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Research Project T1803, Task 16
Pedestrian Safety

A MOTORIST AND PEDESTRIAN BEHAVIORAL ANALYSIS RELATING TO PEDESTRIAN SAFETY IMPROVEMENTS

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT

The objective of this project was to evaluate motorist and pedestrian behavioral changes that resulted from changes in the roadway environment, traffic enforcement activities, and a public information campaign. A "before" and a four-phased "after" analysis was conducted to evaluate motorist and pedestrian behavioral changes at the study sites: N. 165th St and N. 170th St on SR 99 in the City of Shoreline. The main measures of effectiveness used to evaluate this project were pedestrian crossing locations, changes in pedestrian behaviors (e.g., whether pedestrians used the crosswalks), and changes in motorist behaviors (e.g., the willingness of drivers to stop for pedestrians in crosswalks before and after the improvements).

The results of the study showed that the safety treatments had a positive effect on pedestrian behavior in that pedestrians used the installed refuge island for crossing. The safety treatments also significantly improved vehicle compliance in yielding for pedestrians. However, poor driving behavior can still be improved. A reduction in pedestrian conflict rates and a lack of change in vehicle evasive behavior imply that pedestrians were not any less careful after implementation of the treatments.

While the true effect of each treatment phase may have been limited at the study sites because of the implementation process, construction constraints, and project schedule, the study observed the following findings for the various treatments. First, no meaningful difference was observed in vehicles yielding at marked vs. unmarked crosswalks. The push-button activated roving eyes signs had a positive effect on motorists' yielding action. Motorists responded positively to yield bars. This study may be limited in reflecting the true impact of traffic enforcement.

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SECTION ONE
PROJECT OVERVIEW

The stretch of SR 99 through the City of Shoreline (Aurora Avenue N) has a significant history of pedestrian collisions. During the period of 1992 to 1996, 42 pedestrian-auto collisions occurred[1]. Of these collisions, 38 percent were fatal or disabling accidents in comparison to 26 percent on other roads. Several factors have contributed to this problem, including insufficient facilities for pedestrians; a lack of motorist and pedestrian regard for rules-of-the-road coupled with limited resources for enforcement of pedestrian/motorist laws; urban sprawl land use patterns; and a lack of public understanding of the importance of pedestrian safety measures in communities. Pedestrian safety can include access management, defined driveways and curbs, pedestrian refuges, and safe crossing opportunities. To address the pedestrian safety issues in this corridor, a pedestrian safety project was initiated on Aurora Avenue North within the City of Shoreline.

The project adopted a set of safety solutions developed by the Washington Quality Initiative, a multi-disciplinary team comprising representatives from the Washington State Department of Transportation (WSDOT), Washington State Patrol (WSP), and several local agencies. These solutions were selected to fit within the City of Shoreline's existing corridor improvement plan and citizen involvement program and included roadway enhancements to improve safety for pedestrians, activities to enforce motorists' compliance with crosswalk laws, and a public information campaign to increase public awareness about pedestrian safety. If these proposed solutions proved successful, they could be replicated at other pedestrian accident locations on state routes.

[1] Source: Washington State Department of Transportation.

SITE DESCRIPTIONS

Two sites were selected for the "before" and "after" analysis[2]. Both study sites are unsignalized intersections with no marked crosswalks on Aurora Avenue North (SR 99), which consists of two general purpose lanes in each direction with a center two-way left-turn lane. Existing asphalt pavement width ranges from 56 to 68 feet, with a shoulder width of 6 to 8 feet. Frequent individual driveways to commercial/retail shops and isolated sidewalks can be found among commercial strip developments. There is little illumination along the entire stretch of road, making it hard for motorists to see pedestrians. Transit service is provided by Route 358, which runs between northern and downtown Seattle along Aurora Avenue North. Transit stops are located in both directions at the study locations. The average weekday transit ridership for the two locations combined is approximately 1900. The average daily traffic volumes are about 41,000 at N 165th St and N 170th St. The speed limit on Aurora Avenue North is 40 mph. Below is a brief description of each of the study locations.

N 165th St and SR 99

The N 165th St site is an unsignalized, four-way intersection. From this intersection, the nearest signalized intersections are located one quarter of a mile to the south at N 160th St and one half mile to the north at N 175th St. Traffic on N 165th St has a stop sign and can turn in both directions onto SR 99. Commercial establishments at this site include a U-Haul office with a parking lot, a 76 gas station with a convenience store, *The Seattle Times* office building, and the Arden Rehabilitation Center. The Shoreline Motel lies on the northern edge of this observation zone. Residential areas are located on both sides of SR 99 just a block from the major arterial street. Transit stops are located southbound in front of the Arden Rehabilitation Center and northbound in front of the 76

[2] While "before-after" studies were conducted at N 165th St and N 170th St, "before" data were collected at N 152nd St as well.

gas station. On average, 130 people get on and off Route 358 buses each weekday at N 165th St.

N 170th St and SR 99

The intersection of N 170th St and SR 99 is a T-intersection, with N 170th St entering from the west side of the highway. Signalized intersections are located a half mile to the south of N 170th St at N 160th St, and one quarter of a mile to the north at N 175th St. The area around this intersection is predominantly commercial, with several restaurants and bars (e.g., Parkers's Bar and Casino, Sugar's, Lupe's Taqueria, and the Baro Deli). In addition, a video store and retail establishments such as Maytag, Simmons Mattress, and Pawn Exchange are within 250 feet of the N 170th St intersection. Residential neighborhoods lie to the east and west of SR 99. Shorewood High School is located two blocks to the west of this intersection. SR 99 has sidewalks on both sides for most of this location, except on the east side of the highway just south of N 170th St. Transit stops are located southbound in front of Parker's and northbound in front of the Pawn Exchange. On an average day, 80 passengers get on and off Route 358 at this location.

REPORT PURPOSE AND APPROACH

The objective of this project was to evaluate motorist and pedestrian behavioral changes that resulted from changes in roadway environment, traffic enforcement activities, and a public information campaign. A "before" and "after" analysis was conducted at the two study sites. The main measures of effectiveness used to evaluate this project were pedestrian crossing locations, changes in pedestrians' behaviors (i.e., whether pedestrians used the crosswalks), and changes in motorists' behaviors (i.e., the willingness of drivers to stop for pedestrians in crosswalks before and after the improvements).

An evaluation of the effects of the selected roadway changes on improving pedestrian safety was considered important because it could help WSDOT in planning for future improvements. Successful elements of this project could be used in other locations with similar pedestrian safety problems. Another use of this evaluation could be in justifying the cost of improvements by demonstrating quantitatively the improvements and their effect on the surrounding neighborhood.

REPORT CONTENT

This report documents the project tasks and findings as follows:

Section 2 – Research approach

Section 3 – Safety treatments evaluated in the study

Section 4 – Before and after analysis

Section 5 – Discussion and conclusions

The research reported here is part of a larger demonstration project. For more detailed project information, please contact WSDOT's Community Economic Partnerships Office (Urban Partnerships Branch) for the main project report.

SECTION TWO
RESEARCH APPROACH

The main tasks of the project were the following:

- Administer data collection
- Perform before-after analysis
- Document project findings and recommendations

These tasks are described in more detail in this section.

ADMINISTER DATA COLLECTION

Data were collected "before" and "after" the implementation of the safety treatments. A public opinion survey was also conducted as part of the "before" data collection to learn more about the community's experiences as pedestrians and/or as drivers within the study corridor. Survey results were used to help select roadway improvements. The results of the survey are included in Appendix A. The "after" data were collected in four cycles because various safety treatments were implemented in phases[3]. Section 3 provides more information about the treatments evaluated in this study. Both the "before" and "after" field observations were conducted following specified protocols.

Observation Boundaries

The range of observations for each site was taken within 250 feet in each direction from the intersection, the legal crosswalk for pedestrians[4]. This observation distance has also been used by the Center for Applied Research for measuring pedestrian "paths of crossing."

[3] Dr. Ron Van Houten from the Center for Education and Research in Safety was instrumental in the process of setting up the research procedure.

[4] A legal crosswalk is defined as a crossing at any intersection, regardless of whether a crosswalk is signalized or marked.

Observation Periods

Pedestrian and vehicle behavior at the study locations were observed during weekday AM and PM peak periods (see Table 1). The "before" data were collected during four 2-hour periods (AM peak, midday, PM peak, and dark). The "before" data sample showed that pedestrian volumes seemed to be higher during the AM peak period (6AM to 9AM) at N 165th St and during the PM peak period (3PM to 6PM) at N 170th St. Thus, the "after" data collection was administered during the highest volume period for each study location. Each phase took three weekdays; each day had a 3-hour observation period.

Table 1. Observation Periods

	Before Treatment	After Treatment			
		I. Basic Construction	II. Crosswalks and Yield bars	III. Roving Eyes	IV. Enforcement
N 165th St					
Total Sample Size (N)	31	36	41	34	34
Hours of Observations	8 hours	9 hours	9 hours	9 hours	9 hours
Date of Observation	November 1999	June 2002	September 2002	December 2002	January 2003
N 170th St.					
Total Sample Size (N)	40	54	36	59	58
Hours of Data Collection	8 hours	9 hours	9 hours	9 hours	9 hours
Date of Observation	November 1999	June 2002	September 2002	December 2002	January 2003

Data Elements

The following data elements were collected and noted for all pedestrian crossings that took place within 250 feet of the unmarked legal crosswalk at each side leg of the intersection:

- sex and age group of the pedestrian
- crossing locations and paths

- pedestrian and driver evasive actions
- vehicle yielding for those who crossed in the observation boundary
- vehicle yielding for those who crossed in the legal crosswalks
- vehicle yielding positions relative to stop bars
- shielding conflicts (when vehicles in the lane closest to the pedestrian yield while vehicles in the adjacent travel lane still proceed)

An example of the data collection sheet is included in Appendix B.

PERFORM BEFORE-AFTER ANALYSIS

Data elements collected before and after the safety treatments had been implemented were then processed and summarized to better understand the crossing behaviors and patterns and to determine each treatment's effectiveness in improving pedestrian crossing safety.

SECTION THREE
SAFETY TREATMENTS EVALUATED IN THE STUDY

The corridor being studied has a history of pedestrian crossing concerns. Most crossing pedestrians observed at the study locations showed extreme caution, even when they were crossing in a legal unmarked crosswalk. Many waited a very long time for a gap in traffic to cross the street without stopping at the center turn lane, while others crossed one lane-direction at a time waiting in the center turn lane for another gap to finish crossing. A large portion of crossing pedestrians observed at N 170th St after dark ran across the street, even if they were not in direct danger of being hit.

Three groups of community members from a Pedestrian Roadshow, hosted by WSDOT in the City of Shoreline on November 16, 1999, identified community barriers to pedestrian safety. The lists developed by the three groups were similar; the most frequently mentioned barriers to walking included

- Poorly lit streets – overall lack of lighting
- Lack of pedestrian crossing opportunities
- Lack of sidewalks/shoulders
- Lack of access control (too many driveways)
- Speeding vehicles/aggressive motorists
- Two-way left turn lanes
- Generally unattractive pedestrian environment

On the basis of the community's input, the project's goal and resources, and Dr. Ron Van Houten's input on safety-related technologies, methods of safety enhancements were developed (see Table 2). Note that the roadway safety improvements were similar for both sites; the only difference is that marked crosswalks were put in at N 170th St but not at N 165th St. For evaluation purposes, these treatments were implemented in phases.

Table 2. Safety Treatments

	N 165th St	N 170th St
Phase I - Basic Construction	Landscaped median serving as a refuge for crossing pedestrians New curbing and crosswalk landings at the end of each crosswalk Asphalt walkway improvement Landscape enhancement along the east and west edge of Aurora Avenue Increased pedestrian and roadway lighting	
Phase II – Yield Bars and Marked Crosswalks	Advance yield bars and a symbol sign prompting motorists to yield to pedestrians	Advance yield bars and a symbol sign prompting motorists to yield to pedestrians Marked crosswalk
Phase III - Push Button activated Roving Eyes	"Roving Eyes" push button activated pedestrian warning lights to warn pedestrians of on-coming traffic "Roving Eyes" push button activated traffic warning lights to warn motorists of pedestrians	
Phase IV - Police Enforcement	Traffic enforcement operation to heighten awareness of pedestrian activity in the study area. Citations and warnings would be issued for motorists who did not comply with pedestrian crosswalk laws	

In addition to roadway treatments, the project also included an education campaign. This involved a series of outreach tools including billboards, pamphlets, a graphic logo, posters, and a speakers' bureau to promote community awareness about pedestrian safety. Please refer to the main project report for more detailed information about the public outreach and other components of the project.

SECTION FOUR
BEFORE AND AFTER ANALYSIS

This section presents the motorist and pedestrian behavioral changes observed as a result of the roadway design improvements, traffic enforcement activities, and public information campaign. The studied treatments were intended to encourage pedestrians to migrate to one central location to cross instead of crossing indiscriminately, and to increase the probability that motorists would yield to crossing pedestrians. The findings are grouped as follows:

- First, demographic information about the pedestrians is provided.
- A description of observed changes in pedestrians' crossing paths is presented. This examines the level of change in pedestrians' safety behaviors (e.g., whether pedestrians used the crosswalks and pushed the button to activate roving eyes).
- The next section discusses the level of change in motorists' behaviors related to pedestrian safety (e.g., the willingness of drivers to stop for pedestrians in crosswalks before and after the implementation of marked crosswalks, roving eyes, and enforcement).

Please note that because of schedule constraints, the evaluation did not have the ability to filter out any potential novelty effects[5] of each treatment phase (e.g., by collecting data after waiting for a certain time period of time following the implementation of each phase). Also, given the nature of the project progress, it was not possible to control or separate seasonal and weather effects.

[5] "Novelty effects" is used here to describe the phenomenon of people reacting differently to a treatment when it is new than when it has been in place for awhile.

DEMOGRAPHIC PROFILE

Table 3 summarizes the major demographic profile for this study. No significant changes from phase to phase were observed that would serve as variables for the analysis. Most of the pedestrians observed during various phases were adults (60 to 100 percent). There were significantly fewer teenagers during the first phase (basic construction) of the "after" data collection because it occurred during the summer when school was out. The pedestrians observed crossing the street at the study sites were predominately male (67 to 87 percent). Most of the pedestrians observed at N 165th St were transit users. N 170th St had fewer pedestrians who were transit riders; this may be because of its pedestrian-oriented land use.

Table 3. Demographic Profile

	Before Treatment	After Treatment			
		I. Basic Construction	II. Crosswalks and Yield bars	III. Roving Eyes	IV. Enforcement
Date of Observation	November 1999	June 2002	September 2002	December 2002	January 2003
N 165th St	N=31	N=36	N=41	N=34	N=34
Adult	87% (27)	100% (36)	76% (31)	88% (30)	82% (28)
Male	81% (25)	67% (24)	78% (32)	71% (24)	79% (27)
Transit Users	61% (19)	72% (26)	73% (30)	53% (18)	44% (15)
N 170th St	N=40	N=54	N=36	N=59	N=58
Adult	60% (24)	96% (52)	71% (27)	75% (44)	78% (45)
Male	83% (33)	87% (47)	72% (26)	73% (43)	78% (45)
Transit Users	30% (12)	26% (14)	22% (8)	25% (15)	16% (9)

Shaded area – The change between the before treatment and the after treatment was significant at the 0.05 level based on chi-square statistic.

CHANGES IN PEDESTRIANS' BEHAVIOR

The study results revealed that after treatment implementation, people tended to cross the road using the median refuge, whereas before they were crossing randomly

north and south of the intersection. Overall, the necessity for pedestrians to evade traffic decreased.

Pedestrian Crossing Paths

The before study revealed that the factors affecting how pedestrians crossed included the characteristics of the intersections, the origins and destinations of the observed pedestrians, and whether there was a gap in traffic for crossing. The data showed that pedestrians were coming from and going to a variety of locations (see figures 1 and 2).

After the treatments had been implemented, more pedestrians used the refuge areas (see figures 1 and 2). The data showed relatively high usage rates for the median refuge for both locations (over 85 percent of the crossing events). Table 4 shows the percentage of pedestrian crossing events in which pedestrians used the medians for crossing at various treatment phases. At N 170th St, the data showed that marked crosswalks had no significant impact on persuading pedestrians to use the median refuge area (46 percent vs. 56 percent).

Table 4. Use of the Median Refuge

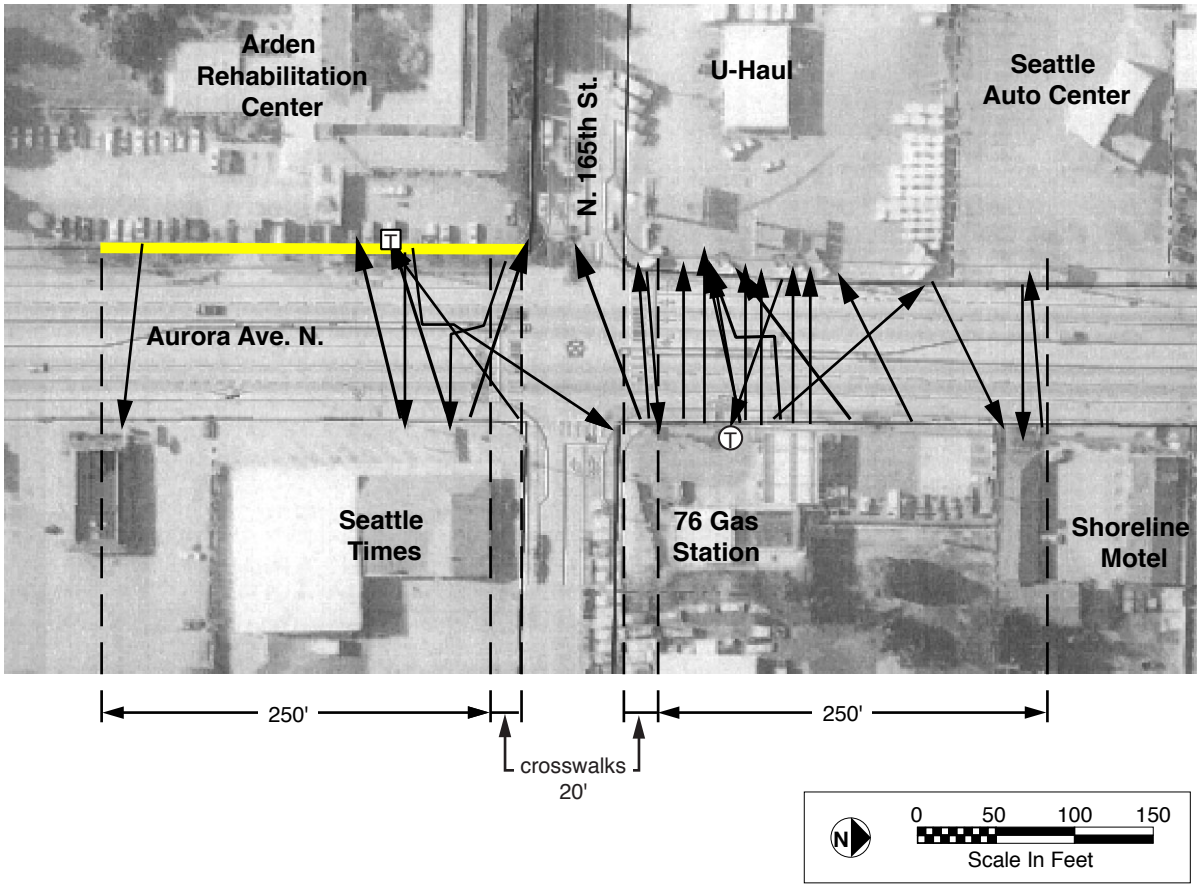
	After Treatment			
	I. Basic Construction	II. Crosswalks and Yield bars	III. Roving Eyes	IV. Enforcement
N 165th St	N=36	N=41	N=34	N=34
Median Refuge	36% (13)	71% (29)	79% (27)	85% (29)
N 170th St	N=54	N=36	N=59	N=58
Median Refuge	46% (25)	56% (20)	85% (50)	97% (56)

Shaded area – The change between the basic construction and the other treatments was significant at the 0.05 level based on chi-square statistic.

Use of the Button to Activate the Roving Eyes

The results revealed that about 30 percent of the pedestrians observed at N 165th St. activated the roving eyes by pushing the button versus 40 percent at N 170th St. (see Table 5). It is unclear why a much higher percentage of pedestrians at N 170th St pushed

Before (N=31)



After (N=34)

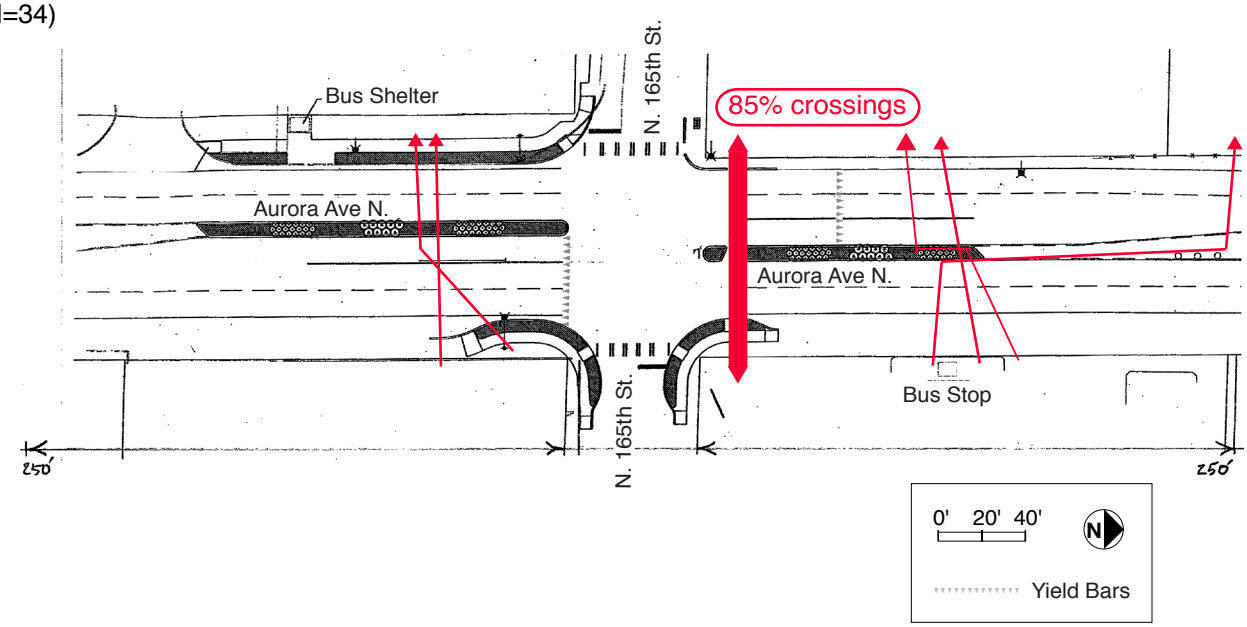
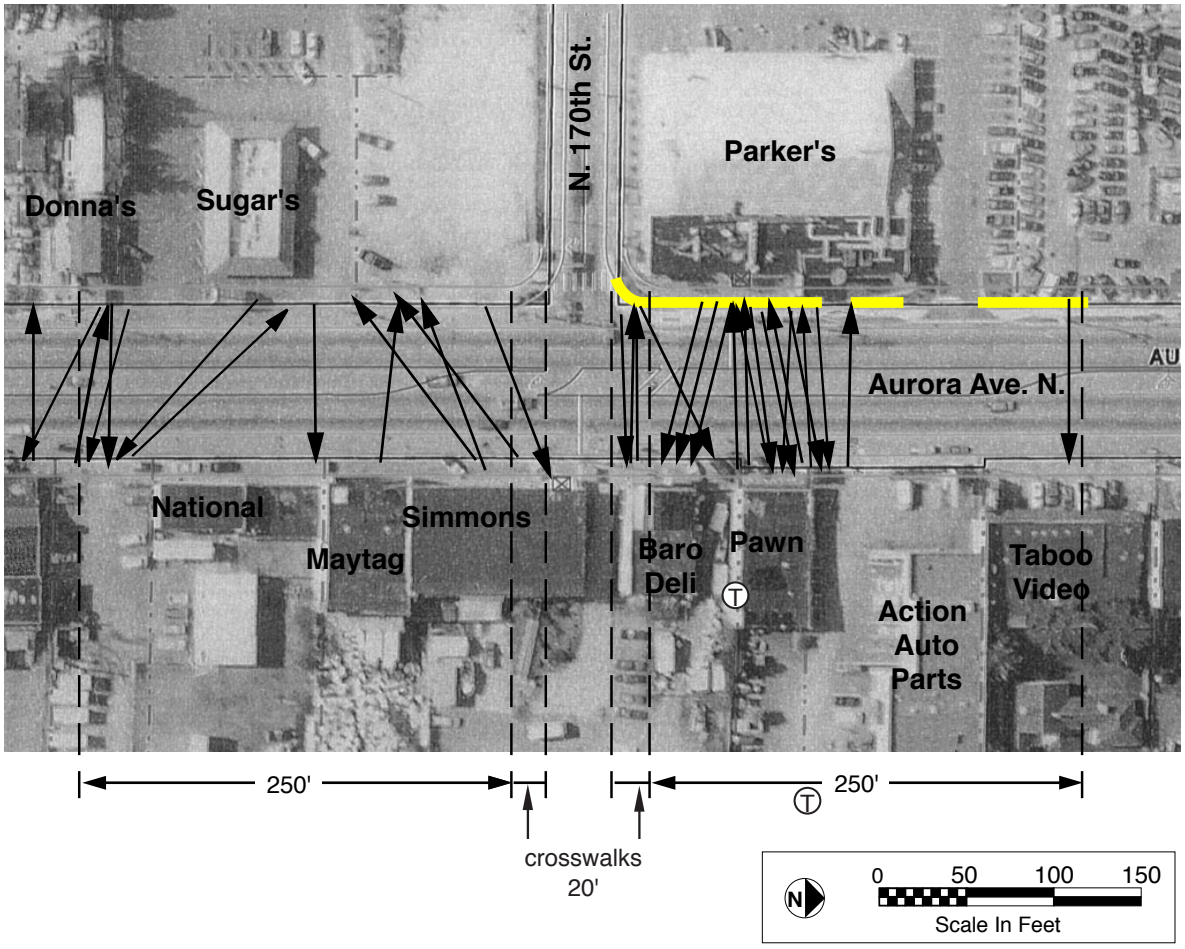


Figure 1. Before-After Pedestrian Crossing Patterns at N. 165th St.

Before (N=40)



Source of background arterial map: City of Shoreline, CH2MHill

After (N=58)

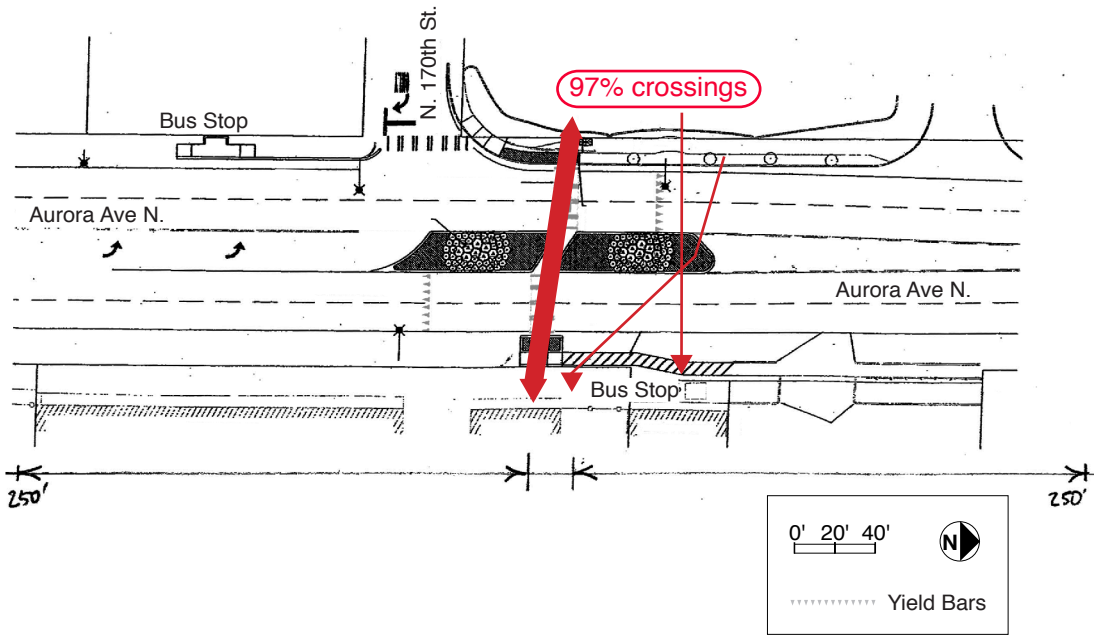


Figure 2. Before-After Pedestrian Crossing Patterns at N. 170th St.

the button after the enforcement phase (about 40 percent vs. 70 percent). As previously mentioned, this evaluation did not have the ability to filter out any short- vs. long-term effects that each treatment phase might have (e.g., an increase or decrease in usage over time). Note that although there were instances when pedestrians would still try to cross the street without activating the signals, it is reasonable to anticipate a learning curve for pedestrians to realize that they need to push the button to activate the signs. Once they understand how it works, they may be more inclined to use it.

Table 5. Pedestrians Who Pushed the Button

	Phase III Roving Eyes	**Phase IV Enforcement**
N 165th St	32% (11/34)	44% (15/34)
N 170th St	39% (23/59)	69% (40/58)

Shaded area – The before-after difference was significant at the 0.05 level based on chi-square statistic.

Pedestrian Evasive Behavior

Table 6. Pedestrian Evasive Behavior

	Before Treatment	After Treatment			
		I. Basic Construction	II. Crosswalks and Yield bars	III. Roving Eyes	IV. Enforcement
N 165th St	N=31	N=36	N=41	N=34	N=34
Pedestrian Evasive Behavior	39% (12)	3% (1)	15% (6)	0% (0)	0% (0)
N 170th St	N=40	N=54	N=36	N=59	N=58
Pedestrian Evasive Behavior	8% (3)	17% (9)	22% (8)	3% (2)	0% (0)

Shaded area – The change between the before treatment and the after treatment was significant at the 0.05 level based on chi-square statistic.

Pedestrian evasive behavior is defined as a pedestrian being forced to jump or step back to avoid a vehicle, or running to avoid being struck. As Table 6 shows, pedestrian evasive behavior at N 165th St was observed as frequently as 40 percent of the time in the before period. After the first treatment, the reduction in the frequency of pedestrian evasive behavior was significant (down to 3 percent). For N 170th St,

generally no significant change in evasive behavior was observed, given that the pedestrian evasive behavior was not as frequent to begin with.

CHANGES IN MOTORISTS' BEHAVIOR

While the before study revealed that very few motorists stopped or yielded to pedestrians, the analysis showed that after the safety treatments had been implemented, the combination of raised median, roving eyes, yield bars, and enforcement significantly improved vehicle compliance in yielding for pedestrians (see Table 7). Overall, as much as half of the time motorists yielded at N 165th St versus 71 percent at N 170th St.

Table 7. Vehicle Compliance for Pedestrian Crossings

	Before Treatment	After Treatment			
		I. Basic Construction	II. Crosswalks and Yield bars	III. Roving Eyes	IV. Enforcement
N 165th St	N=31	N=36	N=41	N=34	N=34
Southbound	0% (0)	3% (1)	17% (7)	47% (16)	47% (16)
Northbound	3% (1)	0% (0)	0% (3)	18% (6)	24% (8)
N 170th St	N=40	N=54	N=36	N=59	N=58
Southbound	0% (0)	7% (4)	28% (10)	25% (15)	62% (36)
Northbound	0% (0)	7% (4)	33% (12)	56% (33)	71% (41)

Shaded area – The change between the before treatment and the after treatment was significant at the 0.05 level based on chi-square statistic.

Effect of Basic Construction on Yielding Behavior

Analysis revealed that the basic construction had no significant effect on improving motorist yielding behaviors. This was expected because the main purpose of the basic construction, such as a raised refuge island and landscaped enhancements, was to change pedestrians' behavior by improving pedestrians' walking and crossing environment. These basic improvements were not intended to have a direct impact on motorist behavior.

Effect of Crosswalks and Yield Bars on Yielding Behavior

Higher motorist yielding rates were observed for both directions at the N 170th St location with marked crosswalks; motorists yielded as often as 33 percent of the time in comparison to 7 percent before the crosswalks were marked. At N 165th St, where only yield bars were implemented[6], a significant change in vehicle compliance was observed only in southbound traffic (an increase from 3 percent to 17 percent).

Effect of Roving Eyes on Yielding Behavior

Table 7 shows that the effect of the roving eyes on yielding behavior differed by direction, although improved yielding behavior was measured in both directions. The percentage of motorists who yielded in southbound traffic at N 165th St increased from 17 percent to 47 percent after the roving eyes had been installed. The percentage of motorists who yielded in northbound traffic at N 170th St increased from 33 percent to 56 percent after the roving eyes had been installed. It is important to realize that since only about one third of the pedestrians pushed the button to activate the roving eyes (see more discussion in the following section), the results of this study may not have captured the full effect of the roving eyes in encouraging motorists to yield.

However, the data suggest that when pedestrians pushed the button to activate the signs, motorists were more likely to yield. Phase III in Table 8 shows that for pedestrians who pushed the button at both locations, almost 90 percent of the time traffic from one direction would yield, whereas when pedestrians did not push the button, traffic would yield only half the time or less. This finding suggests that the roving eyes system has a positive effect on motorists' yielding action.

[6] While the yield bars were supposed to be evaluated with the activation of the roving eyes, because of construction requirements, the yield bars were striped before implementation of the roving eyes.

Table 8. How Motorists Reacted to Roving Eyes

	N 165th St		N 170th St	
	Phase III. Roving Eyes (N=34)	Phase IV. Enforcement (N=34)	Phase III. Roving Eyes (N=59)	Phase IV. Enforcement (N=58)
Pedestrians who pushed the button	32% (11)	44% (15)	39% (23)	69% (40)
Either SB or NB motorists yielded	91% (10)	87% (13)	87% (20)	95% (38)
Motorists from both directions yielded	36% (4)	53% (8)	43% (10)	80% (32)
Pedestrians who DID NOT push the button	68% (23)	56% (19)	61% (36)	31% (18)
Either SB or NB motorists yielded	26% (6)	16% (3)	50% (18)	39% (7)
Motorists from both directions yielded	9% (2)	0% (0)	0% (0)	0% (0)

Shaded area – The before-after difference is significant at the 0.05 level based on chi-square statistic.

Effect of Enforcement on Yielding Behavior[7]

Police enforcement was conducted at N 170th St on three days over a four-week period[8]. While one might expect that enforcement activities would be associated with higher vehicle compliance rate, the results do not show consistent improvement (see Table 7). While the studied locations were relatively close to each other, the effect of the before and after the enforcement activity was not significant at N 165th St. The lack of effect on vehicle compliance rates may have been the result of how the operation was implemented. For example, because enforcement was conducted randomly over a period of time, it may not have been frequent enough to catch motorists' attention during the observation period.

[7] The final round of data collection occurred before the enforcement task was finished because of the schedule for evaluation completion. The enforcement activity was scheduled to occur over a total period of two months.

[8] Traffic enforcement was conducted at N 170th St during the following times: December 19, 2002, from 14:00 to 17:00; January 3, 2003, from 14:00 to 17:00; and January 7, 2003, from 18:30 to 21:30. Data were collected from January 8 through 10, 2003, from 15:00 to 18:00.

Although the enforcement significantly affected motorist yielding on southbound traffic at N 170th St (25 percent vs. 62 percent), this may have been the result of a significant increase in the number of pedestrians, from 40 to 70 percent, pushing the button to activate the roving eye lights occurred only at N 170th St (see Table 8). Note earlier discussion about motorists were more likely to yield when pedestrians pushed the button to activate the signs.

Motorists' Response to Yield Bars

Table 9 shows that most of the time, motorists stopped at the yield bars (see figures 1 and 2 for yield bar placement). Although enforcement did not consistently increase vehicle compliance rates, when motorists stopped, the enforcement seems to have reminded almost all motorists to stopped at the yield bars.

Table 9. Motorists' Response to Yield Bars

	After Treatment			
	I. Basic Construction	II. Crosswalks and Yield bars	III. Roving Eyes	IV. Enforcement
N 165th St				
Southbound	N/A	71% (5/7)	75% (12/16)	100% (16/16)
Northbound	N/A	67% (2/3)	50% (6/7)	100% (8/8)
N 170th St				
Southbound	N/A	70% (7/10)	87% (13/15)	100% (36/36)
Northbound	N/A	50% (6/12)	64% (21/33)	95% (39/41)

Shaded area – The before-after difference was significant at the 0.05 level based on chi-square statistic.

Vehicle Evasive Behavior

Vehicle evasive action is defined as a vehicle forced to abruptly brake or swerve to avoid striking a pedestrian. As mentioned previously, pedestrians were generally cautious about crossing the street, and most observed pedestrians crossing at the study locations showed extreme caution, even when they were crossing in a legal unmarked crosswalk. Many waited a very long time for a gap in traffic to cross the street without stopping at the center turn lane; others crossed one lane-direction at a time, waiting in the

center turn lane for another gap to complete the crossing. Therefore, vehicle evasive behavior was relatively infrequent during the before study. However, if vehicle evasive behavior occurred, it was associated with a pedestrian waiting in the center turn lane (most of the pedestrians in the after study used the refuge area). No significant "before-after" change was observed in this study (see Table 10).

Table 10. Vehicle Evasive Behavior

	Before Treatment	After Treatment			
		I. Basic Construction	II. Crosswalks and Yield bars	III. Roving Eyes	IV. Enforcement
N 165th St	N=31	N=36	N=41	N=34	N=34
Vehicle Evasive Behavior	3% (1)	0% (0)	1% (3)	0% (0)	0% (0)
N 170th St	N=40	N=54	N=36	N=59	N=58
Vehicle Evasive Behavior	3% (1)	4% (2)	1% (2)	7% (4)	2% (1)

Shaded area – The change between the before treatment and the after treatment was significant at the 0.05 level based on chi-square statistic.

Shielding Conflict

Shielding conflict is defined as vehicles in the lane closest to the pedestrian yielding while vehicles in adjacent travel lane(s) still proceed. Shielding conflict was not recorded in the before study. In general, no significant changes in the frequency of shielding conflict occurred during the various treatments, except for the northbound direction at N 170th St (see Table 11). During the period after basic construction and when the roving eyes device was in place, shielding conflict increased significantly from 2 percent to 17 percent. (However, pedestrian evasive behavior actually decreased from 17 percent to 3 percent during this time.) Also, it is worth noting that shielding conflict can contribute to pedestrian evasive behavior either because pedestrians are not looking or motorists are not yielding (see Table 12). After phase III, WSDOT installed extra warning signs to remind pedestrians to watch for vehicles when crossing.

Table 11. Shielding Conflict

	After Treatment			
	I. Basic Construction	II. Crosswalks and Yield bars	III. Roving Eyes	IV. Enforcement
N 165th St	N=36	N=41	N=34	N=34
Southbound	3% (1)	2% (1)	0% (0)	6% (2)
Northbound	0% (0)	2% (1)	3% (1)	0% (0)
N 170th St	N=54	N=36	N=59	N=58
Southbound	0% (0)	0% (0)	3% (2)	0% (0)
Northbound	2% (1)	11% (4)	17% (10)	2% (1)

Shaded area – The change between the basic construction phase and the other treatments was significant at the 0.05 level based on chi-square statistic.

Table 12. Shielding Factor Contributing to Pedestrian Evasive Action

		After Treatment			
		I. Basic Construction	II. Crosswalks and Yield bars	III. Roving Eyes	IV. Enforcement
N 165th St	No. of Pedestrian Evasive Action	1	6	0	0
	With Shielding Conflict	1 (SB)	1 (NB)	0	0
N 170th St	No. of Pedestrian Evasive Action	9	8	2	0
	With Shielding Conflict	0	1 (NB)	1 (SB)	0

SECTION FIVE
DISCUSSION AND CONCLUSIONS

The intent of this evaluation was to examine the effects of a set of roadway design improvements, traffic enforcement activities, and a public information campaign on pedestrian safety. A "before" and a four-phased "after" analysis was conducted to evaluate motorist and pedestrian behavioral changes at the study sites – N 165th St and N 170th St on SR 99 in the City of Shoreline. While an effort was made to gain a better understanding of the effect of each of the four "after treatment" phases, the evaluation emphasizes whether this package of safety treatments resulted in positive motorist and pedestrian behavioral changes at the studied sites. The key findings are listed below.

The safety treatments had a positive effect on pedestrian behavior in that pedestrians used the median refuge for crossing.

A significant percentage of pedestrians used the median refuge at both studied sites. This suggests that pedestrians may feel that the refuge area provides an additional margin of safety.

The study results do not suggest that pedestrians gained a false sense of security.

The results of the study do not suggest pedestrian overconfidence. Although an examination of pedestrian "looking" behavior[9] was not conducted in this study, the reduction in pedestrian conflict rates and the lack of change in vehicle evasive behavior imply that pedestrians were not any less careful after implementation of the treatments. Furthermore, while the shielding conflict increased significantly from 2 percent to 17 percent on northbound SR 99 at N 70th St during part of the implementation process, pedestrians' evasive behavior actually decreased from 17 percent to 3 percent during the same time. This suggests that most pedestrians were still cautious about watching for

[9] A specific determination of how carefully pedestrians looked for on-coming traffic.

coming traffic when crossing the street. Thus, there is no strong evidence that pedestrians felt more protected in marked crosswalks and acted more carelessly in the new environment.

Nevertheless, shielding conflict can contribute to pedestrian evasive behavior, either because pedestrians do not look or motorists do not yield. The potential for gaining further understanding of this topic was limited in this study. It would be interesting to determine whether changes in pedestrian or motorist behavior occurred over time. Even with safety treatments in place, such as marked crosswalks and pedestrian and traffic warning lights, it is also helpful to remind pedestrians to always be cautious about crossing the street.

The safety treatments significantly improved vehicle compliance in yielding for pedestrians.

It can be concluded that the combination of the safety treatments implemented in this study had an overall positive effect on pedestrian crossing paths and vehicle compliance rate at the two locations studied. While the vehicle compliance rates improved from nearly no compliance to as high as 50 percent at N 165th St and 70 percent at N 170th St, improvements are still needed in poor driving behavior.

Higher motorist yielding rates were observed at marked crosswalks.

A significant change in vehicle compliance rates was observed only at the N 170th St location with marked crosswalks. (Motorists yielded as often as 33 percent of the time in comparison to 7 percent before the crosswalks were marked.)

The push button activated roving eyes signs had a positive effect on motorists' yielding action.

The study results revealed that motorists at both sites were more likely to yield to pedestrians when the warning lights were activated for motorists. However, because only a fraction of pedestrians pushed the button to activate the traffic warning device, the

results of this study may not capture the full effect of the device in encouraging vehicle compliance. Additional effort is recommended to remind pedestrians to push the button to activate the traffic warning lights.

Motorists responded positively to the yield bars.

When motorists did yield to pedestrians, they tended to stop at the yield bars. It is interesting to note that although enforcement did not consistently increase the vehicle compliance rate, motorists who yielded were more likely to stop at the yield bars.

This study may be limited in reflecting the true impact of traffic enforcement.

While one might expect that enforcement activities would be associated with higher vehicle compliance rates, only one direction at one of the studied sites showed significant improvement in vehicle compliance. Note that the enforcement component was not completed at the time of data collection. The infrequent and random timing of the enforcement schedule may have prevented the enforcement efforts from catching enough motorists' attention during the observation period.

The true effect of each treatment phase may have been limited at the study sites because of the implementation process, construction constraints, and project schedule.

The timing of various rounds of data collection for this evaluation depended on the schedule of the project implementation. Therefore, it was not possible to separate seasonal and weather effects, as the project timing resulted in before data collection in the fall of 1999 and after data collection during the summer, fall, and winter of 2002. The data collected during this study may or may not portray long-term behavior for several reasons: (1) they are a snapshot of pedestrian and motorist behavior that were captured during specific time periods shortly after implementation of a given treatment, and (2) for safety and schedule reasons, data collection usually occurred one week after a treatment had been placed and thus could not capture any novelty effects.

APPENDIX A

SUMMARY FINDINGS
OF "BEFORE" PUBLIC OPINION SURVEY

SUMMARY FINDINGS
OF "BEFORE" PUBLIC OPINION SURVEY

As part of the treatment design process, a public opinion survey was conducted to provide a qualitative assessment of community members' experiences as a pedestrian and/or a driver on Aurora Avenue North between N 152nd St and N 170th St. During January 2000, 1,233 surveys were sent to business owners and local residents near the project location between N 165th St and N 170th St on Aurora Avenue North. The overall response rate was about 12 percent (152 returned surveys). The findings are categorized below to reflect the perspectives of two groups: pedestrians and drivers.

DEMOGRAPHIC CHARACTERISTICS

Slightly more than half of the survey respondents were female (see Figure 1). The ages of the respondents ranged primarily from 31 to 50 (see Figure 2). Seniors filled out one quarter of the returned surveys. As shown in Figure 3, 62 percent of the survey respondents possessed a college degree or had received post-graduate education, 24 percent had attended community college, and 14 percent had finished only high school.

PEDESTRIANS' BEHAVIOR

Of all respondents, 21 percent indicated that they always, often, or sometimes walked and crossed Aurora Avenue North somewhere between N 165th St and N 170th St (see Figure 4). Of those pedestrians, 66 percent indicated that they always or sometimes crossed because they got on or off a transit bus (see Figure 5). Figure 6 shows that most of the walk trips were related to shopping, work, leisure, or getting food.

Figure 1. Sex
(Overall response rate: 95%)

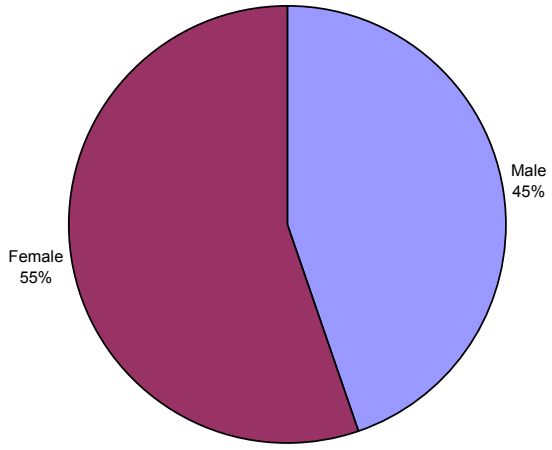


Figure 2. Age
(Overall reponse rate: 95%)

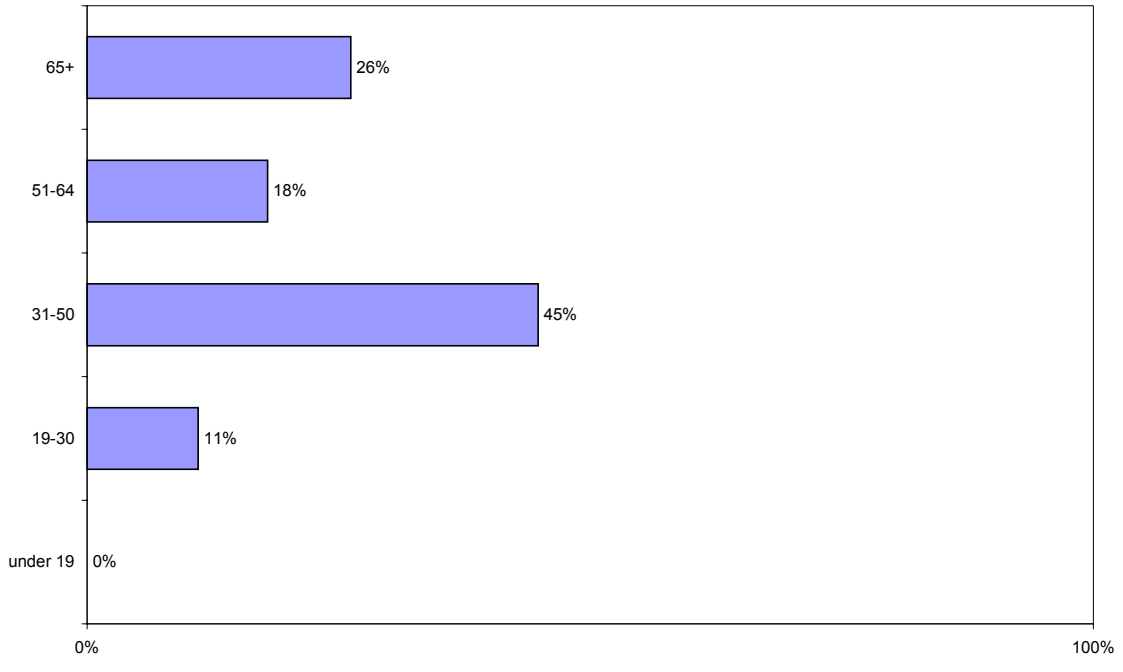


Figure 3. Education
(Overall response rate: 93%)

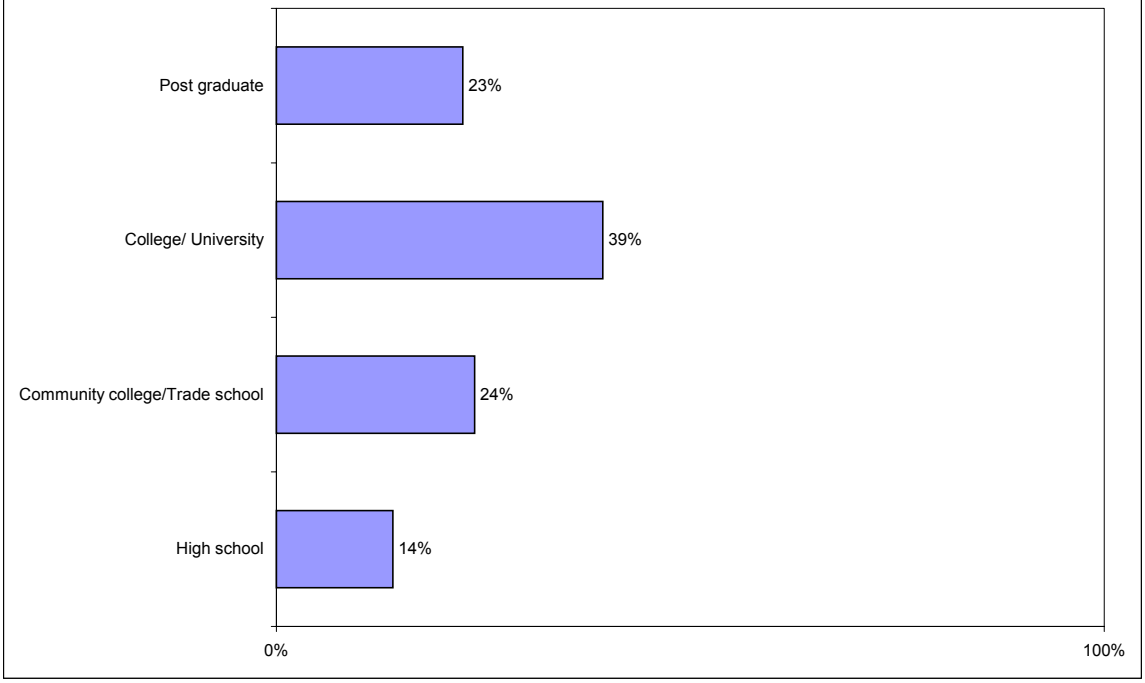


Figure 4. Pedestrian Activity
(Overall response rate: 98%)

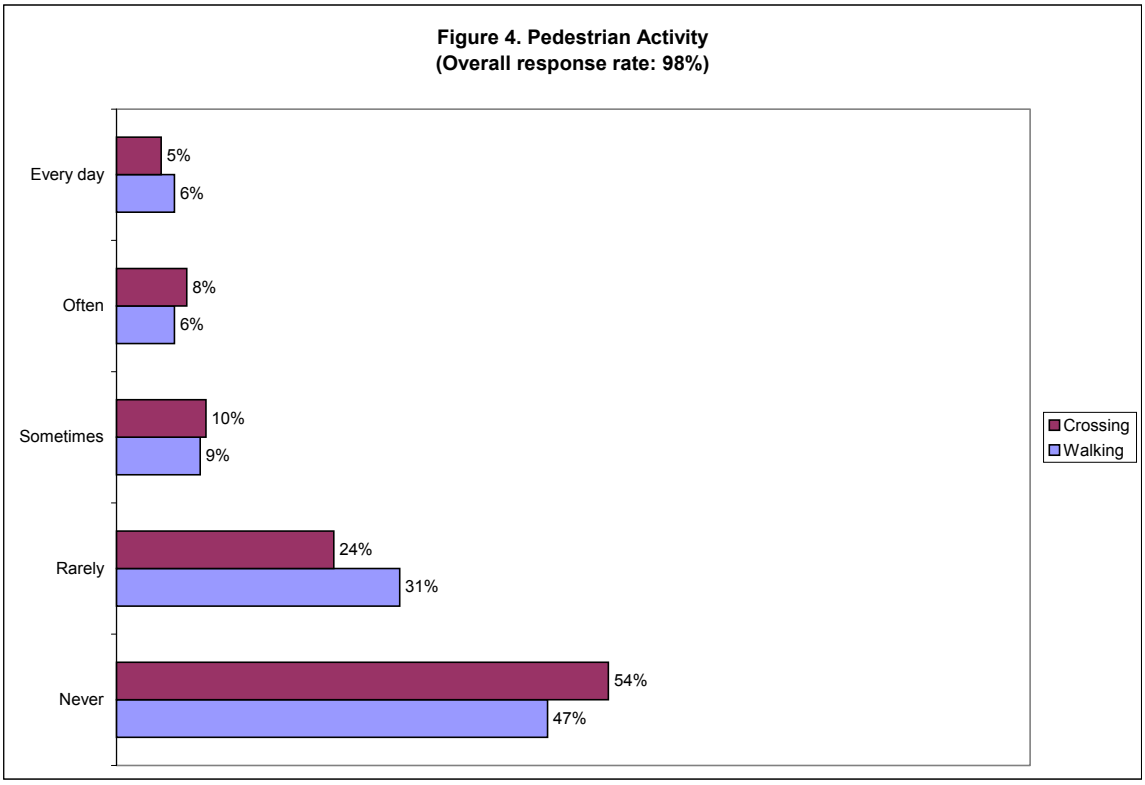


Figure 5. Pedestrians Who Ride Bus
(Overall response rate: 21%)

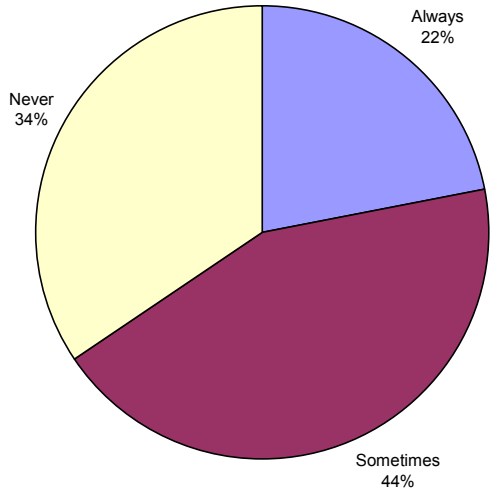
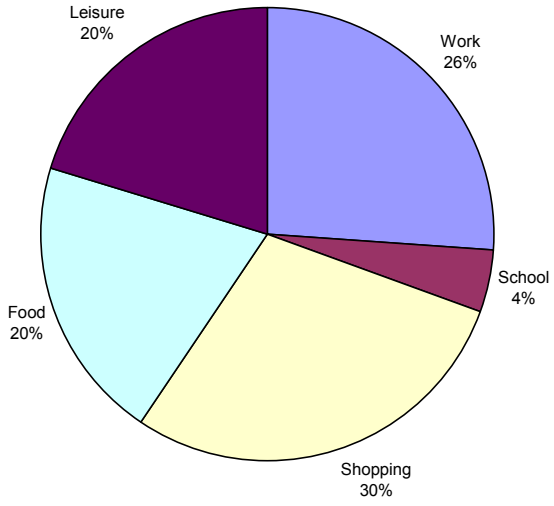
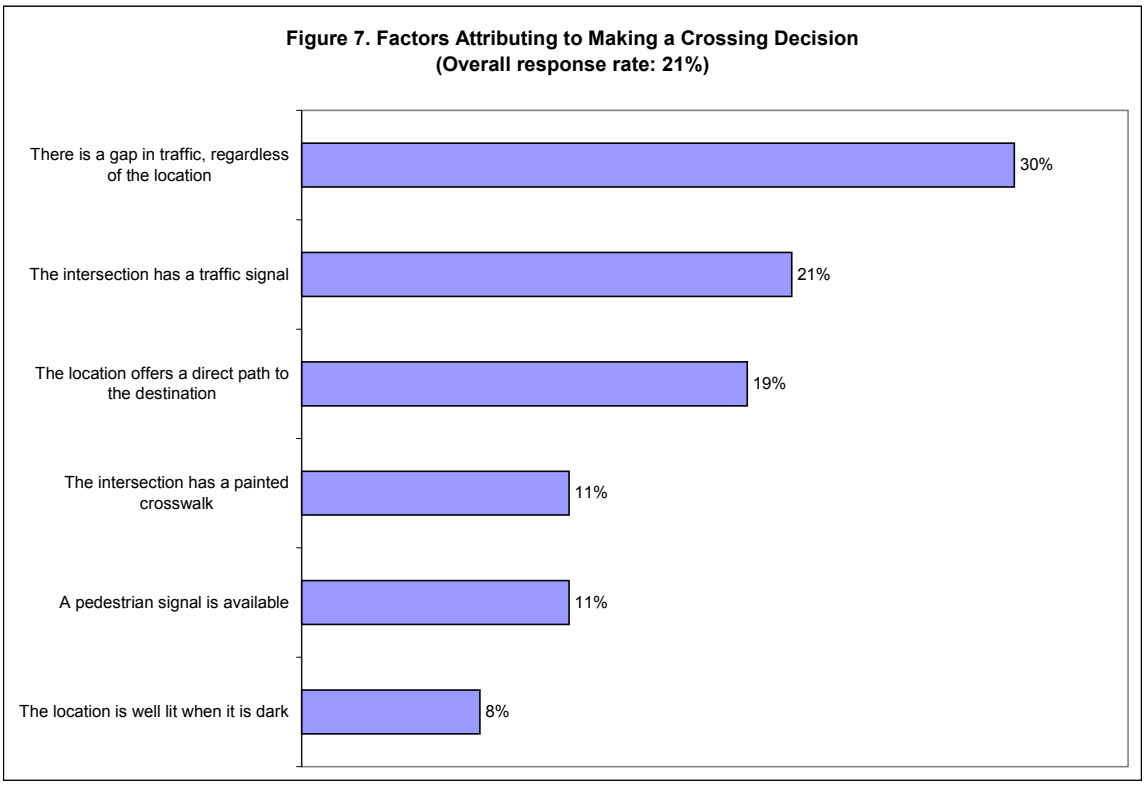


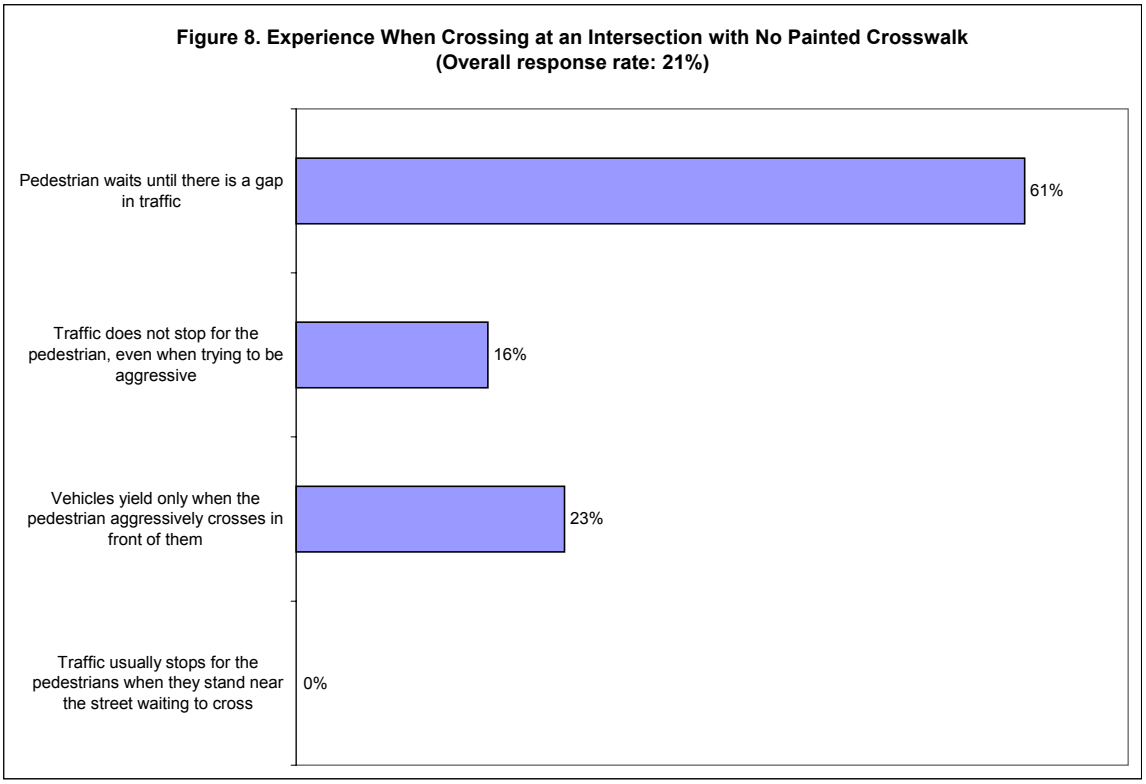
Figure 6. Purpose of Walk Trip
(Overall response rate: 21%)



Because there were no traffic lights or painted crosswalks near the study location, pedestrians often chose to wait for a gap in traffic to cross the street, regardless of the location (see Figure 7). The survey results also revealed that about 40 percent of the time the pedestrians' crossing decisions were affected by whether the intersection had a traffic signal and whether the location offered a direct path to their destination. To a lesser extent, the decision about where to cross the street might be based on whether the intersection had a painted crosswalk, a pedestrian signal was available, or the location was well lit at night. Other factors included visibility and whether a police officer was nearby.



Traffic usually would not stop for the pedestrians when they stood near the street waiting to cross (see Figure 8). Twenty-three percent of the surveyed pedestrians indicated that vehicles only stopped for them when they aggressively crossed in front of drivers.



DRIVERS' BEHAVIOR

Nearly 80 percent of the drivers saw pedestrians crossing near the study location sometimes or as frequently as every day (see Figure 9). When asked about how frequently they had stopped to let a pedestrian cross, only 26 percent of the respondents said they stopped their vehicles whenever they saw a pedestrian waiting to cross (see Figure 10). Twenty-three percent of the respondents said that they had not stopped to let a pedestrian cross in the last month. Some indicated that they would stop only if there were no vehicles behind them. About 27 percent of drivers said they had stopped because a pedestrian was in the roadway ahead of them.

Figure 9. Frequency of Driver Seeing Pedestrian Crossing at the Studied Locations (Overall response rate: 97%)

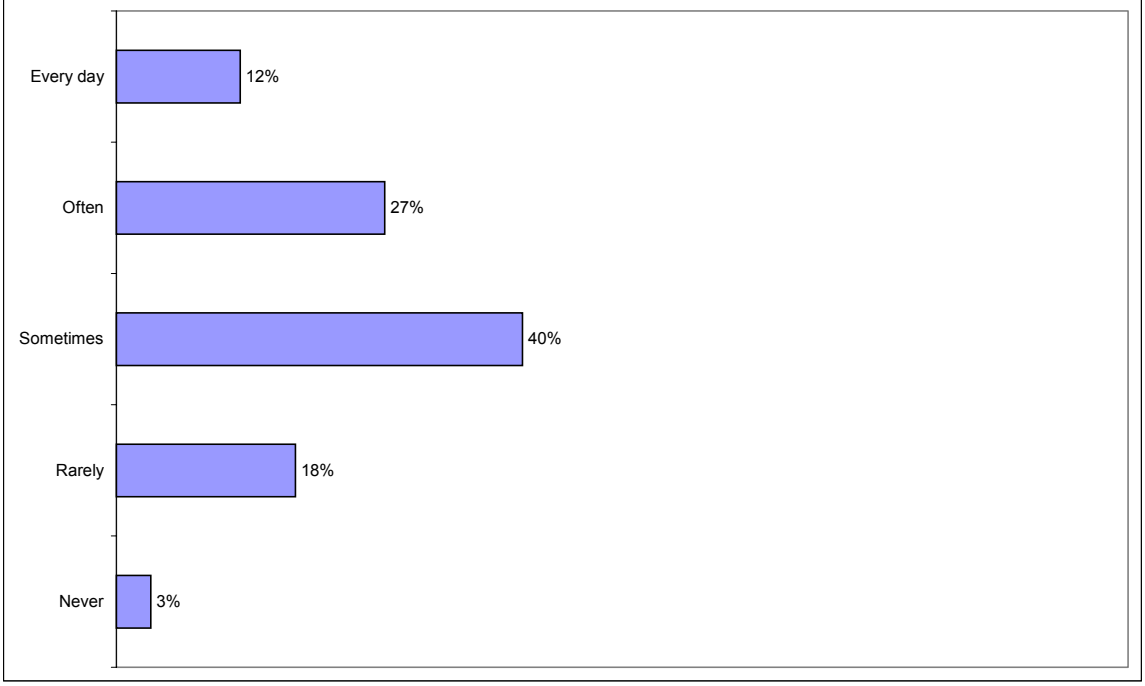
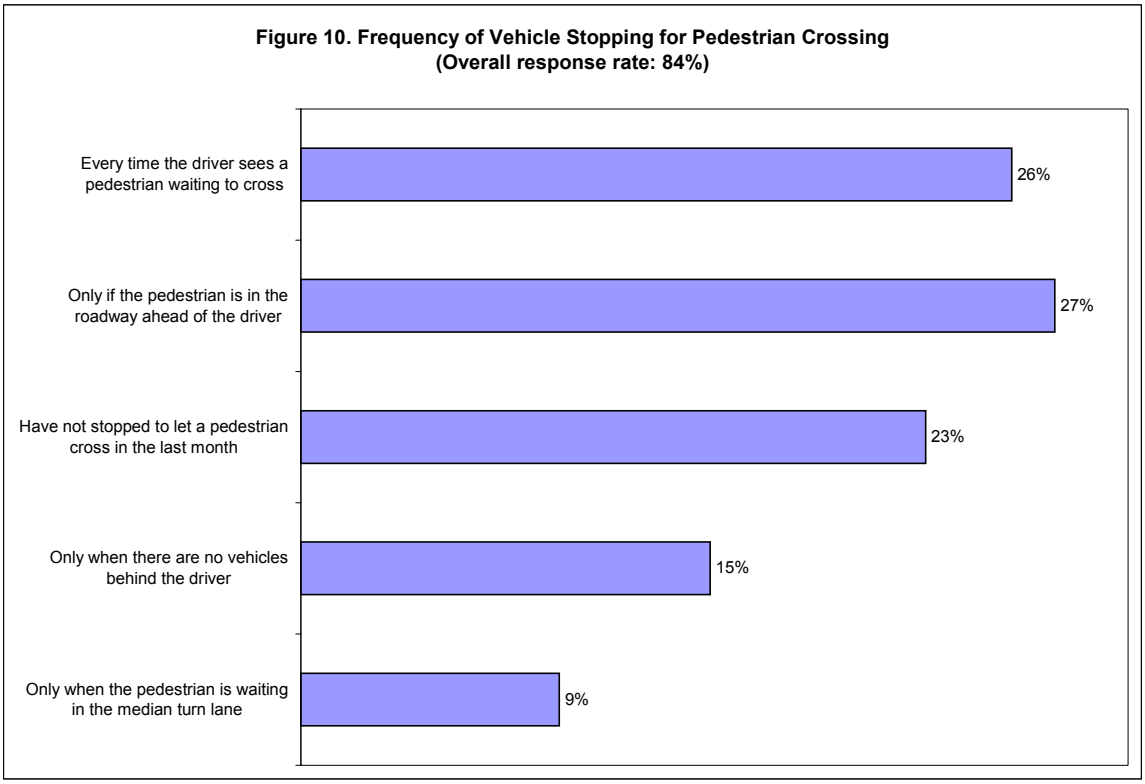
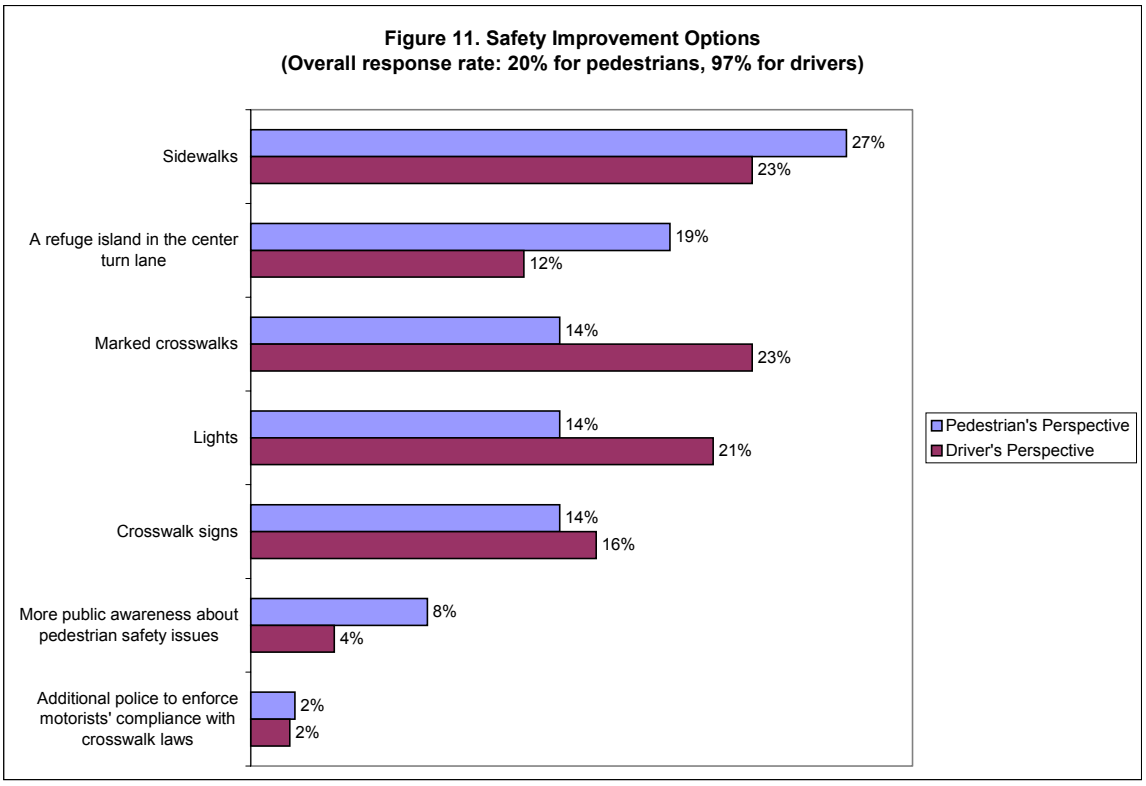


Figure 10. Frequency of Vehicle Stopping for Pedestrian Crossing (Overall response rate: 84%)



POTENTIAL IMPROVEMENTS

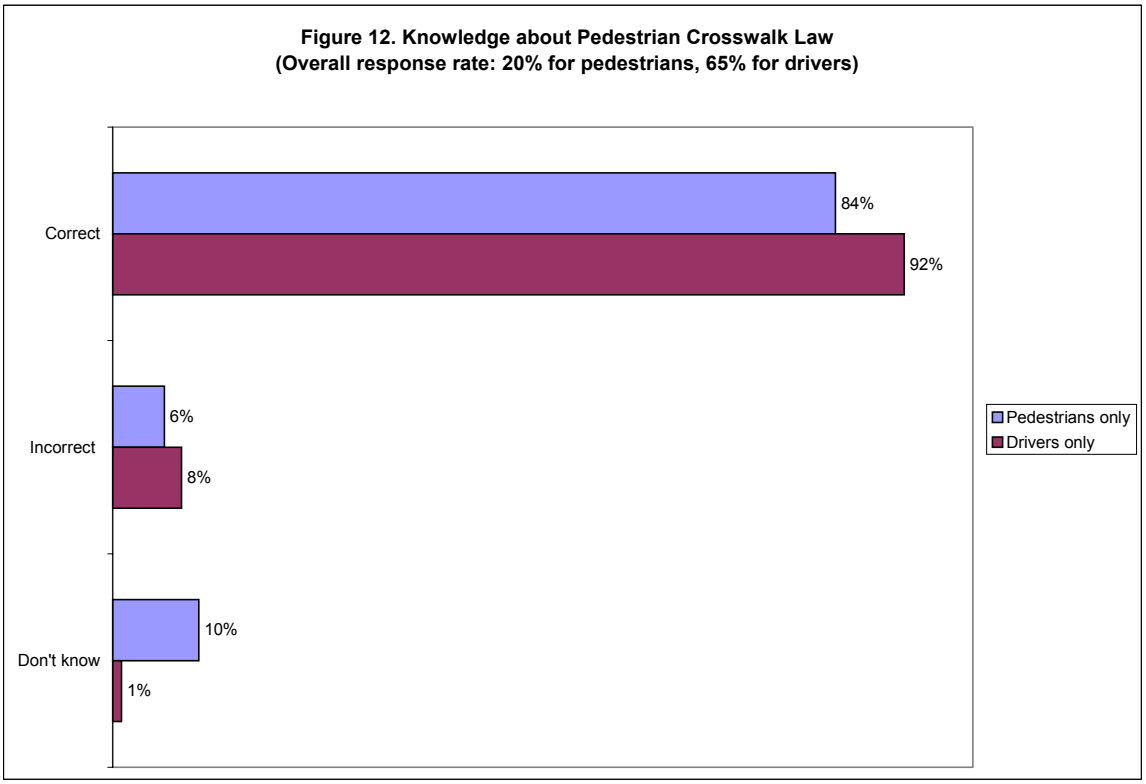
Surveyed pedestrians and drivers ranked safety improvement options similarly (see Figure 11). Adding sidewalks was the most preferred option. Surveyed pedestrians viewed marked crosswalks, lights, and crosswalk signs as equally important. Crossing pedestrians favored a refuge island in the center turn lane more than drivers did. Additional police to enforce motorists' compliance with crosswalk laws and public awareness about pedestrian safety issues were viewed by both groups as low priority in comparison to the other options. Other improvement suggestions included reduced traffic speed, building an underpass or overpass walkway, controlled pedestrian lights with overhead lighting, pedestrian signals, and lighted crosswalks.



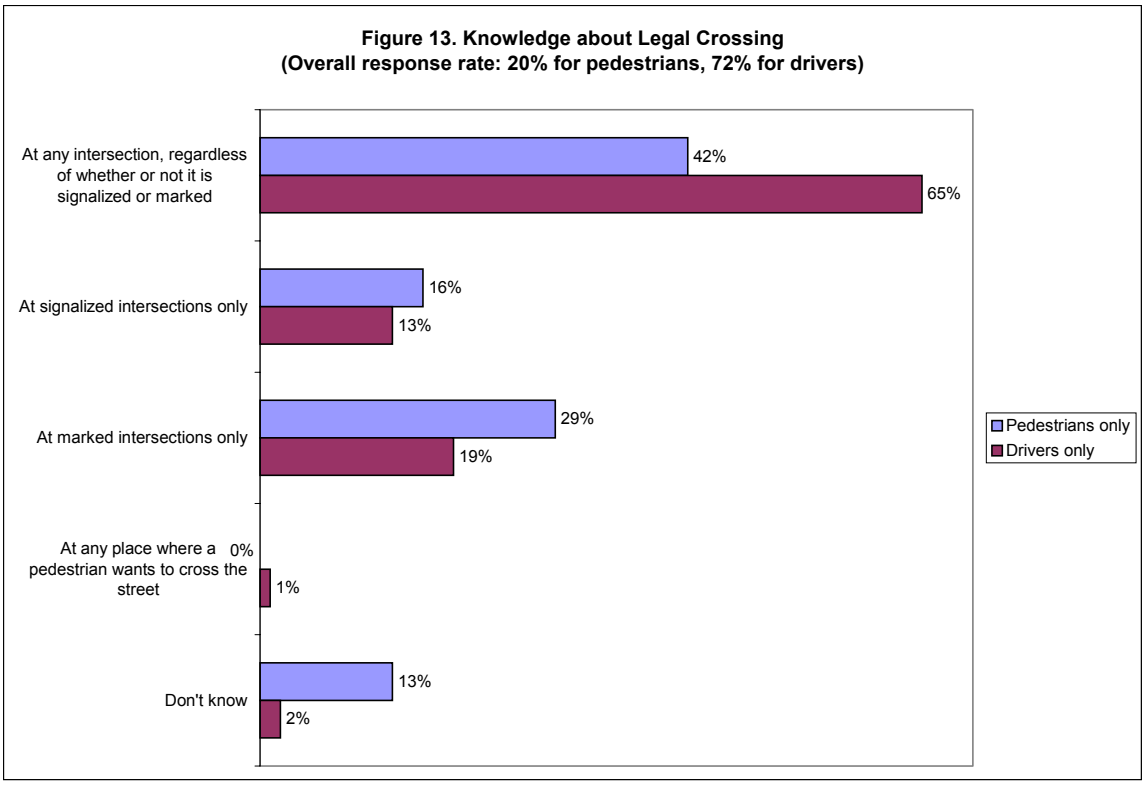
KNOWLEDGE ABOUT PEDESTRIAN CROSSWALK LAW

Overall, 80 percent of the survey respondents answered correctly about the pedestrian crosswalk law[1] (see Figure 12). However, when asked specifically about what is considered a legal crossing, over 30 percent of all respondents from both groups thought that a legal crossing occurs only at either signalized intersections or marked intersections (see Figure 13). As much as 30 percent of the surveyed pedestrians considered a legal crossing to be crossing at marked intersections only.

Figure 12. Knowledge about Pedestrian Crosswalk Law
(Overall response rate: 20% for pedestrians, 65% for drivers)



[1] The pedestrian crosswalk law states that pedestrians have the right-of-way at crosswalks and intersections, whether or not the crosswalk is marked or painted. Drivers must yield where necessary to avoid striking pedestrians who are legally crossing the road.



COMMENTS FROM THE MAIL-OUT SURVEY

Below are the comments gathered from the returned surveys.

- "Aurora Ave N needs overhead pedestrian crossings like the one at 130th, and while you're at it how about a second deck on Aurora Ave before it's too late!"
- "The casinos in the future between 165th and 170th will need pedestrian consideration now. Not later when it's out of control and even more expensive."
- "In the last week, both myself and my wife have had to dodge someone standing in the median. Them trying to cross Aurora and us trying to turn left off Aurora. Both were at night and people wearing dark clothes."
- "Thank you for finally addressing this problem. Aurora Ave is NOT pedestrian friendly or accessible for many who must use it"

- "Sidewalks – bad idea for bicycles; marked crosswalks – only on traffic intersection lights; crosswalk signs – bigger the better; motorists should not strain to see the signs through shadows of light."
- "Aurora between 145th and 205th is very poorly lighted for both drivers and pedestrians. I drive Aurora daily between 175th and 185th and note that the lighting is particularly poor and hazardous in rain and snow conditions."

APPENDIX B

PEDESTRIAN AND MOTORIST OBSERVATION FORM

Intersection _____ Observer _____ Date _____ Time _____to_____ Weather _____

						Southbound Vehicles			**Northbound** Vehicles			**Conflicts**			
	# of Ped Observed	Transit Origin - Dest.	Ped Age	Sex	Push Button	Yielding	Position to yield bars	Shielding Conflicts	Yielding	Position to yield bars	Shielding Conflicts	PE	VE	MD	NM
1		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
2		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
3		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
4		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
5		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
6		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
7		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
8		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
9		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
10		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
11		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
12		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
13		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
14		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
15		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
16		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
17		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
18		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
19		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				
20		O D NA	P C T A S	M F	Y N	Y N	Before After	Y N	Y N	Before After	Y N				

# of Ped Observed = Assign one number for each group of peds

Transit = pedestrian traveling either to (D) or from (O) adjacent Metro stop

P = pre-school (0 - 5)
C = child (6 – 12)
T = teen (13 – 18)
A = adult (19 – 60)
S = senior (60 +)

Shielding conflicts = Vehicle yields within 10 ft of the Xwalk while a vehicle in the next travel lane still proceeds

Pedestrian evasive action (PE) = Pedestrian had to jump or step back or was forced to run.

Vehicle evasive action (VE) = Vehicle had to hit brakes or swerve to avoid striking a ped.

Ped wait in median (MD)= When pedestrian had to stop and wait in median for more than five seconds.

Near Miss (NM) = A pedestrian/vehicle collision almost occurred.