included the presence of the emergency fire signal with "stop here on red" signs, advanced pedestrian warning signs and a school zone. Thus it was determined that the nearside crosswalk at 4th Avenue and Lyon Street with the single curb extension provided the best opportunity to measure the effectiveness of the recently installed curb extensions.

The nearside crosswalk at 4th Avenue and Lyon Street allowed for a comparison of pedestrians crossing from the curb extension side and those crossing from the side without a curb extension. This unique crossing also allowed for the evaluation of advance stop bars with and without a pedestrian waiting on a curb extension. This comparison also benefited from the same motorist population, continental marking, and visual environment.

The measures of effectiveness (MOE) used to evaluate the pedestrian improvements were:

- Average number of vehicles that pass before a pedestrian-cross
- Percent of pedestrians crossing with yield
- Percent of vehicles yielding at the advance stop bar

These MOEs were determined for the near and far lane for each crossing. Note that the near and far lanes were defined relative to the side from which a pedestrian was crossing.

Data were collected using a video camera set up approximately one block downstream from the intersection and positioned such that both approaching vehicles and pedestrians could be observed. Weather varied from cloudy to sunny on days of data collection. Crossings were only recorded during daylight hours.

The *average number of vehicles that pass before a pedestrian-cross* was determined by counting the number of vehicles that passed through the crosswalk after the pedestrian arrived at the curb line. The number of vehicles that passed was counted separately for the near and far lane for the respective side of crossing. If a vehicle yielded for the pedestrian then it was noted after counting the number of vehicles that had first passed. If X number of vehicles passed a waiting pedestrian without yielding and the pedestrian crossed in a gap in the flow of traffic, then the crossing was considered a failure to yield.

Percent of pedestrians crossing with yield was based on the proportion of crossings when a motorist yielded to a pedestrian to the total number of pedestrian crossings when traffic was present. Pedestrian crossings that occurred when no traffic was present were not included in the analysis. In some cases, traffic was only present in one lane during a pedestrian crossing. The lane clear of traffic was also not included in this analysis. Another case excluded from the analysis was when vehicles spilled back from the signal one block downstream, thus stopping vehicles and allowing pedestrians to cross between queuing vehicles.

Percent of vehicles yielding at the advance stop bar was based on the proportion of the vehicles that did yield at the stop bar to the total number of vehicles yielding to pedestrians. Vehicles that yielded more than one foot beyond the advance stop bar were considered a failure to yield at the advance stop bar.

Observations showed that pedestrian volumes at this crosswalk were moderately low with 30 to 40 pedestrians per day. Staged pedestrians were thus used to acquire a sufficient number of observations. Staged pedestrians were both male and female, wearing both dark and bright clothing. The staged pedestrians also varied their behavior to better reflect a wider range of the pedestrian population. For example, the participant would sometimes stand a little back from the edge of curb and other times step off the curb facing traffic. Both of these behaviors were observed with non-staged pedestrians, but waiting at the curb line was most prevalent. The staged pedestrians would only approach the crosswalk when a platoon of vehicles was approaching the intersection.

2.4 DATA ANALYSIS PROCEDURE

A two-sample t-test was performed on the measures of effectiveness to determine if there was a statistically significant difference in means. Basic statistics were also performed to compare the standard deviation and variation of the datasets.

3.0 RESULTS

3.1 VEHICLES PASSING BEFORE A PEDESTRIAN-CROSS

The analysis of the *average number of vehicles that pass before a pedestrian-cross* showed fewer passing for crossings from the side with the curb extension compared to crossings from the unimproved side. This reduction for the curb extension side occurred in both the near and far lanes with a statistically significant difference in means. (Table 3.0). The mean number of vehicles that passed before the pedestrian could cross from the side with no curb extension was 2.58 for the near and 2.36 for the far lane.

For pedestrians crossing from the curb extension side, the mean number of vehicles that passed was reduced to 1.81 for the near lane and 1.76 for the far, resulting in a reduction of 42.7% and 33.9% respectively. Acceptable p-values of less than 0.05 from the t-test analysis validate the statistical difference in the means. The analysis included n = 219 pedestrian crossings for the near lane and n = 214 for the far lane. There was a difference in samples sizes because the case where a pedestrian crossed and one lane was clear of traffic only counted as an observation for the lane where vehicles were present.

In both cases the average number of vehicles that passed before the pedestrian-cross was lower in the far lane as compared to the near lane. This is likely attributed to the fact that the motorist has a greater sight distance because of the increased lateral separation. Basically the driver in the far lane will be able to see the pedestrian around the on-street parking sooner than the driver in the near lane and will have more time to stop.

The near lane, however, experienced a greater reduction in the average number of vehicles that passed before a pedestrian-cross when comparing the curb extension side to the side without. This greater reduction in average number of passing vehicles likely occurred because the near lane experienced a greater improvement in sight distance over the far lane with the addition of the curb extension. The driver in the near lane always has less time to see the pedestrian and yield, even though a yellow curb is provided for adequate stopping sight distance. With the addition of the curb extension though, the sight distance between the motorist and the waiting pedestrian is as far as visibility conditions allow, since there are no obstructions.

Figures 3.0 and 3.1 show the spread of the number of vehicles that passed before a crossing in the near and far lanes respectively. In both lanes the treatment (curb extension) side had a lower mean, but they also had the overall highest number of vehicles that passed before a pedestrian cross. These high values seem to be a random event, because the observations showed that the pedestrian was in plain view and there were no other factors that were different from other crossings.

Table 3.0: Results for average number of vehicles passing before a pedestrian-cross

	Lane	Non-Curb Extension	Curb Extension	Percent difference in means	Sample Size (n)	t-test p-value	Difference in Means
Average number of vehicles that pass before pedestrian cross	Near	2.58	1.81	-42.7%	219	0.0017	Significant
	Far	2.36	1.76	-33.9%	214	0.0362	Significant

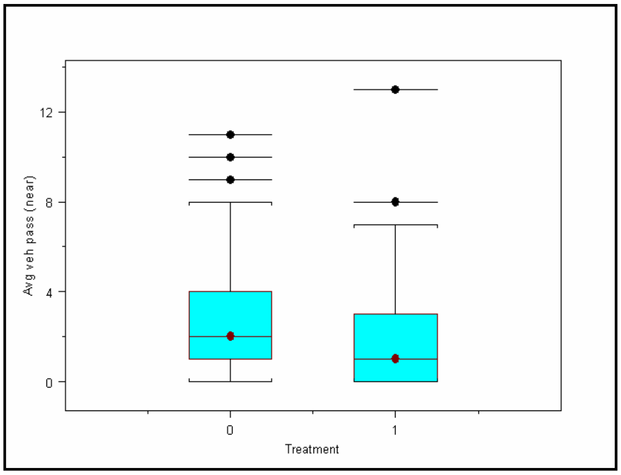

Figure 3.0: Number of vehicles that pass in NEAR lane before pedestrian-cross

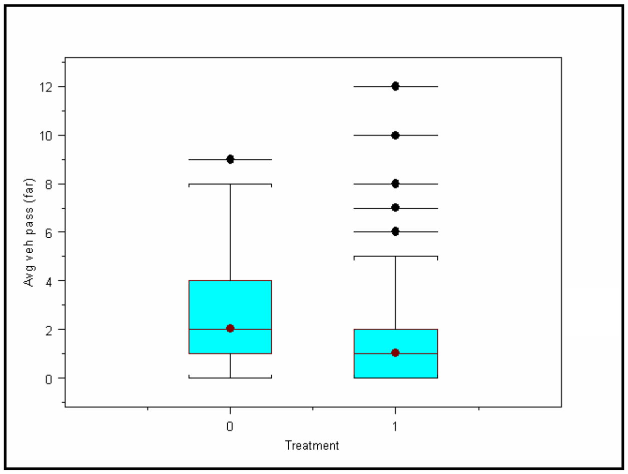

Figure 3.1: Number of vehicles that pass in FAR lane before pedestrian-cross

3.2 PERCENT OF CROSSINGS WHERE A MOTORIST YIELDED

The *percent of the pedestrian crossings where a motorist yielded* had improvements for the curb extension side in both near and far lanes (Table 3.1). This improvement was weak, however, and the t-test proved insignificant. The near lane had 65% crossing with yielding motorist for the unimproved side and 66.7% for the curb extension side for an increase in 2.7%. The far lane increased from 58.6% to 63.4% from the unimproved side to the curb extension side respectively, resulting in an increase of 7.7%. A total of 234 crossings were analyzed to determine the percent of crossings where motorists yielded. While there was a slight but insignificant improvement favoring the curb extension side, overall approximately 60 percent of the pedestrian crossings occurred when a vehicle yielded. The 60 percent yielding rate becomes even less favorable when considering that before a yield occurs, the average number of vehicles that pass before the pedestrian cross (Table 3.0) must be taken into account.

Table 3.1: Analysis results for percent of pedestrian crossings with yield

	Lane	Non-Curb Extension	Curb Extension	Percent difference in means	Sample Size (n)	t-test p-value	Difference in Means
Percent pedestrian crossing with yield	Near	64.9%	66.7%	2.7%	234	0.7729	Insignificant
	Far	58.6%	63.4%	7.7%	234	0.4489	Insignificant

3.3 PERCENT OF VEHICLES YIELDING AT ADVANCE STOP BAR

The *percentage of vehicles that yielded at the advance stop bar* also increased from the unimproved side to the curb extension side (Table 3.2). This improvement, however, was statistically insignificant with t-test p-values greater than 0.05 for both lanes. Both the near and far lanes of the control side were exactly the same at 42.6% of vehicles yielding at the stop bar. Crossings from the curb extension experienced a roughly 20% increase in both lanes to 53.8% in the near lane and 51.9% in the far lane. This increase with the curb extension is likely attributed to the fact of longer sight distance for both lanes. While this improvement trend with the curb extension was not statistically significant, overall only about half of the drivers were stopping at the advanced stop bar. The risk of "multi-threat" crashes is high on this type of road, and only having 50 percent of the "yielding" drivers stopping at the advance stop bar would likely have a minimal impact on reducing this risk. The sample size for this analysis included 99 crossings.

Table 3.2: Analysis results for percent of vehicles yielding at advance stop bar

	Lane	Non-Curb Extension	Curb Extension	Percent difference in means	Sample Size (n)	t-test p-value	Difference in Means
Percent of vehicles yielding at advance stop bar	Near	42.6%	53.8%	21.0%	99	0.2261	Insignificant
	Far	42.6%	51.9%	18.0%	99	0.3563	Insignificant

4.0 OBSERVATIONS AND DISCUSSION

Many interesting observations on the behavior of motorists, pedestrians and bicyclists were made while performing this study. These observations are both from the field and video analysis.

4.1 MOTORIST BEHAVIOR

When observing the types of motorists who would yield to pedestrians, there were several groups who appeared to consistently yield more often. One such group was public vehicles. These vehicles included school busses, county and city vehicles, public transit, DOT vehicles and emergency vehicles. More times than not, public vehicles were observed immediately yielding to pedestrians. This was as expected though, as many public employees are required to take driver education courses. Public employees may also be scrutinized by the public if they fail to obey traffic laws.

Another group of drivers who consistently yielded for pedestrians was commercial truck drivers. This was likely because most are trained professional drivers. For these drivers, failing to obey traffic laws can cost them their livelihood. There is also a known greater risk to pedestrians if they are involved in a collision with a semi-truck.

On several occasions, semi-trucks were observed abruptly stopping to yield to pedestrians. While these drivers were obeying traffic laws, this situation increased the risk of a "multiple-threat" collision when the truck yielded in the near lane. Even when these trucks did yield at the advance stop bar, the size of the trucks blocked the sight distance for both the pedestrian and any motorists in the far lane. Some pedestrians were observed stopping mid-crossing and "peeking" around the truck to see if the far lane was clear. One near "multiple-threat" crash was observed when a school bus yielded in the near lane and a vehicle in the far lane nearly collided with the crossing pedestrian.

While many professional truck drivers were observed obeying traffic laws, some delivery vehicles created another kind of hazard. Several times a day, delivery vehicles were observed parking in the "yellow curb" zone upstream to the crosswalk. While these delivery stops were only for a short duration, the sight distance was dramatically reduced, posing a hazardous threat to pedestrians. Parking in the yellow zone by non-commercial drivers was also observed on several occasions. The yellow curb prior to the crosswalk on the east end was sometimes used for short term parking for customers shopping at the liquor store. The yellow curb prior to the crosswalk on the west end was periodically used as a waiting spot for drivers waiting to pick up passengers from the Old Armory. No parking enforcement was ever observed during the four days of data collection. The occurrence of vehicles parking in these yellow curb zones was only a few times a day and only for a short duration, but when this regulation was violated a greater threat was posed to a crossing pedestrian.

Large vehicles yielding to pedestrians led to another common type of motorist behavior. As a large vehicle yielded to a pedestrian, the driver of the vehicle behind could not see why the large vehicle was slowing or stopping. If the adjacent lane was clear, then it was common to observe vehicles changing lanes at the last minute and accelerating around the larger vehicle. This is another scenario that increases the risk of a "multiple-threat" collision. Last minute lane changes appeared to be common with the general motorist behavior. A great deal of lane changing occurred when a driver was traveling below the desired speed and the adjacent lane was free of traffic ahead. Lane changing maneuvers also seemed to be more common just before an intersection when the leading vehicle slowed to turn or begin to yield.

The likelihood of a motorist yielding to a pedestrian also appeared to depend on when the pedestrian arrived in relation to the traffic stream. For example, if a pedestrian arrived at the curb just prior to a platoon arriving, then the first car often yielded to the pedestrian. If the pedestrian arrived in the middle of a platoon, then typically several vehicles would pass before one would yield; or in some cases none yielded at all. This situation was observed on several occasions, but there was insufficient data to test this theory.

Another observation made was driver inattention. A large number of motorists were talking on a cell phone while driving. Others were engaged in conversation with passengers, and some were focused on radio or other controls. Some drivers may have been able to focus on driving while performing these tasks, but many drivers were observed doing these activities and driving right past a pedestrian at the curb line without appearing to notice the pedestrian. Drivers exhibiting distracting behaviors may be one factor in the overall low yielding rate or failure to yield at the advance stop bar. Driver inattention is also one of the leading causes of traffic accidents. (*Wang, Knipling and Goodman 1996*)

While some drivers passed pedestrians without ever appearing to notice them, other drivers made eye contact with the pedestrian and then continued through the crosswalk. The reason for this blatant disregard for a pedestrian waiting at a crosswalk was unknown. This behavior and the overall low yielding percentage could be a reflection of a lack of driver education or full understanding of the yield to pedestrian law.

4.2 PEDESTRIAN AND BICYCLIST BEHAVIOR

Pedestrian behavior varied from being passive to aggressive. Those who exhibited passive behavior often stood back from the curb several feet and waited for a vehicle to yield or an acceptable gap. Pedestrians with aggressive behavior were observed stepping off the curb, facing traffic and sometimes using hand gestures to try and get vehicles to yield. Some pedestrians also showed more risky behavior by running across the street during small gaps in traffic.

Observations also showed that pedestrians were more likely to use the marked crosswalk during heavy traffic. During non-peak hours, pedestrians were observed crossing wherever convenient. However, there were some pedestrians who crossed the street at convenient mid-block locations during heavy traffic. These pedestrians were often the ones observed with risky behavior, such as running between vehicles.

The majority of pedestrians crossing from the non-curb extension side were observed waiting one step out from the curb. This may have increased their visibility, but it also left them exposed. Right turning vehicles often come close to the curb and are not expecting a pedestrian standing off of the curb. This situation is eliminated with the use of curb extensions.

Bicycle volumes through this intersection were low, but some common behaviors are noteworthy. On multiple occasions, bicyclists were observed using the sidewalks to travel southbound against traffic instead of continuing one block over and then traveling with the direction of traffic. No bicycle-pedestrian collisions were observed on the sidewalks, but the potential was still present. Bicycles crossing Lyon Street on 4th Avenue either crossed using a vehicle lane with an acceptable gap or using the crosswalk. Those using the crosswalk did not dismount from their bicycles, however. Both situations are acceptable methods according to the Oregon Bicyclists Manual, but those using a crosswalk must dismount from their bicycles (*ODOT 2000*). Motorists were never observed yielding to the bicyclists using the crosswalk, but there was also a very small sample size for this situation. Bicyclists also were able to successfully cross the street with a smaller gap than that required by a pedestrian who walked.

5.0 CONCLUSION AND RECOMMENDATIONS

The findings of this research suggest that curb extensions contribute to a significant reduction in the average number of vehicles that pass a waiting pedestrian before yielding to the pedestrian. Basically pedestrians approaching from the curb extension side experienced a vehicle yielding sooner than those coming from the non-improved side of the crosswalk. This reduction in the average number of passing vehicles yielding is best explained by the increased visibility offered by the curb extension.

A greater reduction in the number of unyielding vehicles occurred in the near lane for the curb extension side of the crosswalk. This is likely because the near lane has a greater increase in sight distance when comparing the treatment and control. While the near lane experiences a greater improvement in sight distance with the addition of the curb extension, the far lane will always have an overall greater sight distance. This explains the lower mean number of passing vehicles in the far lane for both the treatment and the control.

The change in percentage of pedestrian crossings with a yielding vehicle between the treatment and the control was insignificant but showed a weak trend towards improvement with the presence of a curb extension. Further research with a greater sample size may prove this trend significant. Regardless of significance, however, about one third of the pedestrians in this study were forced to wait for an acceptable gap to cross because no vehicle would yield. This high percentage of motorists failing to yield was possibly a driver behavior issue and not necessarily a lack of appropriate pedestrian facilities.

The change in percentage of vehicles yielding at the advance stop bar between the treatment and the control also proved insignificant, but the curb extension side experienced roughly a 20 percent increase in the number of vehicles stopping at the advance stop bar. This analysis was based on a small sample size, however, which may be the reason for the lack of statistical significance in this difference. Again though, the overall percentage with or without the improvement was only slightly over 50 percent. While there could be several reasons for this low rate, possible causes are driver behavior or perhaps a lack of visibility and understanding of the advance stop bars.

One recommendation to improve the percentages of vehicles that yield and yield at the advance stop bar is to install advance yield signs. These signs would say "Yield Here to Pedestrians" placed at the advance stop bar. Past research shows that these signs can produce a reduction in vehicle/pedestrian conflicts and an increase in motorists yielding to pedestrians at multilane crosswalks with an uncontrolled approach. (*Van Houten 2001*). Van Houten also recommends that advance stop bars be placed 15 meters (~50 ft.) from the crosswalk. The Albany advance stop bars are only 20 feet from the crosswalk.

Recommendations to address the driver behavior issues include increased driver education and enforcement of pedestrian yielding laws. If further research indicates similar motorist behavior in relation to yielding to pedestrians, perhaps a statewide pedestrian awareness campaign may be effective. The National Highway Traffic Safety Administration's highly publicized "Click it or Ticket" campaign has been successful with increasing safety belt usage rates. (*Solomon, et al. 2003*). Another measure may be an increased focus on pedestrian yielding laws in the Oregon Driver's Manual. Increased law enforcement may be effective for spot locations such as this site. This driver population appears to have substantial commuter traffic, so the periodic presence of law enforcement may have a large impact on local driver behavior.

The presence of a curb extension at the intersection of 4th and Lyon Street resulted in a significant reduction in the mean number of vehicles that passed from the time a pedestrian arrived at a crosswalk to the time they were able to cross. While the change in the percentage of pedestrian crossings with a yielding vehicle and the percentage of vehicles yielding at the advance stop bar proved insignificant, there are other safety benefits that curb extensions provide to the pedestrian. These benefits include improved sight distance, elimination of exposure to turning vehicles and shorter crossing distance. Additional research covering a greater number of crosswalk and crossings may allow for further elaboration on motorist yielding behavior with the presence of curb extensions.

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