RESEARCH REPORT
Agreement T2695, Task 94
Pedestrian Safety Treatments

AN EVALUATION OF ENGINEERING TREATMENTS AND PEDESTRIAN AND MOTORIST BEHAVIOR ON MAJOR ARTERIALS IN WASHINGTON STATE

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16. ABSTRACT

This report examines pedestrian and motorist behavior on arterials in Washington State and determines how, if at all, these behaviors change when various engineering treatments are applied. The treatments that were examined included crosswalk markings, raised medians, in-pavement flashers, signage, stop bars, overhead lighting, and sidewalks. The relationships between pedestrian travel and transit use, origin-destination patterns, traffic signals, and schools were also explored.

The study examined seven locations in the state of Washington. These were State Route (SR) 7 at South 180th Street in Spanaway, SR 99 at South 152nd Street in Shoreline, SR 99 at South 240th Street in Kent, SR 2 between South Lundstrom and King Streets in Airway Heights, SR 2 at Lacrosse Street in Spokane, SR 2 at Rowan Avenue in Spokane, and SR 2 at Wellesley Avenue in Spokane.

Because pedestrian-vehicle collisions are rare when specific locations are studied, other criteria were used to evaluate the conditions and behaviors that were present. These included "conflicts" such as running behavior, motorists having to brake unexpectedly to avoid a pedestrian, pedestrians waiting in the center lane to cross, and more. These unreported, but very common, occurrences enabled the researchers to gain a better understanding of both pedestrian and motorist concerns and behaviors and the effects that improvements might have.

The study concludes that the causes of conflicts are highly varied: ignorance of or noncompliance with the law (by the motorist or the pedestrian), inattention, vehicles following too closely, impatience, anxiety in attempting to catch a bus, use or non-use of pedestrian facilities, placement of features in the built environment, and more. While pedestrian/motorist interaction improves with improved visibility (something which can be obtained through better engineering design and the removal of visual clutter) better education and/or enforcement will also be needed to achieve significant safety benefits.

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CHAPTER 1: INTRODUCTION

Pedestrian travel is one of the most basic forms of transportation that humans have at their disposal. Older cities were designed with the pedestrian (and/or retail customers) in mind: there were wide sidewalks and awnings and trees for protection from the elements, as well as ambiance. But since the arrival of the car, design standards have been changed, and many of these pedestrian amenities have been reduced or eliminated (Maricopa Association of Governments 2008). In fact, the AASHTO Green Book, considered by many to be the “Bible” of transportation engineering design, once went so far as to describe pedestrians as “unpredictable, obstinate, ignorant, inattentive, or defiant” (qtd. in King 2003). In the 1990s, state departments of transportation began to reverse this trend by integrating pedestrians back into their planning processes and stressing their importance. In Washington State, the Pedestrian Policy Plan was first published in 1993 and has been updated and revised many times since then (VTPI).

Since modes of travel other than the automobile are now being given greater consideration, pedestrians—including those with disabilities—bicyclists, automobiles, freight carriers, and emergency vehicles must all be considered when new roads are designed. The problem that arises is that so many facilities have already been built without this careful regard. Because of this, we are left with thousands of miles of pavement designed for the almost exclusive use of the automobile. These are the nation’s arterials—roads once built for speed through cities. They can be narrow, flanked by buildings and shops, or very wide, connecting a vast expanse of strip malls, but they are normally cluttered and rarely are they an enjoyable experience for the pedestrian traveler. An example of this environment can be seen in Figure 1.1.

Figure 1.1. Typical streetscape of an arterial near Seattle, Washington (Jones & Stokes 2007)

This leaves us with an interesting problem: on the one hand is the pedestrian—maneuverable, all-terrain, but comparatively slow; and on the other hand is the "greater good"—moving people and goods to their destinations as quickly as possible. The greater good gives us long blocks, traffic signals tailored to the major vehicle flows, and ever-wider roads. Pedestrians, knowing their limitations, vulnerabilities, and strengths, will attempt to cross these roadways where it is most convenient—or has the highest perception of safety—for the pedestrian. Some pedestrians cross lawfully at intersections; others may see a gap in traffic and cross then to avoid a possible future conflict; still others may be late for an appointment or bus and will cross in front of traffic to be on time, though risking their lives in the process.

About 5,000 pedestrians are killed and over 60,000 pedestrians are injured each year in collisions involving automobiles. This study examines the behaviors that may lead to these incidents and explores engineering treatments that may be able to improve the environment on arterials—for all users. No amount of engineering can prevent all collisions, but a better understanding of what is happening on our roadways will enable us to make better design and amenity decisions on future projects.

PROBLEM STATEMENT

With so many pedestrians dying or being permanently disabled after collisions with vehicles, more information on the causes of and possible remedies for these collisions were sought. The effectiveness of various pedestrian safety treatments needed to be tested, and more needed to be known about pedestrian and motorist behavior to be able to select the appropriate treatments for a given site. Two questions were paramount to this study:

- What causes vehicles to yield to pedestrians?
- What causes conflicts between vehicles and pedestrians?

PURPOSE

The purpose of this research was twofold: to examine pedestrian and motorist behavior on arterials in Washington State and to determine how, if at all, these behaviors might change after various engineering treatments were applied. The treatments that were examined included crosswalk markings, raised medians, in-pavement flashers, signage, stop bars, overhead lighting, and sidewalks. The relationships that arise between pedestrian travel and transit use, origin-destination patterns, traffic signals, and schools were also explored.

The Washington State Department of Transportation (WSDOT) had conducted previous research that identified high pedestrian accident locations on arterials in Washington State. From these locations, the study sites were selected. Some sites were chosen only for study of their current conditions, while others were selected to receive engineering improvements. The sites that received improvements were studied both before and after the improvements had been made.

Because pedestrian-vehicle collisions can be fairly rare when a single location is studied, other criteria were used to evaluate the conditions and behaviors that were present. These included "conflicts" such as pedestrian running behavior, motorists braking unexpectedly to avoid a pedestrian, pedestrians waiting in the center lane to cross, and more. These unreported but common occurrences enabled the researchers to obtain a better understanding of both pedestrian and motorist concerns and behaviors and the effects that the improvements had.

METHODOLOGY

The main tasks of the project were the following:

- data collection
- before-after analysis
- documentation of project findings and recommendations.

These tasks are described in more detail below.

Perform Data Collection

Video Technology

The project planned to collect data on motorist and pedestrian movements with a video image detection system marketed by Digital Traffic Systems, Inc. (DTS). The DTS system was designed to allow automated monitoring of pedestrian and vehicular movements in the roadway. This image tracking technology would enable the researchers to conduct cost-effective, long-term data collection that would increase the statistical reliability of the analysis. The goal of the project was to use the advanced system to improve the state's ability to test the effectiveness of a variety of safety treatments.

WSDOT staff built a self-contained system for the video collection effort that included a cabinet assembly with six batteries, a camera controller, and two digital video recorders (DVRs). The cabinet would be connected to a power or light pole with two solar panels and two dome cameras attached.

Unfortunately, the video device exhibited many problems during data collection. Difficulties arose in maintaining the power level to keep the cameras and DVRs operating. In addition, problems with obtaining permission to place the cameras on existing power poles sometimes resulted in placement of the system on a temporary pole. The height of that temporary pole could cause problems in the image detection software, which could not be calibrated to accurately detect pedestrian crossings. In fact, the software rarely identified pedestrians and was inconsistent for vehicle movements as well. A near-vertical angle of view was found to be necessary to accurately detect pedestrians, and this angle did not allow the robust view of pedestrian behavior (i.e., jaywalking) and vehicle-pedestrian interaction that was desired for this study. Consequently, the data were reduced manually to determine pedestrian and vehicle behaviors at the crosswalks, including crossing location, yielding, wait time, conflicts, and various other measures. Manual data reduction required a significant amount of time and eliminated the potential for using performance measures related to vehicle speeds and speed changes.

Continual problems with the original equipment prompted the purchase of a new video data collection system for the project. In collaboration with WSDOT’s Northwest Region Signals Shop, a new system was developed to improve the process. A new battery cabinet was designed, and a new DVR system was purchased. These products had been tested by the Northwest Region for other projects and were deemed successful. The new equipment eliminated the power problem. However, the data from the new equipment still had to be analyzed manually because the problems with the image detection software had not yet been resolved. Because of the software’s potential to help researchers more cost effectively conduct these kinds of studies, its use will continue to be explored in future projects (Kopf and Hallenbeck 2005).

Data Elements

Data analysis was conducted to determine pedestrian and motorist safety-related behaviors. Table 1.1 outlines the performance measures collected from the video of various sites.

Perform Before–After or Site Analysis

Data elements were collected before and after the safety treatments had been modified. These data were then processed and summarized to better understand pedestrian crossing behaviors and patterns, motorists reactions to these behaviors, and how the local environment, including the various changes in safety treatments, influenced these behaviors and pedestrian crossing safety in the area. For sites where no improvements were made or no *after* data were available, a site analysis was performed. The same statistics and performance measures were used to evaluate baseline conditions for motorist and pedestrian behavior in these cases (Kopf and Hallenbeck 2005).

This report includes a summary of the observed pedestrian crossings categorized several factors, such as natural light condition, crossing location, and more. Statistical analysis methods, such as calculation of means, proportions, and standard deviations, as well as t-tests, were applied to analyze the impacts of changes or the similarities and differences between study sites (Levy 2007).

Document Project Findings and Recommendations

This report outlines the results of the evaluation and can be used as a guideline for future treatments on the arterials studied, as well as for other pedestrian projects in the state (Kopf and Hallenbeck 2005).

Table 1.1. Performance measures (Kopf and Hallenbeck 2005)

Pedestrian events	• Date and time • Direction of crossing
Pedestrian crossing locations and strategies	• Crossing locations • Use of pedestrian treatments (raised median, flashers, etc.) • Crossing strategies used (cross half of street, run all or half of street, etc.)
Environmental conditions	• Weather, light condition, road surface condition
Transit origin or destination and characteristics	• Determine if the pedestrian is using transit • Record whether bus was present or in view at time of crossing
Pedestrian delay	• Amount of time pedestrian waited on shoulder or sidewalk to cross • Amount of time pedestrian waited in center lane to finish crossing
Pedestrian behavior while crossing	• Pedestrian feels pressured to run so vehicles do not have to yield or to minimize time of yielding
Occurrence of vehicle-pedestrian conflicts	• Pedestrian evasive action: Pedestrian had to jump or suddenly step back • Vehicle evasive action: Motorist had to engage in abrupt braking or had to change lanes suddenly to avoid a pedestrian • Center lane wait: Pedestrian waited five or more seconds in the center lane before continuing to cross • Center lane conflict: Motorist had to stop or change direction to avoid pedestrian in center lane • Near miss: a pedestrian-vehicle collision almost occurred (note: no collisions were observed in this study) • Turning conflict: A turning motorist had to stop or change direction to avoid a crossing pedestrian
Vehicle yielding behavior	• Whether or not a vehicle yielded to pedestrian • Number of vehicles that passed before one stopped and waited for pedestrians to cross the street • Stop bar compliance
Shielding conflicts	• Vehicle in one lane yields while vehicles in the other lane(s) proceed

CHAPTER 2: STUDY SITES

Several sites around Washington State were chosen for study. They were chosen primarily on the basis of pedestrian-vehicle accident history but also to represent a variety of intersection and channelization complexity. They are presented below in the order of least complexity to most complexity (except for Lacrosse Avenue, which is presented with the other two Spokane study sites):

- State Route 7 at South 180th Street in Spanaway, Washington
- State Route 99 at South 152nd Street in Shoreline, Washington
- State Route 99 at South 240th Street in Kent, Washington
- State Route 2, between South Lundstrom and King streets in Airway Heights, Washington
- State Route 2 at Lacrosse Street in Spokane, Washington
- State Route 2 at Rowan Avenue in Spokane, Washington
- State Route 2 at Wellesley Avenue in Spokane, Washington

In general, the sites have factors in common that have contributed to the pedestrian safety problems observed. These include insufficient facilities for pedestrians, a lack of motorist and pedestrian regard for rules of the road, 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 (Nee and Hallenbeck 2003).

Some of the sites studied underwent improvements during the study period. When construction and project schedules warranted, sites were studied both before and after the improvements were made. These improvements, if deemed successful, could be replicated at other problem locations throughout the state. This chapter details each site's collision history, *before* and *after* descriptions (if applicable) of the sites, and a brief overview of the area in which each site is located.

I. STATE ROUTE 7—SPANAWAY, WASHINGTON

Site History

Since 1999, nine collisions involving pedestrians and eight collisions involving bicyclists have occurred on a 1-mile section of State Route 7 through Spanaway in Pierce County (Bernard 2007b). Of these collisions, 88 percent (15 collisions) resulted in injury to the pedestrian or cyclist. In this area, pedestrian safety is especially important, as walking is a common transportation mode choice in the community. School children and transit riders rely on safe walking routes to their bus stops. Pierce Transit reports that more than 220 transit riders board buses within 1 mile of the 1-mile study area per day. In particular, the SR 7 corridor has a high proportion of older road users (age 65 and above) who are dependent on good pedestrian walkways (Kopf and Hallenbeck 2005).

To address the safety issues in this corridor, a federally funded pedestrian safety project was initiated. The highway improvement project focused on safety conditions for pedestrians and motorists between South 176th Street and South 189th Street along SR 7 in Spanaway. This portion of the project evaluated the pedestrian improvements on SR 7 near S. 180th Street. The improvements included concentrating pedestrians at a single crossing point and relocating bus stops closer to where pedestrians attempt to cross the main street. Also, because SR 7 is a heavily traveled street, a median was built with a pedestrian refuge island to allow pedestrians to cross the traffic one direction at a time. (Note: The *before* and first *after* phase of improvements at this location were originally studied by Kopf and Hallenbeck in 2005. Portions of their study (text, data, figures) were used in the preparation of this report, with their permission, and are cited where appropriate.)

Site Description

South 180th Street intersects with SR 7 from the east. In the *before* phase of this project, there were marked crosswalks to the north and south of S. 180th Street. These were removed as part of the first phase of pedestrian improvements. They were then consolidated into one crosswalk just south of S. 180th Street, and the markings were reinstalled during the second phase of improvements. The roadway consists of two general-purpose lanes in each direction, with a center two-way left turn lane. The posted speed limit for the corridor is 40 mph. The fence for the Fort Lewis Military Reservation borders the west side of the roadway. The east side contains numerous driveways to commercial shops. In the *before* phase and during the first phase of improvements, there were no sidewalks, only shoulders. With the second phase of improvements, shoulders, sidewalks, curbs, gutters, and overhead lights were added. Crosswalk markings were also reinstalled. The average daily traffic volume for the area is approximately 40,000, as recorded in the *WSDOT 2006 Annual Traffic Report*.

The *before* analysis focused on the marked crosswalks to the north and south of S. 180th Street. Figure 2.1 displays the camera view looking north. The crosswalk to the north of S. 180th Street is approximately 400 feet from the camera. The driveway near the crosswalk enters and exits a Kmart parking lot. Transit stops are located on both sides of the crosswalk. The nearest signalized intersection is one quarter mile north at S. 176th Street.

Figure 2.2 shows the camera view looking south. The crosswalk to the south of S. 180th Street is approximately 660 feet from the camera. The crosswalk is at the intersection of SR 7 and S. 182nd Street. There are bus stops on both sides of the crosswalk.

Figure 2.1. Observation boundaries north of S. 180th Street—*before* phase—Spanaway (Kopf and Hallenbeck 2005)

Figure 2.2. Observation boundaries south of S. 180th Street—*before* phase—Spanaway (Kopf and Hallenbeck 2005)

During the *after* analysis, the camera was placed to the south of S. 180th Street (this time on the west side of the street), facing north. Figure 2.3 displays the observation boundaries for the first phase of the *after* data collection.

Figure 2.3. Observation boundaries for *after—phase I* data collection—Spanaway (Kopf and Hallenbeck 7)

Figure 2.4 shows the observation boundaries for the second phase of the *after* data collection.

Figure 2.4. Observation boundaries for *after—phase II* data collection—Spanaway

Because not all crossings are made at the designated crossing area, data were taken for as much of the camera view as was feasible. The range of observations collected for all stages of the project at this site was about one tenth of a mile.

II. STATE ROUTE 99—SHORELINE, WASHINGTON

Site History

State Route 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 (Giles 2008c). Of these collisions, 38 percent (16 collisions) were fatal or disabling accidents. To address the safety issues in this corridor, improvements were planned and constructed. Bus lanes, sidewalks, curbs, gutters, and a traffic signal were added, and lighting and streetscape improvements were made.

Site Description

North 152nd Street intersects with Aurora Avenue North (SR 99) from the east. It consists of one lane in each direction. At SR 99, the westbound lane is marked for right turn movements only. During the *before* evaluation, SR 99 consisted of two general purpose lanes in each direction, a two-way left turn lane running the entire length of the study area, and shoulders on both sides of the roadway, ranging from 4 to 10 feet wide. Both sides of SR 99 had numerous, closely spaced driveways leading to commercial properties. The sidewalks in the study area were discontinuous and concentrated only around areas of newer development, with large gaps in between. There was little illumination in the project area. After construction, there are now two general purpose lanes and one high occupancy vehicle (HOV)/bus lane in each direction, as well as a landscaped median (with occasional left- and U-turn opportunities) where the center two-way left turn lane once existed. Sidewalks, curbs, and gutters were added throughout the project area, as was overhead illumination. A traffic signal was added at North 152nd Street, and many other aesthetic elements, such as colored concrete crosswalks (an example of which is shown in Figure 2.5 below), benches, and street trees, were added. Transit service is provided by Metro Transit, route 358. The posted speed limit is 40 mph. The average daily traffic volume for this area is approximately 39,000 vehicles, as recorded in the *WSDOT 2004 Annual Traffic Report*.

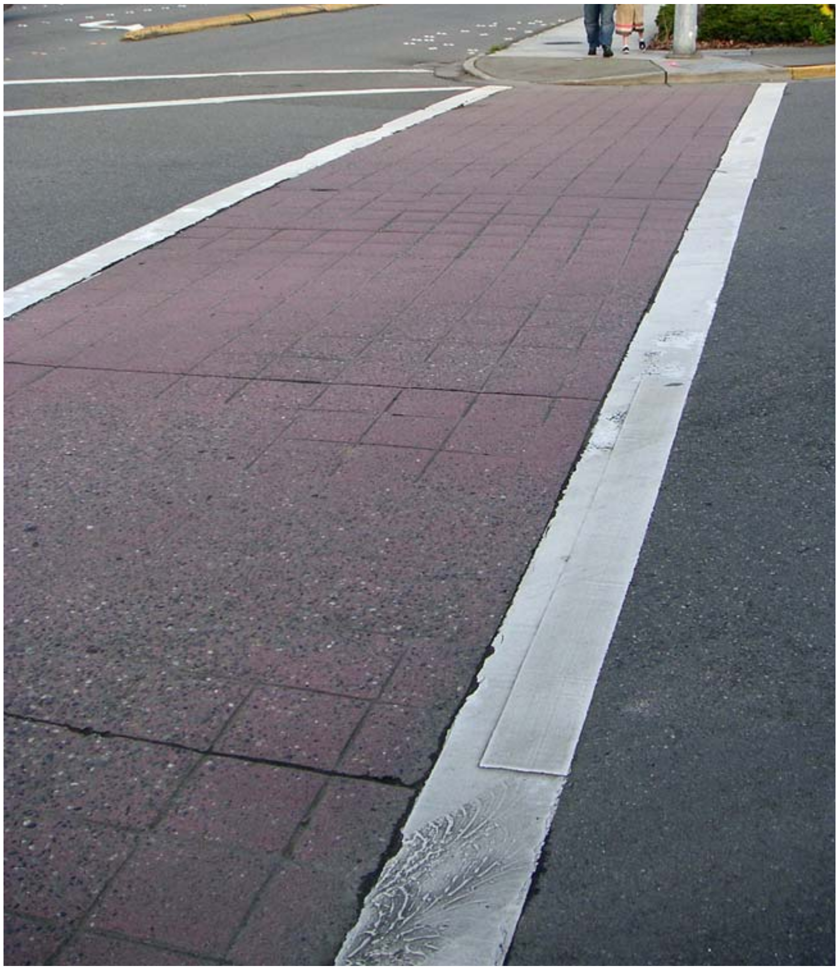

Figure 2.5. Example of a crosswalk made with colored concrete

The site analysis focused on the unmarked crosswalks at North 152nd Street. Figure 2.6 shows the camera view looking north along SR 99. The camera is approximately 320 feet south of North 152nd Street. Bus stops are located on the north corner of North 152nd Street in the southbound direction of SR 99 and 100 feet south of the intersection in the northbound direction. Signalized intersections are located one sixth of a mile to the north at North 155th Street and one third of a mile to the south at North 145th Street. Commercial properties in the area consist of several restaurants and fast food establishments (Goldie’s, Shari’s, McDonalds), two strip mall-type developments housing many small shops (Parkwood Plaza and Westover Plaza), and some detached retail facilities (The Car Connection, Maddy's Automotive, Multitronics). Residential neighborhoods lie one to two blocks to the east and west of SR 99.

Figure 2.6. Observation boundaries, SR 99 south of N 152nd Street—*before* improvements—Shoreline

Again, data were collected for the crossings that could be accurately seen on the video. The range of observations for this site was roughly one quarter of a mile.

Figure 2.7 is an aerial image of the Shoreline site and the surrounding area.

Figure 2.7. Aerial view of project and surrounding area, SR 99 and N 155th Street to N 152nd Street—Shoreline (Google Maps)

Because of construction and project schedules, no *after* study was performed at this site. Figure 2.8 shows the site as it existed as of the writing of this report. Additional research at this site would be beneficial to determine the effects of the improvements on vehicle and pedestrian behavior, especially the landscaped median and the traffic signal that was added at North 152nd Street.

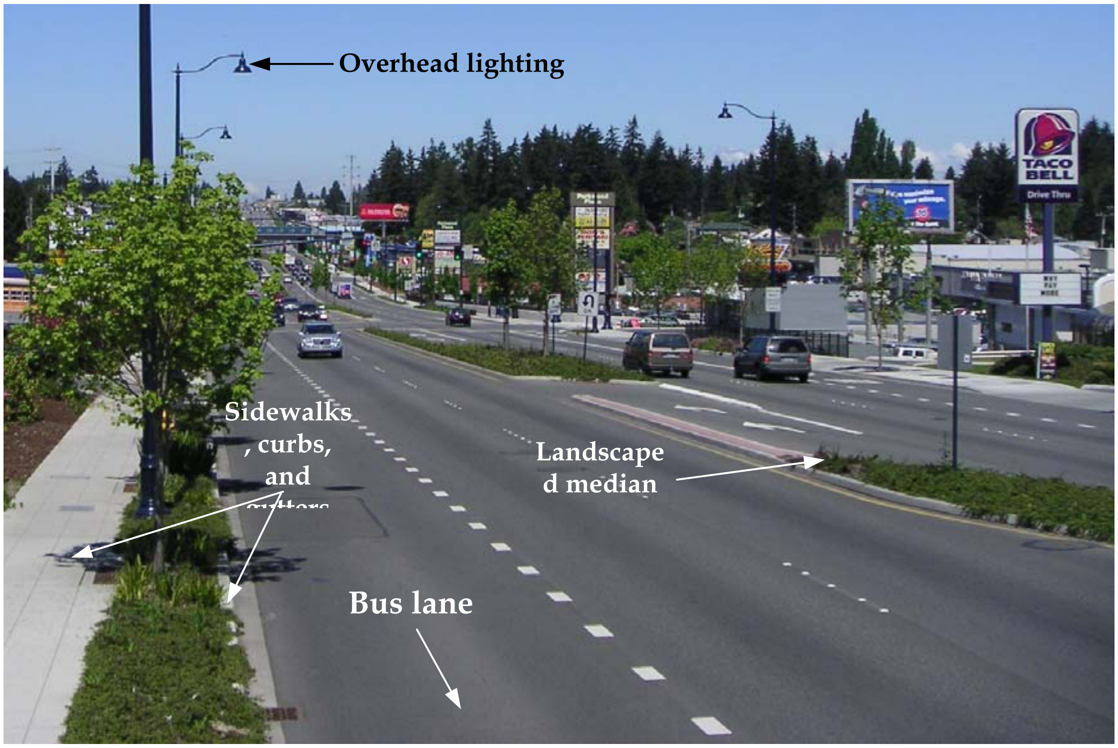

Figure 2.8. View of the improvements made to the project and surrounding area, SR 99 and N 152nd Street—Shoreline

III. STATE ROUTE 99—KENT, WASHINGTON

Site History

State Route 99 through the City of Kent (Pacific Highway South) also has a history of pedestrian collisions. During the period of 2000 to 2005, 21 pedestrian-auto collisions occurred (Giles 2008a). Of these collisions, 95 percent (20 collisions) resulted in pedestrian injuries and 19 percent (four collisions) were fatal or disabling accidents. To address the concerns in this corridor, an improvement project was initiated on Pacific Highway South within the City of Kent. The project adopted a set of safety solutions developed by WSDOT and several local agencies. These solutions were selected to fit within the City of Kent's existing corridor improvement plan and citizen involvement program and included roadway enhancements to improve safety for all users: landscaped medians, sidewalks, curbs and gutters, improved overhead lighting, and a designated

HOV/bus lane. The *before* phase of the study evaluated the original conditions of the corridor, and the *after* phase studied the pedestrian and motorist behavior associated with the roadway enhancements detailed above.

Site Description

South 240th Street intersects with Pacific Highway South (SR 99) from both the east and west. It consists of one lane in each direction. At SR 99, a left turn only lane begins in both directions. In the westbound direction on the west side of SR 99, a right turn only lane begins for access to the parking lot of Highline Community College. Before the improvements, SR 99 consisted of two general purpose lanes in each direction, a two-way left turn lane that ran the entire length of the study area (which included a traffic curb on the east side of the turn lane that extended from South 240th Street to the north 250 feet), right turn only lanes in both directions at South 240th Street, and shoulders on both sides of the roadway, ranging from 2 to 10 feet wide (*before* conditions). Both sides of SR 99 had numerous, closely spaced driveways leading to commercial properties. During the *before* study, the only sidewalks in the study area were located at the intersection of South 240th Street and SR 99 and extended for a very limited distance on each leg of the intersection (15 to 100 feet). Also, there was little overhead illumination in the project area other than that provided at the intersection with South 240th Street. In the *after* study, one HOV/bus lane was added in each direction, and the two-way center left turn lane was converted to a landscaped median. Sidewalks, curbs, and gutters were added along with overhead lighting. The left turn pocket at South 240th was extended to accommodate more vehicles. Shoulders were eliminated. The posted speed limit is 45 mph. Metro Transit, routes 166, 174, 175, and 191, provide transit service to approximately 3,400 riders in the corridor per weekday (Bez 2006). The average daily traffic volume for this area is approximately 26,000 vehicles, as recorded in the *WSDOT 2006 Annual Traffic Report*.

The *before-after* analysis focused on the midblock crossings made between South 240th Street and the camera location. Figure 2.9 shows the camera view looking south along SR 99. The camera is approximately 450 feet north of South 240th Street. A bus stop is located 275 feet north of the intersection with South 240th Street in the northbound direction and 325 feet south of the intersection in the southbound direction. Signalized intersections are located less than one tenth of a mile to the south at South 240th Street and four tenths of a mile to the north at South Kent-Des Moines Road (SR 516). Commercial properties in the area consist of restaurants (JJ's Bar and Grill, Sze Wok Chinese Restaurant), gas stations/mini-markets, a three-story office building, and detached retail facilities (Bucky's Brake and Muffler, Midway Tropical Fish and Pets). A mobile home park is located on the east side of SR 99, next to Bucky's Brake and Muffler; single family residential neighborhoods lie one to two blocks to the west of SR 99; and several multifamily apartment buildings lie one block to the east of SR 99.

Figure 2.9. Observation boundaries, SR 99 north of S 240th Street—*before* conditions—Kent

The camera view used in the *after* study is shown in Figure 2.10.

Figure 2.10. Observation boundaries for the *after* data collection—Kent

Crossing data were collected in a range from the foreground of these camera views to the signalized intersection at South 240th Street, a distance of about one tenth of a mile.

Figure 2.11 is an aerial image of the Kent site and the surrounding area.

Figure 2.11. Aerial view of project and surrounding area, SR 99 and S. 240th Street—Kent (Google Maps)

VI. STATE ROUTE 2—AIRWAY HEIGHTS, WASHINGTON

Site History

Airway Heights is a city in Eastern Washington located 6 miles west of Spokane. State Route 2 traverses the city center. Airway Heights is approximately 2 miles long. Its business district is located primarily to the south of SR 2, and its residential areas are primarily to the north. Pedestrians trying to cross State Route 2 have to cross four lanes of traffic and a center turn lane. High traffic volumes during some times of the day did not leave sufficient gaps for a person to cross without stopping in the center turn lane.

From 1999 to 2006, there had been six collisions between vehicles and pedestrians or bicyclists, one third of which were fatal (two collisions) (Giles 2008b). A crosswalk safety enhancement project was implemented within the city to address these safety concerns. In-pavement warning lights were installed at three locations along the corridor. Median refuge islands were built in the center turn lane to allow for two-phase crossing. Signage (some with pedestrian-actuated warning beacons) was also added to the roadway.

This portion of the study evaluated the pedestrian environment on SR 2 between South King Street and South Lundstrom Street, the location of one of these three refuge islands. The *before* phase evaluated the pedestrian and motorist behaviors associated with the in-pavement warning lights and the median refuge island in the center lane. The *after* phase studied pedestrian and motorist behaviors after the installation of the additional signage and striping, but with fewer functioning in-pavement warning lights.

Site Description

The study site was located on SR 2, a five-lane facility with two general purpose lanes in each direction, a center two-way left turn lane, and 4-foot wide shoulders on both sides of the roadway. There are sidewalks, with 6-inch high curbs on both sides of the sidewalk (shown in Figure 2.12). The sidewalks are on both the north and south sides of the street, with occasional driveways on the north side to commercial properties. While there are no driveways on the south side of SR 2 in this area, West 14th Street runs parallel to SR 2, approximately 50 feet to the south and provides access to the commercial properties located on the south side of the highway. Single-family housing and apartment buildings are located on the north side of SR 2, less than a block from the highway. Light poles are installed approximately every 240 feet on both sides of the roadway. The posted speed limit for the corridor is 35 mph. The average daily traffic volume for the corridor is approximately 21,000, as recorded in the *WSDOT 2006 Annual Traffic Report*.

Figure 2.12. SR 2 sidewalk and parking detail (looking west)—Airway Heights

The analysis focused on the in-pavement warning lights, stop bars, and the median installed on SR 2 between South King Street and South Lundstrom Street. There are no signalized crosswalks at these intersections. The nearest signalized intersection with north-south crosswalks is located 720 feet to the east at the intersection of SR 2 and South Lawson Street.

Spokane Transit’s Route 25 serves the area every 30 minutes on weekdays and every 60 minutes on weekends. The nearest transit stop on the north side of the roadway is 465 feet to the east of the study area. The nearest transit stop on the south side of the roadway is approximately 285 feet to the east of the study area.

Figure 2.13 shows the camera view that was used in the *before* portion of the study.

Figure 2.14 shows the camera view used in the *after* study.

Figure 2.13 Observation boundaries, SR 2 west of S. King Street—*before* configuration—Airway Heights

Figure 2.14. Observation boundaries for the *after* data collection—Airway Heights

At this site, the data collection was centered on the marked crosswalk, but other crossings made near the intersection at Lundstrom Street were also included. The total observed distance was roughly one tenth of a mile. At this site, the only differences between the *before* and *after* pedestrian treatments were the stop bars that were added in advance of the crosswalks, the slightly different signage and sign locations that are shown above, and the reduction in number of functioning in-pavement lights.

Figure 2.15 is an aerial image of the Airway Heights site and the surrounding area.

Figure 2.15. Aerial view of project and surrounding area, SR 2 and pedestrian treatment between S. Lundstrom Street and S. King Street—Airway Heights (Google Maps)

V. STATE ROUTE 2—SPOKANE, WASHINGTON—THREE SITES

Site History

In Eastern Washington, North Division Street runs directly through the City of Spokane, dividing the city into its east and west halves. The corridor has had many pedestrian safety issues. During the period of 2000 to 2006, 33 pedestrian-auto collisions occurred (Bernard 2007a). Of these collisions, 88 percent (29 collisions) resulted in pedestrian injuries and 12 percent (four collisions) were fatal or disabling accidents. To determine what the specific pedestrian safety issues were within the North Division Street corridor and to continue to address them, three intersections were chosen for study: Lacrosse Avenue, Rowan Avenue, and Wellesley Avenue. An aerial view, indicating the relative locations of the three Spokane study sites, is shown in Figure 2.16.

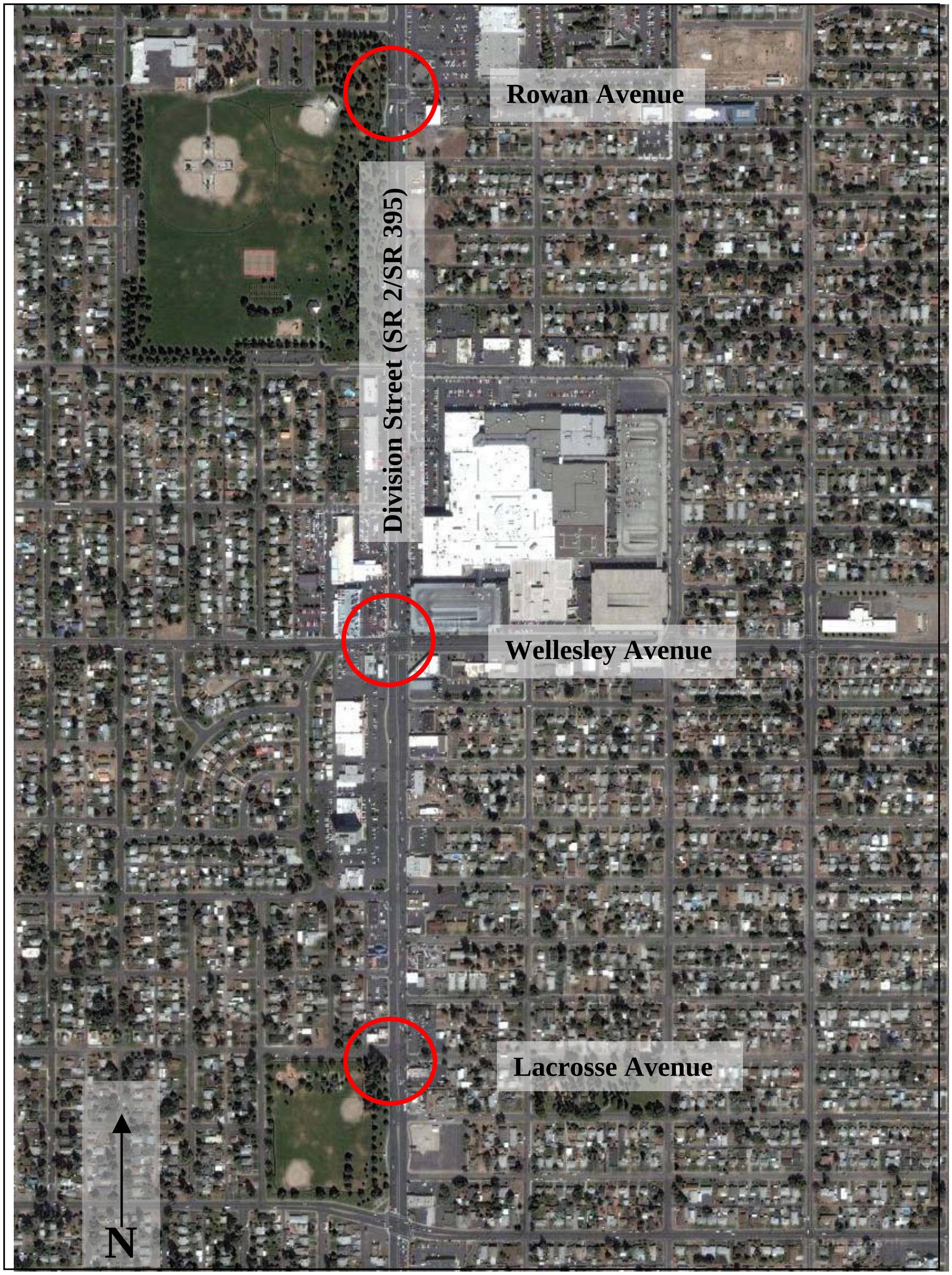

Figure 2.16. Aerial view of the three study sites on Division Avenue (SR 2/SR 395) in Spokane, Washington (Google Maps)

Site Descriptions

North Division Street (SR 2/SR 395) acts as a major urban arterial through Spokane. It carries approximately 42,000 vehicles per day, as recorded in the *WSDOT 2006 Annual Traffic Report*. It consists of three 11-foot lanes in each direction, a 12-foot center turn lane, and a 2-foot wide, 6-inch tall concrete divider that separates north- and southbound left turning traffic. The speed limit is 30 mph. There are frequent side streets and alleys, as well as driveways to commercial properties and residences. Overhead illumination is provided about every 250 feet along both sides of the roadway. Six-foot wide sidewalks are located on both sides of the street. Transit service is provided by Spokane Transit's Route 25. The average weekday transit ridership for the study corridor is approximately 1,000 (Stewart 2007). Below is a brief description of each of the three study locations.

Lacrosse Avenue and North Division Street (SR 2/SR 395)

From just 2003 to 2006 there were two pedestrian-vehicle collisions at this intersection (Bernard 2007a). Both collisions resulted in pedestrian injuries. The Lacrosse Avenue site is an unsignalized, four-way intersection (Lacrosse intersects Division with offset approaches), with unmarked crosswalks leading across Division Street (note: the crosswalk markings were barely visible at this location, making it unclear whether they were allowed to wear to this condition on purpose or simply had not been maintained). The nearest signalized intersections are located four tenths of a mile to the north at Wellesley Avenue and about one tenth of a mile to the south at West Garland/East Empire Avenue. Traffic on Lacrosse is controlled by stop signs, and there are no turning restrictions. Lacrosse is a local street, with no centerline markings. Parking is permitted on both sides of the street. Single-family residential neighborhoods lie about one half of a block to the east and west of SR 2. B.A. Clark Park, which covers about four city blocks in area, lies to the west of SR 2 and south of Lacrosse Avenue. To the north of the park are commercial properties, including a gun and pawn shop, a glass art studio, Casa de Oro Mexican restaurant, a jewelry store, and an International House of Pancakes restaurant. The east side of Division Street is home to University Appliance, a Tuff Shed outlet, a KFC restaurant, Peking North Chinese restaurant, Muffler Mart, and Don's Quality Auto.

The site analysis focused on the crossings made between East Garland Avenue (two blocks south of Lacrosse) and the camera location. Figure 2.17 shows the camera view looking south along SR 2. The camera is approximately 300 feet north of Lacrosse Avenue. There is a near side (before the bus passes through the intersection) bus stop located at Lacrosse in the northbound direction and bus pullout stops 450 feet south of the intersection in both the northbound and southbound directions. The total usable distance observed by the camera was roughly one tenth of a mile.

Figure 2.17. Observation boundaries, SR 2 north of Lacrosse Avenue—Spokane

Figure 2.18 is an aerial view of the Lacrosse Avenue study site and the surrounding area.

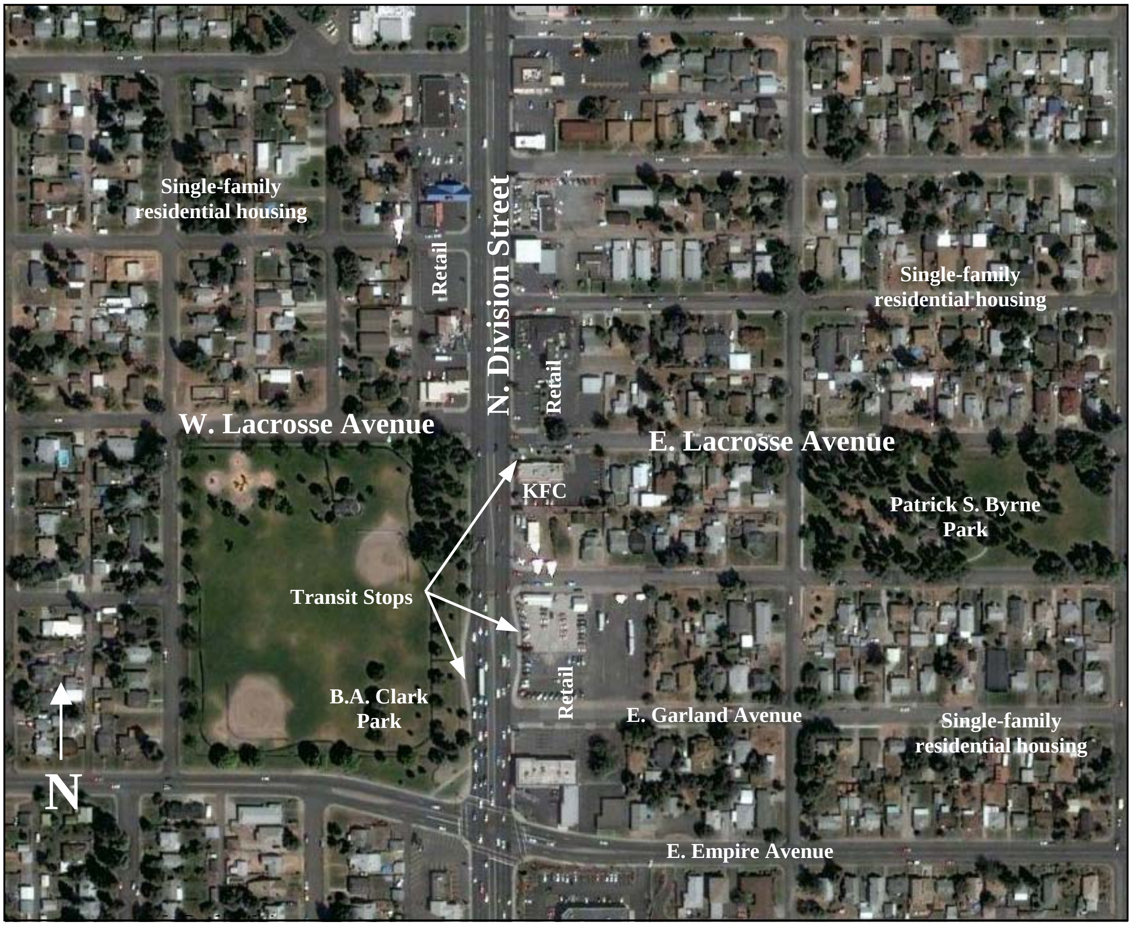

Figure 2.18. Aerial view of the Lacrosse Avenue and Division Street site—Spokane (Google Maps)

There were no improvements planned at this site; therefore, no *after* study was performed as part of this portion of the project.

East Rowan Avenue and North Division Street (SR 2/SR 395)

At the Rowan Street site, during the period of 1999 to 2004, three pedestrian-auto collisions occurred, with two of those resulting in disabling collisions for the pedestrians involved (Bernard 2007a). The intersection of East Rowan Avenue and North Division Street is a signalized, T-intersection, with Rowan Avenue entering from the east. There are actuated pedestrian signals at each of the crosswalks. Rowan Avenue consists of one 17-foot wide lane in each direction and acts as a collector for the residential neighborhoods located to the east of SR 2. The next signalized intersections are located one quarter of a mile to the north at Central Avenue and one quarter of a mile to the south at Queen Avenue. Franklin Park, which covers about ten city blocks in area, lies across from East Rowan Avenue and largely to the south. To the north of the park along Division Street are single family residences, an apartment complex, and one block of commercial properties, including a denture clinic, insurance agent, hair stylist, bridal shop, and a hearing aid store. Franklin Park shopping center lies to the north on the east side of Division and contains Old Country Buffet, Ross Dress for Less, Rite Aid, Bed, Bath and Beyond, Outback Steakhouse, Guitar Center, Burlington Coat Factory, and Shari's Restaurant. Holy Family Hospital is located directly behind the shopping center, to the east. To the south of Rowan Avenue are a professional center (doctors, dentists, a CPA), several vacant lots, and a Bruchi's Cheesesteak and Subs restaurant.

The site analysis focused on the crossings made between West Nebraska Avenue to the north and the camera location. Figure 2.19 shows the camera view looking north along SR 2. The camera is approximately 250 feet south of West Rowan Avenue. There is a near side (before the bus passes through the intersection) bus stop located at the intersection with Rowan in the northbound direction and a bus pullout stop 100 feet south of the intersection in the southbound direction.

Figure 2.19. Observation boundaries, SR 2 south of East Rowan Avenue—Spokane

Data collection at this site covered about one tenth of a mile.

Figure 2.20 is an aerial view of the Rowan Avenue study site and the surrounding area.

As there were no improvements planned for this location, no *after* study was done.

Figure 2.20. Aerial view of the Rowan Avenue and Division Street site—Spokane (Google Maps)

Wellesley Avenue and North Division Street (SR 2 / SR 395)

The final site studied on SR 2/SR 395 in Spokane (North Division Street) was Wellesley Avenue. It was the most complex intersection of all the study sites and also had a high number of pedestrian-vehicle accidents. During the period of 1999 to 2006, 10 accidents occurred at the intersection—one of which was fatal—and all caused injury to the pedestrians involved (Bernard 2007a). The intersection of Wellesley Avenue and

North Division Street is a signalized, four-way intersection, with Wellesley Avenue entering from the east and west. There are actuated pedestrian signals at each of the marked crosswalks. Wellesley Avenue consists of two 12-foot wide through-lanes and one 12-foot wide left turn lane in each direction. In the westbound direction, there is also a 12-foot wide right turn only lane. Wellesley acts as a collector for the residential neighborhoods to the east and west of SR 2. The next signalized intersections are located one quarter of a mile to the north at Queen Avenue and one half of a mile to the south at West Garland Avenue/East Empire Avenue. Commercial properties in the area consist of an Office Depot, a gas station, Ford and Suzuki auto dealerships, a MoneyTree pay day loan center, a Fedex/Kinkos, a Bank of America, and the Northtown Mall. Single-family residential neighborhoods lie one block to the west and one half block to the east of North Division Street.

The site analysis focused on the crossings made between the northbound bus stop 320 feet to the north of Wellesley Avenue and the camera location. Figure 2.21 shows the camera view looking north along SR 2. The camera is approximately 380 feet south of Wellesley, located at a southbound transit stop.

The total observed distance at this site was one tenth of a mile.

Figure 2.22 is an aerial view of the Wellesley Avenue study site and the surrounding area.

Again, no improvements were planned at this site, so no *after* study was performed.

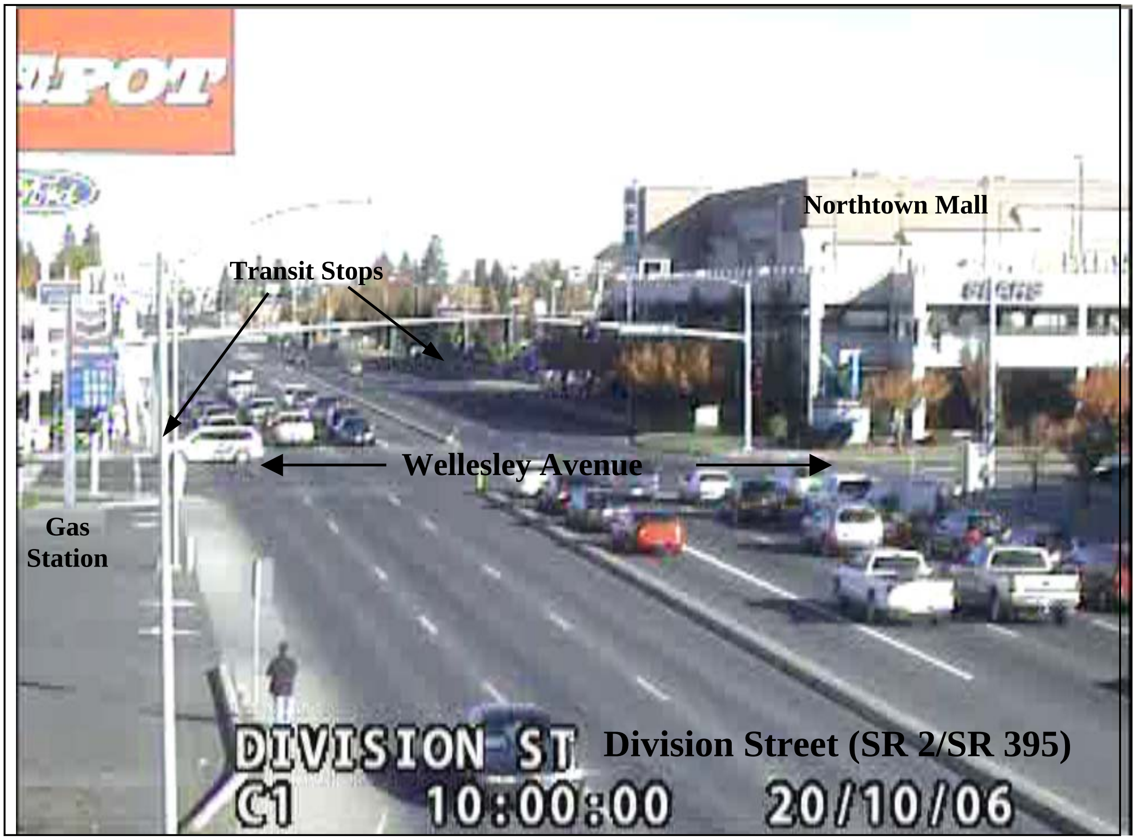

Figure 2.21. Observation boundaries, SR 2 south of Wellesley Avenue—Spokane

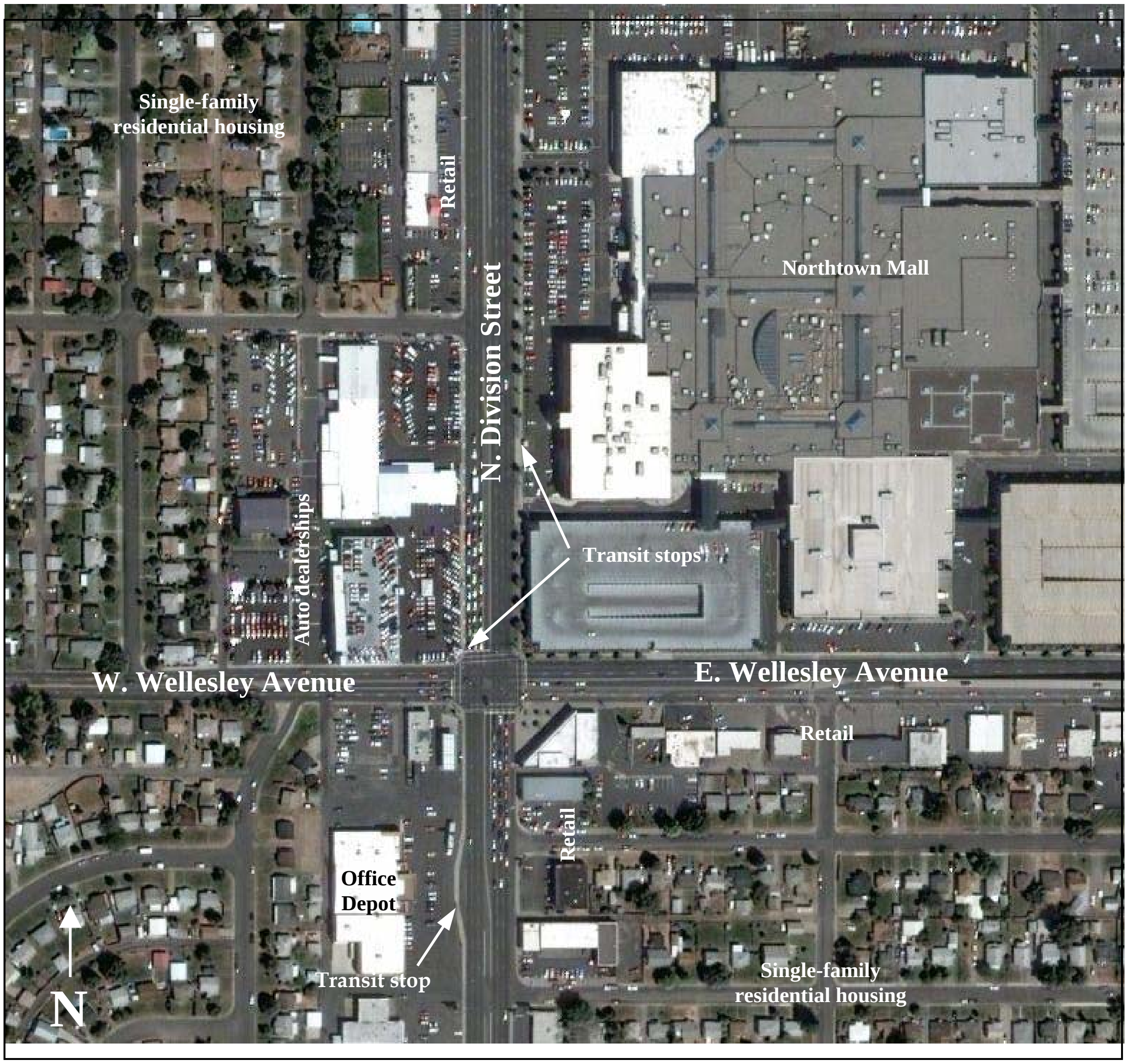

Figure 2.22. Aerial view of the Wellesley Avenue and Division Street site—Spokane (Google Maps)

CHAPTER 3: SAFETY TREATMENTS EVALUATED

Of the seven sites selected for this project, three were studied both before and after improvements were made: Spanaway, Kent, and Airway Heights. Different safety elements were used at each site to get a better understanding of their effects on pedestrian safety, as well as pedestrian and motorist behavior. This section details the treatments that were used at each site, the reasoning behind some of the selections, and the anticipated impact of the elements.

I. SR 7—SPANAWAY

The Spanaway area has a growing population of "older" drivers, pedestrians, and transit users that is expected to continue to increase. Improvements were needed to help them cross the highway safely. Most crossing pedestrians observed at this study location showed extreme caution, even when they were crossing in a legal, marked crosswalk. Pedestrians tended to wait a long time for a gap in the traffic to cross the street. Many had to stop in the center lane and cross one direction of the roadway at a time.

In response to this behavior, WSDOT traffic engineers built a raised median channelization island for the left hand turn from SR 7 onto S. 180th Street. Figure 3.1 shows the median.

A benefit of using a raised median channelization island is the inclusion of a refuge for pedestrians. This median refuge can particularly aid older pedestrians who have walk more slowly and thus have trouble crossing the road in one movement. Pedestrians can cross one direction of the roadway at a time and wait in the refuge for a break in traffic in the other direction. In addition, the channelization for left turns can make drivers feel safer because they do not have to worry about traffic in the center lane.

Figure 3.1. Pedestrian refuge islands at S. 180th Street and SR 7—Spanaway (Kopf and Hallenbeck 2005)

The safety treatment at S. 180th Street also included new transit stop locations. Before the treatment, bus stops were located on each side of the marked crosswalks to the north and south of S. 180th Street. Figures 2.1 and 2.2 displayed the original transit stop locations. With the installation of the new median, the four transit stops were consolidated to two stops, one on either side of the median. Figure 3.2 shows the new locations of the bus stops in relationship to the median. The path across the roadway utilizes the refuge space in the median.

Figure 3.2. Transit stop locations at S. 180th Street and SR 7—Spanaway

Signs warning motorists of crossing pedestrians were made larger and moved from the shoulder of the roadway to the median refuge island during the first phase of improvements. The intent was to let motorists know farther in advance to expect pedestrians at this location and also to give notice about the refuge island so that vehicles would be less likely to hit it.

During the second phase of improvements, sidewalks, curbs, gutters, and overhead lights were installed. New crosswalk markings were placed in line with the crossing path provided by the refuge island (shown in Figure 3.3). Transit stops were enhanced with shelters to improve the comfort of the riders while waiting for the bus to arrive.

Figure 3.3. Front view of median with crosswalk markings—Spanaway

II. SR 99—KENT

The Kent study area is unique in that it borders a community college. Unfortunately, it is also the site of many pedestrian-vehicle collisions. The majority of pedestrians crossing in this area are community college students using transit—and their numbers are expected to increase. Because the pedestrian population is younger, they may be more likely to engage in risky behavior when crossing the street. The improvements in the area were done as a part of a larger SR 99 widening to accommodate bus/HOV lanes and improve the streetscape from Federal Way to SeaTac.

Many of the improvements could also benefit pedestrians. Overhead lighting was added, along with sidewalks, curbs, and gutters. Landscaped medians were installed; driveways to commercial establishments were combined and better defined. The overhead lighting should make it easier for vehicles to see pedestrians crossing in the evening hours, whether or not they choose to cross at the traffic signal. Sidewalks, curbs, and gutters serve to separate pedestrians and vehicles, which should making walking in the corridor safer. The landscaped medians, while improving the overall aesthetics of the area, may also serve to prevent some of the jaywalking that has been occurring by providing a barrier between the pedestrian and the other side of the street. It will also have an effect similar effect to that of the better defined driveways—it will limit vehicle access points and thus the number of conflict areas for which pedestrians must be vigilant while walking in the corridor.

III. SR 2—AIRWAY HEIGHTS

Airway Heights is a city divided: the majority of the housing is on the north side of SR 2 and the services and shops are predominantly located to the south of the highway. This creates a problem for pedestrians and was the focus of the improvements made to this corridor. The analysis examined the effects of in-pavement warning lights, stop bars, and medians installed on SR 2. These mid-block crossing treatments were installed in three locations along the corridor. This analysis focused on the effects of the treatment between South Lundstrom Street and South King Street. The b*efore* data analyzed these basic treatments: marked crosswalk with raised medians, in-pavement flashers, and sign-mounted warning beacons. In the *after* data period, the modified crossing was analyzed, which consisted of the original treatment with modified signage, stop bars, and partial in-pavement flashers (some had stopped working; of the original eight pavement flashers installed in each direction, only three in each direction were still working at the time of the *after* study).

A crosswalk with an in-pavement warning light system consists of amber lights embedded in the pavement along both sides of the marked crosswalk. When a pedestrian activates the lights by pressing a button, the lights flash at a constant rate for a set period, alerting the drivers that a pedestrian is present in the crossing area. Drivers should yield when the lights are flashing to allow the pedestrian to cross.

Figure 3.4 is an example of an in-pavement warning light.

Figure 3.4. In-pavement warning light (Trepanier)

This location also used additional warning lights and signage. Pedestrian crossing warning signs, containing two amber lights per sign and facing on-coming vehicles, were located on either side of SR 2, next to the sidewalk. These lights flashed at the same time and rate as the in-pavement flashers. Two more pedestrian crossing warning signs (one for each direction and both without lights) were located on the raised medians for the *before* condition and in the center left turn lane, upstream of the raised median, for the *after* condition.

Figure 3.5 and Figure 3.6 show the camera view of a pedestrian crossing SR 2 at night with the flashers. The video quality is somewhat better in Figure 3.6, which depicts the *after* condition, but one can see the approximate degree to which the in-pavement flashers are functioning in each scenario.

Figure 3.5. Warning lights lit for pedestrian crossing—*before* condition—Airway Heights

Figure 3.6. Warning lights lit for pedestrian crossing—*after* condition—Airway Heights

The raised medians consisted of two curb-height islands in the the center left turn lane, with a space or refuge between them for pedestrians to walk through or stand in while waiting to cross (see Figure 3.7 and Figure 3.8). As discussed in the Spanaway section, the median refuge can particularly aid older pedestrians who walk slower and thus have trouble crossing the road in one movement. Pedestrians can cross one direction of the roadway at a time and wait in the refuge for a break in traffic in the other direction. Also, because the refuge area is at the same height as the roadway, no additional hazard is imposed by having pedestrians step up onto a ramp or curb to cross. This can also benefit older or disabled pedestrians, who may have trouble with these movements, and will also make it easier for anyone traveling on wheels, whether wheelchairs, strollers, bicycles, or skates. The fact that the refuge area is at an angle to the roadway not only increases the space available for waiting but also ensures that those crossing are turned slightly toward oncoming vehicles, thereby potentially increasing eye contact between pedestrians and vehicles and their awareness of one another.

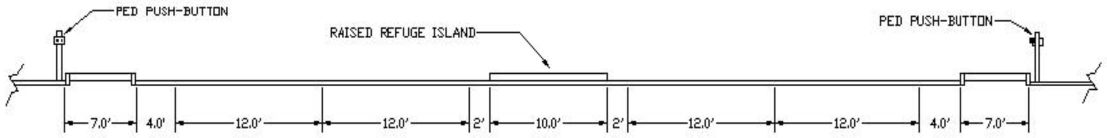

Figure 3.7. Typical roadway section near crosswalk—Airway Heights (Tripp 2003)

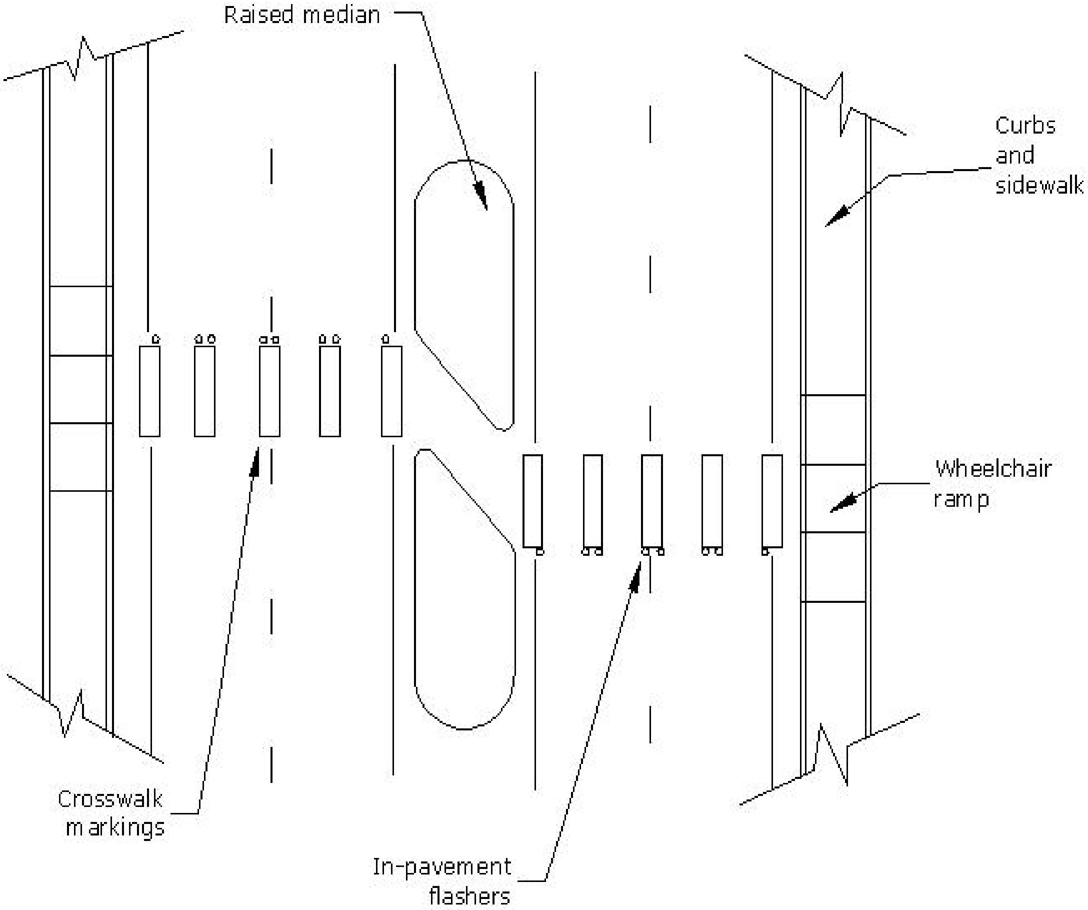

Figure 3.8. Detail of crosswalk/raised median—*before* condition (plan view) —Airway Heights (WSDOT 2007)

Stop bars were added for the *after* condition. They were located 20 feet upstream from the leading edge of the crosswalk in each direction. When this change was made, the signs on the side of the street and in the median were changed slightly. The diagonal down sloping arrow signs that pointed to the crosswalk were changed to “Stop Here for Pedestrians” signs, with arrows pointing to the stop bar. The addition of the stop bars also required the pedestrian crossing signs to be moved from the raised median to the center left turn lane. The goal of the addition of the stop bar was to increase driver awareness and pedestrian safety, as well as to move stopped vehicles farther from the crosswalk, thus increasing sight distance. The changes described can be seen in Figure 3.9 and Figure 3.10.

Figure 3.9. Median sign placement—*before* condition—Airway Heights

Figure 3.10. Median sign and stop bar placement—*after* condition—Airway Heights

Signs located at the pedestrian actuation buttons were present during both the *before* and *after* studies. An example of these signs is shown in Figure 3.11.

Figure 3.11. Signs present at the pedestrian actuation button—Airway Heights

The signs were intended to make pedestrians more vigilant while crossing and pervent them from simply assumly that vehicles would see the flashing warning lights and comply.

CHAPTER 4: FINDINGS

The intent of this assessment was to examine each of the study sites as they relate to pedestrian safety and pedestrian and motorist behavior. Some of the sites received engineering improvements that were evaluated; others were analyzed in their current conditions. This section presents the findings specific to each study site, as well as findings that held true for all of the sites. The detailed analyses upon which the findings in this chapter are based are described in Appendix B.

This study was performed at just seven locations in Washington State. There is no evidence to show that these conclusions would be valid in other regions or at other sites, but it is hoped that this research may spawn future projects that will build on the work done in this study for the good of all those who travel—whether by foot or other means.

I. STATE ROUTE 7—SPANAWAY, WASHINGTON

At this site, phases of pedestrian safety improvements were analyzed. The improvements included concentrating pedestrians at a single crossing point with a pedestrian refuge island and relocating bus stops closer to where pedestrians would attempt to cross the street.

Table 4.1 summarizes the data, including any changes that were seen during the different phases of improvements.

Table 4.1. Summary of data and observed changes—Spanaway

Comments pertain to:	Changes / comments
Use of the crosswalks and median refuge	Use rate is 62% or higher. Crosswalk / median use down 20% in after - phase I. Rebounded to previous levels in after - phase II.
Percentage of crossings when vehicles yielded for pedestrians (excludes crossings made with no vehicles present)	Southbound - yield rate is 9-37%. Down 28% in after - phase I. Rebounded to previous levels in after - phase II.
	Northbound - yield rate is 37-72%. Down 35% in after - phase I. Rebounded 5% in after-phase II, but not all the way to previous levels.
	Northbound vehicles showing higher yielding rates than southbound vehicles by 10-30%.
Average number of vehicles that did not yield per crossing event (excluding events with zero vehicles involved)	Southbound - up in both the after - phase I and after - phase II stages. (Average number not yielding is 5-12 vehicles.)
	Northbound - up in after - phase I. Back to previous level in after - phase II. (Average number not yielding is 5-11 vehicles.)
Percentage of vehicles yielding based on crossing paths (includes only those events where vehicles were present)	Vehicles were more likely to yield to pedestrians in crosswalk or median for both directions, all phases. (Typically 20-30% more likely. In after - phase I, only 10% or less more likely.)
Percentage of vehicles yielding based on wait location (includes only those events where vehicles were present)	Vehicles were 20-40% more likely to yield to pedestrians in center lane than on sidewalk - all phases.
Pedestrian wait time before crossing - Spanaway	Comparable for all phases. (9, 10, and 11 seconds, respectively.)

Table 4.1 continued

Pedestrian wait time in the center lane /median	Increased in after - phase I. Back down in after - phase II. (2, 15, and 6 seconds, respectively.)
Shielding conflicts	Conflicts were down in after - phase I and back up sharply in after - phase II. Possible novelty effects and differing number of crossings between phases. (12, 1, and 41 conflicts, respectively.)
Pedestrian and vehicle conflicts — Spanaway	Center lane waits and pedestrian pressured to run increased in both after phases. Possible novelty and seasonal effects in after - phase II.

The key findings for the Spanaway site are listed below.

The crosswalk markings seem to compel pedestrians to use a particular crossing, more than the median refuge island alone.

During the *before* phase, pedestrians were observed using the marked crosswalks over 80 percent of the time. In the first *after* phase, pedestrians used the median refuge only about 60 percent of the time, and in the second *after* phase, the median/marked crosswalk was used 78 percent of the time. This suggests that pedestrians may not feel that the median refuge provides adequate visibility of a pedestrian crossing area when it is without the crosswalk markings.

The median may have improved pedestrians’ feelings of safety while waiting in the center lane.

Pedestrians were more likely to wait in the center lane during both phases of the *after* study. They also waited longer in the center lane before completing their crossing. This may signify that they are more comfortable waiting in the refuge for a safe gap in which to cross, which will hopefully prevent pedestrians from darting out into traffic, due to frustration caused by having to wait in the center lane for a gap or for vehicles to yield.

Higher motorist yielding rates were observed at marked crosswalks before the median installation.

Vehicle yielding was approximately 20 percent higher at the marked crosswalks in the *before* phase than at the median refuge island in the first *after* phase. When the crosswalk markings were again installed in the second *after* phase, yielding by southbound vehicles rebounded to previous levels, while northbound yielding was still lower than the *before* phase. This may be due, in part, to the traffic signal at S. 176th Street. This signal routinely backs traffic up to the vicinity of the crosswalk, which may be taking some of the motorists' attention away from the crosswalk.

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

Observations of pedestrians indicated that most pedestrians were very cautious about watching for oncoming traffic when crossing the street. There was no strong evidence that pedestrians acted carelessly because they felt more protected in the marked crosswalks or within the median refuge. The length of time pedestrians waited in the median may reflect a better feeling of safety at that location and a resulting willingness to wait for a safe vehicle break for crossing. The lack of change in pedestrian and vehicle evasive behavior also confirms this finding. Even with safety treatments in place, such as marked crosswalks and pedestrian crossing signs, it is also helpful to remind pedestrians to always be cautious about crossing the street.

The true effects of the median installation may have been limited at the study site because of equipment constraints, project schedule, and sample size.

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 (including lighting) and weather effects, as the project timing resulted in *before* data collection in the spring of 2004, the *after—phase I* data collection during the summer of 2005, and the *after—phase II* data collection during the winter of 2007. The data collected during this study may or may not portray long-term behavior for the following reasons. First, they are snapshots of pedestrian and motorist behavior that were captured during specific periods after implementation. Second, because of equipment problems and construction timelines, the *after—phase I* data sample size was limited. Third, data for the *after—phase II* condition was taken just after the installation of the crosswalks. Some drivers may be taken by surprise by the new markings and be unprepared to yield for the first few weeks or months following their installation.

Additional research should study the effectiveness of this type of median at other roadway types.

This location was chosen for the pilot project because it had been designated an at-risk location because of the high proportion of older road users. The special circumstances at this site influenced the installation of pedestrian treatments. However, the site characteristics do not meet the standards typically required for this type of treatment. The low rate of pedestrian crossings (less than 1 crossing per hour) may have prevented the median from being effective; the presence of more pedestrians could increase awareness of the median for both pedestrians and motorists. Thus, a location with more pedestrian crossings could produce better results for the median.

Additional improvements may be beneficial at this location.

It appears that motorist compliance at this location is improving since the first phase of pedestrian treatments. If funding were available, further enhancements could be made, as follows: overhead crosswalk signs, actuated pedestrian signals (flashing warning beacons that are sign mounted, embedded in the pavement, or located overhead), stop bars located in advance of the crosswalks to decrease shielding conflicts, and expanding the sidewalk on the west side of the roadway so that pedestrians may travel on that side of the street grade-separated from vehicles. Further pedestrian treatment research may help identify effective improvements to accommodate pedestrians.

II. STATE ROUTE 99—SHORELINE, WASHINGTON

No improvements were studied at this site. Table 4.2 summarizes the data collected at the Shoreline site. The findings from the Shoreline site analysis are below.

Turning movements are a source of many vehicle-pedestrian conflicts.

Pedestrians experience conflicts while waiting to cross the street while standing on the shoulder or while waiting for a gap in traffic in the center turn lane. These conflicts center on driveways to retail establishments.

Restriction of turning movements may be beneficial. This may take the form of regulatory signs or median treatments. Reduction in the number and/or widths of driveways may also help. In many areas, there is no separation (curb, gutter, or sidewalk) between the street and the driveway. This, along with the increased widths of these driveways, removes many of the barriers to speed and caution in the driver's mind and may contribute to higher numbers of pedestrian-vehicle conflicts.

Pedestrians using transit are likely to cross directly to or from a transit stop, whether or not there is a crosswalk at that location.

Even when there is no crosswalk, 80 percent of transit users at this site crossed directly across the roadway to access a transit stop. The proportion was 90 percent if there was a crosswalk (unmarked, in this case) in the immediate area of the stop. This factor should be taken into account when transit stops are moved or placed as part of planned safety or arterial performance improvements.

A more formalized system of driveways and walkways may reduce conflicts.

This area currently has only short sections of sidewalk that border areas of newer development. The lack of continuous sidewalks also contributes to the issue of poorly defined and very wide driveways mentioned above. Curbs, sidewalks, and gutters would improve pedestrian comfort as well as provide more definition to both the walking and driving environment, which might reduce conflicts in these areas.

Table 4.2. Summary of data collected—Shoreline

Comments pertain to:	Comments
Use of the unmarked crosswalks - Shoreline	62% use rate.
Percentage of crossings where vehicles yielded for pedestrians – Shoreline (includes only those crossings where vehicles were present)	Yield rate is 20-24%.
Average number of vehicles not yielding per crossing event – Shoreline (excluding events with zero vehicles involved)	Average number not yielding is 8-12 vehicles.
Percentage of vehicles yielding based on crossing paths - Shoreline (includes only those events where vehicles were present)	No significant difference in yielding to crossings in unmarked crosswalk vs. unsanctioned crossing.
Percentage of vehicles yielding based on wait location (includes only those events where vehicles were present)	Vehicles were 18% more likely to yield to pedestrians in center lane than on sidewalk.
Pedestrian wait time before crossing - Shoreline	Average wait time was 13 seconds.
Pedestrian wait time in the center lane - Shoreline	Average wait time was 7 seconds.
Shielding conflicts	8 conflicts.
Pedestrian and vehicle conflicts - Shoreline	Center lane wait and pedestrian pressured to run are the most common conflicts.
Pedestrian conflicts related to transit use	Transit riders experience more conflicts than non-transit riders.
	Higher incidence of shoulder conflicts among transit riders.

III. STATE ROUTE 99—KENT, WASHINGTON

At this site, HOV/bus lanes were added, along with overhead lighting, a landscaped median, and sidewalks, curbs, and gutters. Driveways to commercial properties were consolidated, and the bus stop for one route was moved out of the study area.

Table 4.3 summarizes the data collected at the Kent site, as well as any significant changes observed. The key findings for the Kent site are listed below.

Traffic signal cycle length may influence pedestrian crossing location decisions.

Because SR 99 is a high volume arterial, the traffic signal cycle lengths are expected to be longer than on other, lower volume roadways. At the study location, most pedestrians actually experience shorter wait times while crossing in an unlawful manner than at the traffic signal. Since many pedestrians are crossing to get to buses with 30-minute headways or to attend college classes, they may be more likely to make potentially dangerous crossing decisions in order to save time and anxiety.

Measures that increase the perception of safety for the pedestrian or motorist may also increase crossing wait times and decrease motorist yielding.

When a barrier exists, such as a traffic curb on the centerline of the roadway near an intersection, vehicles are less likely to yield when the barrier is between the vehicle and the pedestrian. When the pedestrian is crossing in the other direction and therefore does not have that barrier between himself and the vehicle, drivers are more likely to yield, decreasing wait times.

Table 4.3. Summary of data and observed changes—Kent

Comments pertain to:	Changes / comments
Use of the signalized marked crosswalks - Kent	Use rate is 74-81%. No significant change from before to after.
Percentage of crossings where vehicles yielded for pedestrians (includes only those crossings where vehicles were present)	Southbound - yield rate is 14-17%. No significant difference in before vs. after phases.
	Northbound - yield rate is 7-8%. No significant change in before vs. after phases.
	Southbound vehicles showing higher yielding rates than northbound vehicles by 7-9%.
Average number of vehicles not yielding per crossing event (excluding events with zero vehicles involved)	Southbound - no change. (Average number not yielding is 7-8 vehicles.)
	Northbound - down in after phase. (Average number not yielding is 4-8 vehicles.)
Percentage of vehicles yielding based on wait location (includes only those events where vehicles were present)	Vehicles were 13-14% more likely to yield to pedestrians in center lane than on sidewalk - both phases.
Pedestrian wait time before crossing (mid-block crossings only) - Kent	Comparable for both phases. (13 and 11 seconds, respectively.)
Pedestrian wait time in the center lane - Kent	Down in after phase. (4 and 3 seconds, respectively.)
Shielding conflicts	Comparable in both phases. (2 and 7 conflicts, respectively.)
Pedestrian and vehicle conflicts	Pedestrian and vehicle evasive action and center lane conflicts increased in the after phase. Center lane waits and pedestrian pressured to run conflicts were lower in the after phase.
Percentage of transit related crossings - Kent	No difference in conflicts by transit vs. non-transit riders.

Transit patrons experience different conflicts when traveling to the bus stop versus away from the bus stop.

Transit patrons crossing the roadway to the bus stop are much more likely to experience a vehicle evasive conflict and much less likely to wait in the center lane than those leaving the bus stop. This may again be due to the anxiety involved in catching the bus. Pedestrians may be putting themselves in harm's way to board the bus, rather than wait an additional 30 minutes for the next bus.

The majority of pedestrians at the study site were crossing at the signalized, marked crosswalks.

In both phases of the study, three-quarters or more of the pedestrians were using the marked, signalized crosswalks to cross the roadway. By considering the origins and destinations of pedestrians and working with transit agencies to place bus stops accordingly, unsanctioned mid-block crossings may be further reduced.

The near misses at this site all seemed to be precipitated by pedestrian behavior.

Failure to understand one's visibility when crossing at night, darting out into the street without checking for traffic, and impatience on the part of the pedestrian each led to near misses at the study site. While no engineering treatments can prevent all conflicts, it is helpful to remind pedestrians about their role as roadway users and to be cautious about crossing the street.

An increase in aggressive pedestrian behavior was found in the *after* study.

Pedestrian and vehicle evasive conflicts were higher in the *after* study, while center lane waits and pedestrian running behavior were lower. Groups of two to 20 pedestrians seemed to follow this pattern more than single pedestrians. Often, one person would step into the street and others would follow, blocking many or all of the lanes on SR 99. The groups seemed to use their size to engage in more risky behavior while crossing. This may be due to the widening of the roadway, causing pedestrians to feel more powerless in crossing unless they banded together as a group.

Additional research at this site would be beneficial.

Since the *after* video footage was taken, the northbound bus stop has been moved to a location just south of the intersection at South 240th Street. Additional research could show the effectiveness at this location of that change and could quantify the assumed reduction in unsanctioned, mid-block crossings by pedestrians. Data could also be collected with the camera facing in a northbound direction to explore the use of the landscaped median in reducing these unwanted and often unsafe crossings.

IV. STATE ROUTE 2—AIRWAY HEIGHTS, WASHINGTON

Improvements at the Airway Heights site include the addition of vehicle stop bars and improved signage. In the *after* study, more than half of the in-pavement lights had stopped working.

Table 4.4 summarizes the data collected and any changes that were observed between the *before* and *after* phases.

Table 4.4. Summary of data and observed changes—Airway Heights

Comments pertain to:	Changes / comments
Use of the crosswalk / median – Airway Heights	Use rate is 87-88%. No significant change from before to after.
Percentage of crossings when vehicles yielded for pedestrians – Airway Heights (includes only those crossings where vehicles were present)	Eastbound - yield rate is 65-86%. After phase yielding was down 20% from before phase levels.
	Westbound - yield rate is 62-84%. After phase yielding was down 22% from before phase levels.
Average number of vehicles not yielding per crossing event – Airway Heights (excluding events with zero vehicles involved)	Eastbound - up in after phase. (Average number not yielding is 0-1 vehicle.)
	Westbound - no change. (Average number not yielding is 1 vehicle.)
Percentage of vehicles yielding based on crossing paths – Airway Heights (includes only those events where vehicles were present)	Vehicles were more likely to yield to pedestrians in crosswalk for both directions, in both phases. (In the before phase, 60-66% more likely. In the after phase, only 18-24% more likely.)
Percentage of vehicles yielding based on wait location – Airway Heights (includes only those events where vehicles were present)	Vehicles were 14-53% more likely to yield to pedestrians in center lane than on sidewalk - both phases.
Pedestrian wait time before crossing – Airway Heights	Longer for after phase. (4 and 6 seconds, respectively.)
Pedestrian wait time in the center lane/median – Airway Heights	Comparable for both phases. (0.2 seconds, in both cases.)
Shielding conflicts	Comparable in both phases. (5 and 11 conflicts, respectively.)
Pedestrian and vehicle conflicts – Airway Heights	Pedestrian pressured to run conflicts were down in the after phase. All other conflicts remained constant.

The findings specific to the Airway Heights site are given below

A large majority of pedestrians used the median refuge for crossing.

A 2002 study indicated that 65 percent of pedestrians in this area were crossing at the median (its features were the same as the *before* treatment in this study with the exception of the sign-mounted warning beacons) (Tripp 2003). In mid-2006, the *before* phase saw over 88 percent of the crossings were being made using the median refuge, with more than 80 percent also using the flashers installed in the pavement and in the warning signs. The late-2006 *after* study observed 87 percent of the crossings made with the median and more than 75 percent also used the flashers.

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

Observations of pedestrian crossings indicate that most pedestrians were very cautious about watching for traffic when crossing the street. There is no strong evidence that pedestrians felt more protected in the marked crosswalk/median refuge and acted carelessly. Even with safety treatments in place, such as marked crosswalks, pedestrian crossing signs, and in-pavement flashers, it is also helpful to remind pedestrians to always be cautious when crossing the street.

Higher motorist yielding rates were observed during the *before* phase of the study.

Vehicle yielding was approximately 25 percent higher at the median treatments/ marked crosswalks in the *before* phase than in the *after* phase. Pedestrians also experienced increased wait times to cross the highway and had to wait for more cars to pass them before one would yield during the *after* study. It is likely that this change was related to the decreased number of functioning in-pavement flashers at the crossing. If the in-pavement flashers are too difficult or costly to maintain, the addition of median or overhead actuated flashers should have the same positive effect on vehicle yielding as was seen in the *before* study.

Pedestrian crossing flashers seem to be more effective when multiple types and locations are used.

Yielding rates to pedestrians using the median and flashers were highest during the *before* study when both the sign-mounted warning beacons and in-pavement flashers were functioning for all lanes. Crossings using the median and lights had more serious conflicts (especially vehicle evasive action conflicts) in the *after* study, where the majority of the in-pavement flashers had stopped working. This suggests that pedestrians are less visible to drivers when only the sign-mounted warning beacons are fully functional. These beacons alone provide good visibility in the form of the size and intensity of the lights, but the in-pavement flashers tell the driver exactly what to expect and where. The sign-mounted yellow warning beacons can be used to indicate a variety of things: school zones and construction sites, ice, crossroads, fire stations, or wildlife crossings. The yellow in-pavement flashers are currently only used for pedestrian crossings, and typically only for crossings that may not be expected by motorists, such as those at mid-block locations. The use of both types of flashers ensures that vehicles in all lanes will be able to see when the flashers are activated and will have the same amount of time to react as vehicles in the lane closest to the curb (which is nearest the sign-mounted beacons).

The painted stop bars seemed to give pedestrians a greater sense of security while crossing.

Pedestrian running behavior decreased significantly in the *after* study. This could be due to the addition of the painted stop bars. The bars allow pedestrians to know exactly where vehicles are expected to stop, which gives the pedestrian more time to react if it is clear that a vehicle will not stop in time. The stop bars also allow the pedestrian to better see what is happening in both lanes of travel so that they can avoid possible shielding conflicts. Most pedestrians react to fast-approaching vehicles by stopping to wait and see if the vehicle will stop in time (resulting in a pedestrian evasive action conflict or a longer wait time to cross) or by running. In this study, twice as many pedestrians ran when the vehicle did not stop behind the line as when it did stop behind the stop bar.

Shielding conflicts may be reduced by the addition of a painted stop bar in advance of the crosswalk.

Although there were not enough shielding conflicts in the *after* study to determine whether or not the stop bar was effective at preventing them (or at least giving the pedestrian more time to react if the vehicle did not appear to be able to stop in time), the initial results seem promising. The stop bar gives drivers and pedestrians more chance to see one another while crossing, which should reduce the incidence of this type of conflict. Further research would be beneficial in this area.

Serious conflicts seem to be influenced by the direction of vehicle travel.

Westbound drivers approach this crossing one and one-half blocks after a traffic signal. These motorists were involved in 85 percent of the serious conflicts (pedestrian or vehicle evasive action or near misses). Because the next traffic signal is not for about 3 more miles, these drivers may be less prepared to stop or yield than those traveling eastbound, who will arrive at the traffic signal in less than one quarter of a mile and may be more able to react and stop for pedestrians. This was also seen in the lower stop bar compliance rates among drivers traveling in the westbound direction. Testing this theory at other study sites would be beneficial.

Additional improvements may be beneficial at this location.

Motorist compliance to the pedestrian safety treatment was very good at this location. If funding were available, further enhancements could be made, as follows:

> <u>Sidewalk/curb design</u>—The current design allows at-grade pedestrian access to the sidewalk at wheelchair ramps and driveways. However, no wheelchair ramps have been built on the far side of the sidewalk (away from the highway). They are located only at the street corners—see Figure 4.1. This may present a tripping hazard to some pedestrians and prevent others from accessing the sidewalk, causing them to have to travel through the parking areas of retail establishments until the next access point, which could be dangerous.

Figure 4.1. Wheelchair ramp on SR 2 between King and Lundstrom Streets

Flasher signal timing—The warning flashers currently light both sides of the street at the same time and for the same duration. This often leaves the flashers lit for many seconds after the pedestrian has cleared the crossing. This may contribute to motorists disregarding the flashers and could present a problem when multiple pedestrian crossings occur during one cycle of the flashers. A more sophisticated system of flashers (i.e., lighting one side of the street first and then the second), or having the option to light the flashers for a longer period of time for pedestrians who may need it, might help to alleviate these problems.

Flashers: shielding issues—Shielding conflicts might be reduced by adding additional flashers to the signs in the center medians (or overhead) and/or by changing the lighting scheme of the flashers by side of street as mentioned above.

V. STATE ROUTE 2—SPOKANE, WASHINGTON—THREE STUDY SITES

No improvements were made at any of the Spokane study sites. Table 4.5 through Table 4.7 summarize the data collected at each of the sites.

Table 4.5. Summary of data collected—Lacrosse Avenue, Spokane

Comments pertain to:	Comments
Use of the unmarked / marked crosswalks - Spokane	80% use rate.
Percentage of crossings where vehicles yielded for pedestrians (excluding crossings made in gaps in traffic)	Yield rate is 9-19%. Southbound rates are about 10% higher than northbound.
Average number of vehicles not yielding per crossing event (excluding crossings events made in gaps in traffic)	No significant difference in yielding to crossings in unmarked crosswalk vs. unsanctioned crossing.
Percentage of vehicles yielding based on wait location (Lacrosse Avenue) (includes only those events where vehicles were present)	Vehicles were 22% more likely to yield to pedestrians in center lane than on sidewalk.
Pedestrian wait time before crossing at Lacrosse Avenue - Spokane	Average wait time was 19 seconds.
Pedestrian wait time in the center lane / median (Lacrosse Avenue) - Spokane	Average wait time was 4 seconds.
Shielding conflicts	13 conflicts.
Pedestrian and vehicle conflicts at Lacrosse Avenue - Spokane	Pedestrian pressured to run, center lane wait, and vehicle evasive action are the most common conflicts.

Table 4.6. Summary of data collected—Rowan Avenue, Spokane

Comments pertain to:	Comments
Use of the unmarked / marked crosswalks - Spokane	88% use rate.
Percentage of crossings where vehicles yielded for pedestrians (excluding crossings made in gaps in traffic)	Yield rate is 23-47%. Southbound rates are about 24% higher than northbound. (Small sample size present.)
Average number of vehicles not yielding per crossing event (excluding crossings events made in gaps in traffic)	Average number not yielding is 4-6 vehicles.
Percentage of vehicles yielding based on wait location (includes only those events where vehicles were present)	Vehicles were 37% more likely to yield to pedestrians in center lane than on sidewalk. (Small sample size present.)
Pedestrian wait time before crossing at Rowan Avenue - Spokane	Average wait time was 25 seconds.
Pedestrian wait time in the center lane / median (Rowan Avenue) - Spokane	Average wait time was 0.6 seconds.
Shielding Conflicts	0 conflicts.
Figure 5.68. Pedestrian and vehicle conflicts at Rowan Avenue – Spokane	Turning conflicts, pedestrian pressured to run, and vehicle evasive action are the most common conflicts.

Table 4.7. Summary of data collected—Wellesley Avenue, Spokane

Comments pertain to:	Comments
Use of the unmarked / marked crosswalks - Spokane	94% use rate.
Percentage of crossings where vehicles yielded for pedestrians (excluding crossings made in gaps in traffic)	Yield rate is 61-62%. (Small sample size present.)
Average number of vehicles not yielding per crossing event (excluding crossings events made in gaps in traffic)	Average number not yielding is 1-3 vehicles.
Percentage of vehicles yielding based on wait location (includes only those events where vehicles were present)	Vehicles were 47% less likely to yield to pedestrians in center lane than on sidewalk. (Small sample size present.)
Pedestrian wait time before crossing at Wellesley Avenue - Spokane	Average wait time was 35 seconds.
Pedestrian wait time in the center lane / median (Wellesley Avenue) - Spokane	Average wait time was 2 seconds.
Shielding conflicts	0 conflicts.
Pedestrian and vehicle conflicts at Wellesley Avenue - Spokane	Turning conflicts and pedestrian pressured to run are the most common conflicts.

The findings from the Spokane sites are described below.

Traffic signal cycle length may influence pedestrian crossing location decisions.

SR 2 is a high vehicle volume arterial, so the traffic signal cycle lengths are expected to be longer than on other, lower volume roadways. At the study locations where traffic signals are used (Rowan and Wellesley Avenues), most pedestrians experience substantially shorter wait times while crossing in an unlawful manner than in a lawful manner at the traffic signal. This presents a substantial motivation for some pedestrians to cross at unsanctioned locations. However, because of the traffic volumes on the roadway and its width, these crossings are fairly rare (about 8.5 percent of all observed crossings).

Intersection signalization characteristics determine the types of conflicts that pedestrians experience most.

In this study, unsignalized intersections resulted in higher instances of more serious conflicts (vehicle evasive action and pedestrian evasive action), along with more running behavior. Intersections that were signalized with permissive left turns experienced a large number of turning conflicts. Signalized intersections with protected left turns had very low incidences of conflicts overall. Right turn conflicts were the most common at this location. For all turning conflicts, the vast majority occurred with vehicles that were moving from the minor street onto the arterial.

Perception of safety at lower volume intersections may cause some pedestrians to disregard vehicle signals, pedestrian signals, and pedestrian signal actuation buttons.

At Rowan Avenue, over 9 percent of pedestrians crossing at the signal actually crossed against it. This included starting early, before the conflicting phases had finished; crossing in gaps, while disregarding the signal indication completely; and starting to cross late in the phase (and completing the crossing out of phase). These actions, as well as the failure by many pedestrians to use the signal actuation button and instead choosing to cross by using the vehicle signal indications as a guide, may result in dangerous situations. It is thought that this occurred at Rowan Avenue much more frequently than at Wellesley Avenue because of the lower side street vehicle volumes and the less complex geometry and turning movements at the T-intersection of Rowan Avenue.

Unsanctioned mid-block crossings occur more frequently near unsignalized crossings than near signalized crossings.

Near Lacrosse Avenue (unsignalized), 20.1 percent of the observed crossings were made at unsanctioned mid-block locations. At Rowan and Wellesley Avenues (signalized), this percentage was 12. percent and 5. percent, respectively. This is likely due to the perception of decreased vehicle density (caused by queuing at signals and increased instances of turning movements), as well as a more predictable vehicle flow (pedestrians can time the gaps more easily and often cross with fewer conflicts) at unsignalized locations.

VI. ALL SITES COMBINED

Some trends were observed at more than one of the study sites. These observations are detailed below.

Pedestrian crossing volumes are related to time of day.

At each study site, pedestrian crossing volumes were relatively low before 9:00 AM and after 7:00 PM. The daily peak for pedestrian crossings was midday (9:00 AM to 3:00 PM) or during the afternoon (3:00 PM to 7:00 PM). Weekend days typically had their peak period later in the day than on weekdays. This information could be used to target improvements to the times of day when pedestrians are more numerous.

Pedestrian crossing paths are a function of origin and destination, as well as the built environment.

On the basis of observations of almost 2,000 hours of video, it appears that pedestrians, when deciding on a location to use to cross major arterials, consider a number of factors. These factors include the facilities available for use (sidewalks, crosswalks, traffic signals), the relevance of these features (whether they are convenient to the origin and destination of the pedestrian), and the accessibility of the features (whether connecting paths or parking lots lead to these features or fences and other obstacles block the way; whether heavy traffic flows make it impossible to cross at certain locations or there are gaps). These factors should be considered when roadways are designed, realigned, or improved and transit stops are planned.

Motorist yielding behavior is influenced by the location of the pedestrian.

Depending on whether the pedestrian is standing on the shoulder or sidewalk, or in the center turn lane, vehicle yielding behavior will change. At all applicable study sites (Spanaway, Shoreline, Kent, Airway Heights, and Lacrosse Avenue in Spokane), there was a statistically significant difference in motorist yielding behavior. Motorists are much more likely to yield to pedestrians waiting in the center lane than to those on the sidewalk.

More visual clues to the presence of pedestrians on arterials would be beneficial.

At each of the study sites, the major arterial is lined with business signs and advertising, utility cabinets and poles. Many motorists may simply be tuning out this visual noise and, with it, the presence of pedestrians and their movements. Visual clues to drivers may be beneficial. These could include pedestrian crossing signs, sanctioned mid-block crossing opportunities, or narrower lanes that remind motorists of the presence of pedestrians and make pedestrians more visible. These pedestrian improvements will need to be selected in conjunction with consideration for the need to maintain vehicle flow, given the need for these roadways to remain high volume regional arterials.

Crosswalk use increases when more controls are used.

When crosswalk markings or controls (i.e., signals or flashers) are used, significantly more pedestrians use the crossing than cross at other, unsanctioned locations. At unmarked crosswalks, about 62 percent of pedestrians crossed at the sanctioned location; at marked (but otherwise uncontrolled) crosswalks, an average of about 80 percent used the crosswalk. When flashers are added, 88 percent of pedestrians used the crosswalk, and when the crosswalk was accompanied by a traffic signal, about 91 percent of pedestrians use the crosswalk.

There were two exceptions to this. At the Lacrosse Avenue site in Spokane (unmarked crosswalks), the use of the sanctioned crossing locations was almost 80 percent. It is thought that this was due to a large park being located on one side of the roadway. This park reduced the number of destinations on that side of the street and therefore the lure of making an unsanctioned crossing. The other exception was at the Kent site. In the *before* analysis, use of the signalized crosswalks was about 75 percent (the roadway configuration was four lanes and a two-way left turn lane). In the *after* analysis (with six lanes and a turn lane/landscaped median), 82 percent of pedestrians used the signalized crossing. The lower use rate (versus 91 percent average) may simply be due to roadway volumes. In Kent, the average annual daily traffic is 26,000 vehicles, whereas at the other two signalized crossings, Rowan and Wellesley Avenues in Spokane, the average annual daily traffic is 42,000 vehicles. It is also likely that pedestrians felt safer in crossing at unsanctioned mid-block locations during the *before* study because of a combination of the relatively lower volumes in Kent and narrower roadway (four lanes versus six lanes). During the *after* study, although there was no indication of an increase in traffic volumes, the wider roadway may have caused pedestrians to feel less safe in crossing at locations other than the traffic signal, which led to the increase in signalized crossing use in the after study—which was still much lower than the use rate seen in Spokane.

Pedestrians crossing near unmarked, sanctioned crossings experienced lower yielding, regardless of whether or not they crossed within the sanctioned area.

There was no statistically significant difference in motorist yielding between pedestrian crossings made at an unmarked, sanctioned crossing and those made at an unsanctioned crossing location where there were no marked crosswalks nearby. If there was a marked crosswalk, motorist yielding for those crossing inside the crosswalk was significantly higher, and there was a significant difference in yielding behavior between those crossing within the crosswalk and those crossing outside of it.

Motorist yielding behavior and pedestrian delay is directly related to the type of crossing facility.

Motorists yield more often and more quickly at more obvious crossing locations. Crossings with marked crosswalks and flashers received better motorist compliance than marked crosswalks alone, which, in turn, received better compliance than unmarked crossings. Pedestrian delay echoed this trend and was lower at facilities that promoted higher motorist yielding rates. However, yielding compliance was far from universal at all locations, meaning that it is imperative that pedestrians not be given a false sense of security.

Conflict avoidance strategies pedestrians use to cross arterials are related to the crossing facility.

At crossings with a traffic signal or pedestrian flashers, running across the entire street is the most common strategy used (ignoring simply walking), followed by running across half of the street and crossing half of the street at a time. Crossings made at intersections with marked or unmarked crosswalks use these same strategies, but in the reverse order: crossing half of the roadway is the most common, followed by running across half of the street, and running across the entire street. Mid-block, unsanctioned crossings use a fairly equal number of each strategy and do not seem to have a pattern. At signalized crossings the fewest number of pedestrian conflict avoidance strategies are used, followed by crossings with flashers, and the marked and unmarked crossings. The prominence of pedestrian running behavior, even at signalized intersections, points to the idea that pedestrians do not feel a false sense of security when crossing arterials, no matter what facilities and/or controls are present.

Motorist yielding behavior can be affected by the proximity of a traffic signal and whether the vehicle is traveling toward or away from the traffic signal.

At the study sites where there were traffic signals within about one to two city blocks of the camera location, vehicles traveling toward the traffic signal were significantly more likely to yield to crossing pedestrians. It is possible that drivers moving toward a traffic signal are more prepared to stop and are scanning the roadway more carefully, whereas those who have just come through the traffic signal are less prepared to stop again so soon. Pedestrians may be caught off guard by this difference in behavior, which may lead to more conflicts in these areas.

Shielding conflicts were more common at marked, uncontrolled crossings.

Marked, uncontrolled crosswalks had a significantly higher incidence of shielding conflicts than either unmarked crosswalks or crosswalks that were marked and had pedestrian flashers. The shielding conflicts at marked, uncontrolled crosswalks were also much more varied: they occurred in more of the shielding conflict categories than other sites. Pedestrians need to be reminded of the dangers of crossing multilane streets. Pedestrian signage and education may be helpful in this process.

Vehicle platoons may adversely affect motorist yielding behavior.

Empirical evidence suggests that vehicles located at the front to middle of a platoon are less likely to yield to pedestrians than vehicles near the end of a platoon or those that are not located within a platoon at all. Because this is based purely on observation, more research is needed to confirm this result. Driver following distance may be a factor: drivers near the front or middle of the platoon may believe that if they were to yield to a crossing pedestrian, a rear-end collision would be more likely to occur, whereas for vehicles nearer the end of the platoon or for those not traveling within a platoon of vehicles, a rear-end collision would be less likely.

The effectiveness of flashers may be enhanced by other treatments and technologies.

In general, flashers have a very high compliance rate for vehicle yielding. The addition of an advanced stop bar seems to improve the safety of these crossings even further. Signs on or near the pedestrian actuation buttons to inform the pedestrian what the button will do (red signal, flashers), as well as that oncoming vehicles may not stop, are another enhancement that would be useful. Finally, a dilemma zone loop detector that delays the flashers until any vehicles that are close to the crossing have passed will likely decrease any rear end accidents that may occur as a result of the installation of the flashers.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The purpose of this study was to gain further insight into pedestrian and motorist behavior and the efficacy of various engineering treatments designed to improve pedestrian safety on arterials. It hoped to answer two questions:

- What causes motorists to yield to pedestrians?
- What causes conflicts between motorists and pedestrians?

As described in the findings, vehicle yielding is directly influenced by the visibility of the crossing. Pedestrian crossings with signs, crosswalk markings, flashers, and/or signals seem to have higher yielding rates than those without these features. There is often so much visual clutter on these roadways that pedestrians blend easily into the background if strong signals are not sent to motorists.

The causes of conflicts are much more varied: ignorance of or noncompliance with the law (by motorists or pedestrians), inattention, vehicles following too closely, impatience, anxiety when attempting to catch a bus, use or non-use of pedestrian facilities, placement of features in the built environment, and more. Most of these issues can be addressed with engineering, education, and/or enforcement. Unfortunately, all of these solutions require funding, which is currently in short supply (Harrell 2008).

RECOMMENDATIONS

Improvements to pedestrian safety must compete with new roads, road maintenance and reconstruction, and a host of other priorities for funding. Therefore, only the most promising treatments should be carried forward through design and implementation, and lower cost improvements should be considered first.

- Signing, striping, and advance stop bars are less effective than flashers or signals but also much less expensive and should be considered, as warranted, before other measures.
- Cooperation and communication among agencies and stakeholders are important and must be achieved before a “solution” is chosen. In some cases, improvements may be less expensive when combined into one project, rather than spread out over multiple projects.
- Education and enforcement are still needed. Motorists, including those who drive as part of their livelihood (freight, delivery, transit drivers), need to know and understand the laws about yielding to pedestrians and the importance of proper following distance. Pedestrians and motorists need to understand their own limitations and those of vehicles and be prepared to take evasive action at all times to avoid collisions. Enforcement should be fair and logical and can focus on citing noncompliant motorists and pedestrians, as well as providing some education in terms of the letter and spirit of the law.
- Some small changes, such as the use of different crosswalk marking patterns or materials, may be made that can simultaneously reduce maintenance fees and increase visibility. Agencies need to continue to seek out these changes when possible.
- More work should be done to remove visual clutter from pedestrian areas, where possible. Removable sandwich board signs, business flags and balloons, utility poles, and on-street parking should be carefully placed or removed in areas near major pedestrian crossings. It is understood that this may never be completely attainable, but any improvement would be helpful.

Costs and Benefits

As the recommendations posed above have greatly differing costs and effects on pedestrian safety, a brief discussion of these factors is presented below. Unless otherwise noted, cost estimates were obtained from the WSDOT Unit Bid Analysis system (2008).

- Education and enforcement: although these methods were not used at any of the study sites, they are often included in pedestrian safety projects. The costs of education and awareness campaigns can vary significantly, depending upon the media used and the frequency of use (i.e., radio, television, posters, bus advertising, etc., and how many commercial spots are purchased, posters printed, and more). As an example, a 2002 Washington, D.C., campaign cost about $300,000 and utilized radio, bus advertising (on transit vehicles and shelters, and inside the buses themselves), posters, mailing inserts, and stickers. Researchers were able to show that awareness of the campaign and its issues increased after the campaign concluded (MWCG 2008).

  Enforcement of crosswalks and motorist yielding behavior is typically done as an overtime function of a city police department or a county sheriff's department. Given the Pierce County's 2008 salary scale, this would cost approximately $40 per hour per officer (Pierce County 2008). Again, as this strategy was not used during the study, no effectiveness statistics are available.
- Crosswalk markings: Cost estimates range from $400 for a standard (transverse) pattern painted crosswalk (see Figure 5.1) to approximately $1500 for a thermoplastic continental crosswalk marking (all based on a seven-lane roadway cross-section). The accompanying signage may cost from $200 to $300 per sign (including installation) (Pedestrian and Bicycle Information Center 2008b). At the Spanaway site, motorist yielding behavior increased by 5 to 35 percent when crosswalk markings were present.

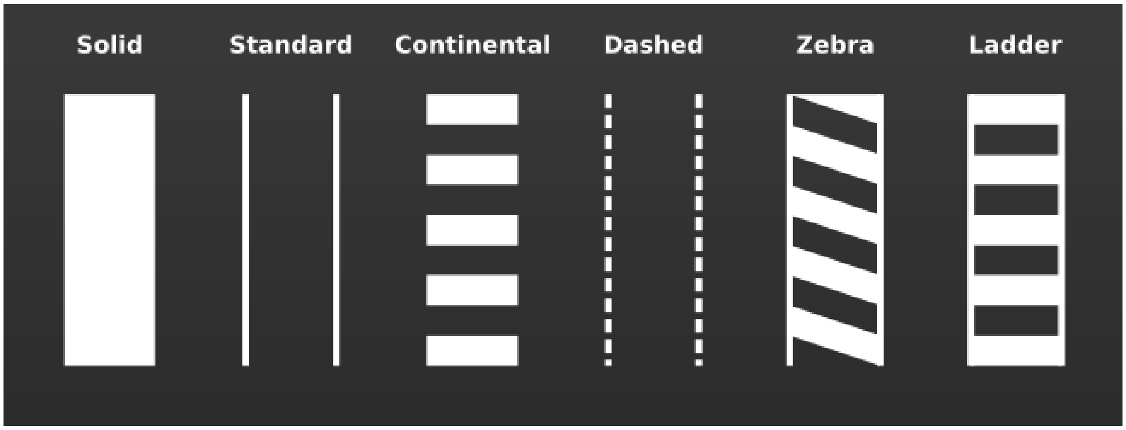

Figure 5.1. Crosswalk marking patterns (Wikipedia 2008)

- Stop bars: Costs range from about $120 for a painted stop line to about $300 for a thermoplastic stop line (based on a seven-lane roadway section). At the Airway Heights site, the stop bars appeared to increase the pedestrians' sense of security by creating more separation between them and the approaching vehicles. This resulted in a significant reduction in pedestrian running behavior. And, although the data were insufficient to make a statistical conclusion, it appeared that the stop bars may have decreased the number and severity of shielding conflicts that were observed at that site.
- Raised medians: The cost for the type of raised median used at the Spanaway site is approximately $5,000 (Pedestrian and Bicycle Information Center 2008a). Because this treatment was added in conjunction with several other changes, the changes in yielding behavior and conflicts strictly related to the median could not be determined. The median did seem to increase pedestrians' feelings of security while waiting in the center lane.
- Overhead illumination: The cost, per pole for overhead illumination is approximately $5,000 to $15,000. Because of a lack of pedestrian crossings made during dark hours in this study, the effects of overhead lighting on vehicle yielding and pedestrian-motorist conflicts could not be examined.

- Sidewalk, curb, and gutter: Costs for this treatment would be about $10,000 per 300 linear feet, plus $1,500 per curb ramp. Although these improvements were not explicitly studied in this project, the treatment would serve to grade-separate pedestrians and vehicles, as well as better define driveways and intersections, which could reduce conflicts for those traveling along a roadway.
- Flashers (actuated): Costs would be $5,000 per crossing with sign-mounted flashers only, and $15,000 to $20,000 per crossing with in-pavement flashers and sign-mounted flashers (Godfrey 1999). Motorist yielding rates at the Airway Heights site were very high—almost 90 percent—when both sign-mounted and in-pavement flashers were present. This rate dropped slightly (to about 70 percent compliance) when the in-pavement lights began to fail but the sign-mounted lights were still fully functional. (Yielding rates at unmarked, mid-block crossings in Kent and Shoreline were 18 percent and 25 percent, respectively.) Center lane waits were also much lower at the Airway Heights site than at any of the other sites.
- Signals: Costs range from $40,000 to $200,000 per signal, depending upon the complexity of the intersection. At the Spokane sites, vehicle yielding was 14 to 28 percent higher at Rowan Avenue (with permissive left turns) than at the unsignalized Lacrosse Avenue intersection. Motorist yielding at Wellesley Avenue (with protected left turns) was 40 to 52 percent higher than at Lacrosse Avenue. Pedestrian and motorist delay will increase with the addition of a traffic signal and turning conflicts will be higher, but most other conflicts (pedestrian and vehicle evasive action, running behavior, and center lane waits) will be dramatically less. Protected left turns lower these rates further than signals that allow permissive left turns.

Future Research

The information presented here represents over 1,700 hours of manually reviewed video and several site visits that were used to determine the interactions between motorists, pedestrians, and engineering treatments on arterials. The study encompassed seven sites in Washington State, three in Western Washington and four in Eastern Washington. The following recommendations for future research are submitted:

- More sites need to be studied and compared for the information presented here to be applicable to other sites in Washington State and possibly other areas of the country.
- Transit stop placement: Since the *after* study in Kent was completed, the bus stops for two routes have been moved to a near side (before the bus passes through the intersection) location. Additional research could verify whether or not this has had an impact on the number of unsanctioned, mid-block crossings and whether pedestrian safety has improved at this site as a result.
- Overhead lighting and the effect of darkness: Not enough crossings during dark conditions were observed to be able to determine either the effects of adding overhead lighting or the effects of darkness on pedestrian-motorist conflicts and motorist yielding behavior.
- Stop bars: The use of stop bars in advance of pedestrian crossings seems promising for reducing shielding conflicts. The sample size of these conflicts was not large enough in this study to provide conclusive results about their effectiveness. Any high-speed road would be an excellent candidate for this treatment and accompanying research.
- Traffic signals and traffic curb: If more study sites were evaluated, more knowledge pertaining to the trends in motorist yielding behavior with respect to these features could be gained (i.e., does the direction of vehicle travel, with respect to a traffic signal or traffic curb, affect the rates at which drivers

will yield to pedestrians attempting to cross the roadway, or are other factors important at these study sites?).

- Adding sidewalks and consolidating driveways: Logically speaking, adding sidewalks and making driveways to businesses more defined and less plentiful should reduce pedestrian-vehicle conflicts. The research presented here could not substantiate that idea. Because the data taken were all concerned with pedestrians *crossing* the arterial, this nuance may have been missed. Future research could also take into account the pedestrians traveling along the arterial who do not cross the roadway and their interactions with vehicles.
- Landscaped medians: Project and construction schedules precluded the study of the landscaped medians that were installed in Kent and Shoreline. Research to determine the effectiveness of this treatment in preventing unsanctioned mid-block crossings, as well as any negative effects on emergency response or freight movement, would be beneficial.
- Airway Heights: Since the *after* study was completed at this location, the in-pavement flashers have been removed. More improvements are also scheduled for installed this site. Given the number of data that are available for this site, further studies there could pinpoint the effectiveness of the improvements with regard to pedestrian safety and behavior.
- Platoons: In some instances, pedestrians were observed forming larger groups to force motorists to yield to them. There was also some evidence that motorists' behavior may be partially due to their location within a platoon (and whether or not a motorist was in a platoon of vehicles at all). More research would help to increase understanding of these events.
- Shoulders: Shoulders were eliminated at the Kent and Shoreline study sites. Research into the effects on bicyclists and any delay due to disabled vehicles

blocking lanes would be useful for a more thorough evaluation of the treatment.

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APPENDIX A: LITERATURE REVIEW

This study focused on the evaluation of vehicle-pedestrian conflicts and vehicle yielding behavior under various conditions. Many of the engineering treatments used in the study areas, as well as the behaviors observed, have been examined by other researchers. The following is a summary of their studies and findings. Crosswalk markings, raised medians, signs and pavement markings, in-pavement flashers, interactions with transit, lighting, and consistency will be discussed.

CROSSWALK MARKINGS

The effects of marking crosswalks that are not accompanied by a stop sign or other traffic control device have been debated since a 1972 study by Bruce Herms was released (UC Berkeley 2003). The study found that six times more pedestrian-vehicle collisions were occurring at marked crosswalks than at those that were unmarked, at the sites selected in San Diego, California. Although many have questioned the study's results and methodologies over the years, it is still used by some agencies and municipalities as an excuse to do nothing to improve pedestrian safety at a site (Zegeer 2004b).

Several other studies have reported similar results. In 1967, the Los Angeles County Road Department reported more than a 300 percent increase in crashes that occurred at 89 intersections that had been converted from unmarked crossings to marked crosswalks. In 1994, another study was completed in California by Gibby et al. Again, pedestrian-vehicle crash rates were shown to be two to three times higher at unsignalized, marked crosswalks, than at those with no markings. A 1988 Swedish study reported that pedestrians were two times as likely to be involved in a crash when using the marked crosswalk (Campbell et al 2004). Koepsell et al (2002) determined that there was a 360 percent increase in crashes involving older pedestrians who used the marked crosswalks.

And Zegeer, Stewart, Huang, and Lagerwey found that installing crosswalks alone on wider (three or more lanes), busier (over 12,000 average annual daily traffic (AADT)) roads led to an increase in pedestrian-vehicle crashes versus unmarked crosswalks (Campbell et al 2004).

A few studies have had opposite conclusions. In 1983, a study by Tobey et al. found that there was a reduced risk of crashes when crosswalks were marked. A 1965 study by Mackie and Older in London, England, reported a lower risk when marked crosswalks were used, as well. Methodology and study site selection have also been called into question in these studies (Campbell et al 2004).

Beyond collision studies, pedestrian and motorist behavior at crosswalks is also important to consider. In a 1999 study, Knoblauch et al. (2000) found that pedestrians displayed no extra feeling of security when using marked crosswalks. They also found that pedestrians traveling alone were more likely to cross within the crosswalk markings, while groups of pedestrians were less likely to use the crosswalks at all. Another study by Hauck (1979) showed that when the crosswalk markings were repainted at several sites, both motorist and pedestrian behavior improved. A 1998 Knoblauch study found that, after crosswalk markings were applied, motorists’ speeds were significantly less when a pedestrian was present at the crosswalk and not looking at approaching traffic (for all other scenarios, there was no significant change in speeds) (Campbell et al. 2004).

Overall, it appears that marked crosswalks may experience a higher incidence of pedestrian-vehicle collisions when the roadways they are crossing are wide (two or more lanes in one direction) and volumes are high (greater than 12,000 AADT). Of the seven sites included in this report, five contained marked crosswalks.

RAISED MEDIANS / PEDESTRIAN REFUGE ISLANDS

Raised medians can be used to separate directions of traffic, change or consolidate business access points, improve the overall streetscape of a location, and provide a refuge for pedestrians crossing the street. The medians can provide a place for all pedestrians, especially slower walkers, with a place to wait for a gap in traffic. The raised islands provide a separation between vehicles and pedestrians. Unfortunately, little research has been done on the refuges made specifically for pedestrian crossings. Bacquie et al, in a 2001 study, found that "over 80 percent of the pedestrians observed crossing the street, used the islands as they were intended" and that "almost all pedestrians surveyed felt that the islands are convenient to use and added to their level of safety" (3). Michael King (2003) reported that, when raised median islands are used in conjunction with curbs and sidewalks, narrowed lanes, and timed signals, there is a "slight effect on vehicle speed [and] a sizable effect on pedestrian exposure risk and driver predictability." Bowman and Vecillio (1994) determined that "pedestrian accidents are minimized by the installation of raised medians" in both the central business district (CBD) and suburban areas. Even with the small amount of research available on the effectiveness of this treatment, it appears that raised medians may be a cost-effective and inexpensive (depending upon design) measure to increase pedestrian safety at crossings. Pedestrian-oriented raised medians were used at the Airway Heights and Spanaway sites in this study.

PEDESTRIAN SIGNS

Signs are installed on the basis of the conditions set forth in the Manual for Uniform Traffic Control Devices (MUTCD). They are typically used to "inform unfamiliar motorists and pedestrians of unusual or unexpected conditions" (ITE 1998). Extraneous signs can add clutter to the visual horizon and make it harder for drivers to distinguish which are more important. And many cities simply do not have the resources to study their sign installations and determine whether they are effective (ITE 1998).

There have been some positive findings in studies involving pedestrian crossing signs. A 1996 study by Clark et al. reported an increase in vehicles stopping or slowing, but no decrease in conflicts between vehicles and pedestrians after new yellow-green crossing signs were installed (Campbell et al. 2004). In a Clearwater, Florida, study, illuminated crosswalk signs and high visibility crosswalk markings showed that vehicles were 30 to 40 percent more likely to yield to pedestrians during daylight hours and 8 percent more likely to yield to pedestrians at night than at other locations without the devices (Huang et al 2000).

A Huang et al study (2000), examined the effectiveness of three different types of signs: a traffic cone with an attached sign reading “State Law: Yield to Pedestrians in Your Half of Road” in New York; an overhead lighted sign system in Tucson, Arizona, with one sign reading “Pedestrian Crossing” that was continuously illuminated and one pedestrian-actuated lighted sign (“Stop for Pedestrian in Crosswalk”) that flashed when the pedestrian button was pushed; and an overhead “Crosswalk” sign in Seattle, Washington, which was used when geography or road features did not allow a clear view of the crossing by motorists. All of the signs had positive results in terms of number of motorists yielding to pedestrians. This study covered only the three treatments listed and only 11 locations; so further research into these methods would be beneficial (Huang et al 2000).

Studies in Sweden and Tokyo, Japan, had opposite results from those above. In Sweden, 16 percent of drivers actually sped up when approaching a crosswalk with a pedestrian crossing, and 57 percent maintained the same speed. In Tokyo, accident rates increased by almost 5 percent after the installation of illuminated crosswalk signs (Huang et al 2000). Signs warning vehicles of possible pedestrian activity were used at the Spanaway and Airway Heights study sites, studied in this report.

ADVANCE STOP OR YIELD LINES

Stop lines are used to indicate to motorists when they should stop to avoid conflicting with other traffic movements. They can be used to stop motorists from intruding into the crosswalk area or painted far in advance of a midblock crossing (as stop or yield lines) to increase the visibility of both the cars and pedestrians on the roadway. This is normally used on multilane roads, where shielding or multiple threat conflicts may occur (i.e., a car in one lane yields to the pedestrian but car(s) in the other(s) proceed). Van Houten studied these markings on more than one occasion and found that stop or yield lines increase the yielding behavior of vehicles approaching a pedestrian in or near a crosswalk, decrease the number of pedestrian-vehicle conflicts at a given site, and increase the distance from the crosswalk at which vehicles stopped for the pedestrians (Van Houten 1988, 2008). In one study, conflicts near the stop bar were reduced by 90 percent (Huang et al 2000). In each of the studies, the lines were accompanied by signage reading "Stop [or Yield] Here for Pedestrians," with arrows pointing to the lines. Because the lines and signs were always applied together in the studies, it is not known how much each element affects the motorists' behavior. Stop bars with accompanying signage were used at the Airway Heights site in this study.

IN-PAVEMENT FLASHERS

In-pavement flashers are "special types of highway traffic signals installed in the roadway surface to warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require road users to slow down and/or come to a stop" (MUTCD 4L-1). They are often used at marked, unsignalized crosswalks to increase motorist compliance or decrease vehicle-pedestrian collisions. A number of studies evaluating the performance of these flashers have been performed. In 1998, a Santa Rosa, California, study by Whitlock and Weinberger Transportation, Incorporated found that the lights changed driver behavior around the crosswalks for the better after the lights were installed, but these effects were much more pronounced during darkness or inclement weather. The study also mentioned that the passive, ultrasonic pedestrian detection system that was used was not always reliable in detecting waiting pedestrians (Whitlock & Weinberger 2008). A 1999 study in Kirkland, Washington, reported that with the in-pavement flashers, driver yielding behavior increased, as did the distance from the crosswalk where vehicles applied their brakes (Godfrey 1999). The city of Kirkland has received almost exclusively positive comments regarding its installations. The report did note that there was concern on the part of some cyclists about the possibility of striking a flasher while riding, but this has not been a problem thus far at any particular site.

In 2000, two more studies were performed. Panos Prevedouros concluded that the maximum and average speeds at which motorists approached crosswalks after flashers had been installed decreased; the average time pedestrians had to wait on the curb to cross decreased; center lane waiting was reduced or eliminated; pedestrian running behavior decreased; and the number of pedestrians crossing outside of the crosswalk decreased. He also noted some disadvantages with the in-pavement flashers: the lights were sometimes hard to see during daylight hours; the device did not receive total compliance by motorists; and there was a possibility that some pedestrians might gain a false sense of security when crossing with the flashers (Prevedouros 2000). This study was conducted on a seven-lane arterial in Honolulu, Hawaii.

Van Derlofske also performed a study during this time in Denville, New Jersey. He found that in-pavement flashers reduced the number of vehicles not stopping for a pedestrian waiting to cross; they increased the visibility of the crosswalk; and they reduced the average motorist’s speed of approach to the crosswalk. He also determined that the approach speed reductions tended to diminish over time (Van Derlofske and Boyce 2001). The final report for this study, published in 2002, also recommended that the flasher units be more robust and plowable to be of widespread use. It went on to say to that active actuation would not have the problems of “false positive” pedestrian detection that the passive activation unit had experienced. Education of the public and instruction for law enforcement personnel about the legal status of the crosswalk flashers was suggested (Boyce and Van Derlofske 2002).

Albert Tripp performed a study in 2003 in Airway Heights, Washington. It focused on the addition of new, midblock crossings with marked crosswalks, raised medians, and in-pavement flashers on a five-lane state highway. He found that there was some motorist speed reduction in the corridor and also reported that many pedestrians were detouring as many as 300 feet to use the new crossings. It was recommended that sign-mounted warning beacons be added to increase the effectiveness of the in-pavement flashers, especially during the daylight hours (Tripp 2003). The enhanced flashers were later installed and have been studied as a part of the sites included in this document.

A Cedar Rapids, Iowa, study in 2004 also reported increased yielding, pedestrians’ perception of safety, and motorist awareness at a five-lane arterial where in-pavement flashers were installed (Kannel 2004). Finally, Gadiel studied the treatment on seven crosswalks in Amherst, Massachusetts. The project found increased motorist yielding rates at the crosswalks where the flashers were installed. However, it also found that yielding for pedestrians at those locations with in-pavement flashers was similar for pedestrians who did not activate the lights. This would lead to the idea that the flashers heighten driver awareness of the crosswalk and thereby increase the safety for pedestrians, whether or not the lights are used (Gadiel 2006).

In all the studies listed above, the positive effects of in-pavement flashers seem to outweigh the negative. Most importantly, there was an increase in yielding and pedestrian safety on roads up to seven lanes wide. Rough estimates put the cost for this treatment at about $25,000. This may be a small price to pay to reduce pedestrian-vehicle accidents at uncontrolled crosswalks. As mentioned above, the Airway Heights site in this study used in-pavement flashers and sign-mounted warning beacons.

TRANSIT INTERACTION

Many pedestrian trips on arterials are made to get to and from transit stops. Moudon and Hess, in their 2003 study, showed that high transit ridership along Washington’s state highways was associated with high vehicle-pedestrian collisions. They postulated that a disconnect between government agencies may be partially to blame for this phenomenon and called on them to increase their efforts in design when it comes to the pedestrian portion of the trip. They felt that highways should have a more multimodal focus and that state, local, and transit agencies should work together to identify locations where transit patrons are at risk and should “plan and fund pedestrian safety improvements” as a team (Moudon and Hess 2003). Other research has not been quite this specific but does recognize bus stop location as a factor in pedestrian safety and is typically concerned with pedestrians crossing behind the bus to avoid the bus screening their crossing. In these cases, studies recommend moving the transit stops to the far side (after the bus has passed through the intersection) of uncontrolled intersections to get the desired pedestrian behavior (Zegeer et al 2005).

The Shoreline, Kent, and Spanaway sites in this study all had high usage by transit patrons.

OVERHEAD LIGHTING

It stands to reason that improved lighting at and near crosswalks would improve pedestrian safety at those locations. In studies dating back to 1972, that is exactly what was found. The 1972 study by Pegrum added sodium floodlights to 63 crosswalks in Perth, Australia. The result was a significant reduction in pedestrian-vehicle collisions during hours of darkness. In a similar study conducted in Israel by Polus and Katz in 1978, the same significant reduction was seen. A more detailed behavioral study was done by Freedman in Philadelphia in 1975. It found that pedestrians in the lit crosswalk were perceived as being brighter to the observer; and drivers and pedestrians both seemed to be more cautious of their surroundings near the crosswalk (Campbell et al 2004). A Wisconsin study found that test subjects were more likely to identify the correct number of pedestrian (wooden) cutouts in a crosswalk from a distance when a new lighting scheme was in place (Hasson and Lutkevich 2008). These studies each included lighting that was specifically designed and oriented for crosswalks. It is not known if increasing the vehicle-scale lighting in an area would have the same effect on collisions or overall behavior.

New overhead lighting was added as part of the improvements made to the Kent and Spanaway study sites.

CONSISTENCY IN PEDESTRIAN MEASURES

One seldom studied or talked about issue in pedestrian safety is consistency. Consistency in pedestrian measures can take many forms: signal timing (including the "Walk," "Don't Walk," and crossing clearance intervals, which can be calculated in a different manner from city to city, intersection to intersection, and even differently on different approaches to the same intersection), pedestrian call button usage and effectiveness, even pedestrian access through construction sites (do they simply close the sidewalk or is there an alternative route? What about the blind—are there cues to guide them?). Consistency and intuitive design are especially important for those with disabilities but affect every user, to some extent. Rodney Tolley, in his book "Sustainable Transport" states, "consistency in the design and operation of the pedestrian environment is crucial for it to be functional" (Tolley 2003). Joanne Laurent is a "cane travel teacher" for the blind and writes, in a letter to the United States Access Board, "I beg you to apply a standard of consistency throughout the nation," referring to audible signals, arterials without sidewalks, curb ramps, and truncated dome indicators (Laurent 2002).

The opinion that pedestrians are more likely to behave in the manner we are trying to achieve when consistent rules are applied is echoed in the 1978 study by Steven Smith. He studied the effects of differing pedestrian clearance intervals in various cities and concluded "inconsistencies in the application of traffic control devices increase the potential for making wrong decisions and, in the long run, create disrespect for the devices" (Smith 1978). The ultimate in pedestrian safety is to give users predictable, intuitive design of the facilities they use.

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APPENDIX B: ANALYSIS

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APPENDIX B: ANALYSIS

This appendix presents the data collected at the various study sites. For the sites where improvements were made and a second (or third) study was performed, the results from each phase are shown and any changes noted are discussed.

OBSERVATION PERIODS

The video equipment used in this study could be configured to record certain hours and/or days of the week, depending on the study site and on what officials hoped to learn there. Specific details on the times and days of recording are given in the section that discusses each site. At all sites, crossings were identified by time and classified as morning peak (6:00 AM to 9:00 AM), midday (9:00 AM to 3:00 PM), or PM peak (3:00 PM to 7:00 PM). Some locations started recording earlier in the morning or ended recording later in the evening and have additional time classifications for crossings. These are also mentioned in the sections below, when applicable.

The sample size at each location consisted of "crossing events," as opposed to the total number of pedestrians. If two or more pedestrians crossed the road as a group, this was considered to be one crossing event because pedestrian and motorist reactions were the same for all members of the group.

I. SR 7—Spanaway

At the Spanaway site, pedestrian and vehicle behavior at the study location was observed between 6:00 AM and 7:00 PM on all days, including weekends. Table B-1 outlines the observation periods for the three phases of analysis.

Table B-1. Observation periods—Spanaway

	SR 7 Spanaway at 180th Street		
	Before	**After — Phase I**	**After — Phase II**
Total Sample Size (N)	N = 220	N = 74	N=314
Hours of Observations	550 hours	161 hours	350 hours
Date of Observation	March - May 2004	July 2005	November - December 2007

II. SR 99—Shoreline

At the Shoreline site, pedestrian and vehicle behavior was observed between 6:00 AM and 7:00 PM, Monday through Thursday. Table B-2 outlines the observation period for the site analysis.

Table B-2. Observation period—Shoreline

Description	SR 99 Shoreline at 152nd Street
Total Sample Size (N)	N = 300
Hours of Observations	35.5 hours
Date of Observation	October 2004

III. SR 99—Kent

At the Kent location, pedestrian and vehicle behavior was observed between 6:00 AM and 7:00 PM, Monday through Thursday, for the *before* study and seven days per week during the *after* study. Data at this site were collected in two phases: Phase 1 collected data for all crossings (signalized intersection and mid-block crossings). Phase 2 collected data for only the mid-block crossings. Many more crossings occurred at the signalized intersection than at mid-block locations. The two phases of data collection allowed the opportunity to assemble ample information on both types of crossings. Table B-3 outlines Phase 1 of the data collection.

Table B-3. Observations in Phase 1: intersection and mid-block crossings—Kent

	SR 99 Kent at 240th Street	
	Before	**After**
Total Sample Size (N)	N_1 = 252	N_1 = 220
Hours of Observations	9 hours	13 hours
Date of Observation	January 2005	February 2007

Table B-4 includes all mid-block crossings for the study period (including mid-block crossings from both Phase 1 and 2).

Table B-4. Observations of all mid-block crossings (Phases 1 and 2) —Kent

	SR 99 Kent at 240th Street	
	Before	**After**
Total Sample Size (N)	N = 302	N = 308
Hours of Observations	46 hours	104 hours
Date of Observation	January - March 2005	February 2007

IV. SR 2—Airway Heights

At the Airway Heights site, pedestrian and vehicle behavior was observed between 5:00 AM and 12:00 AM on all days, including weekends. Additional time classifications at this site included early morning (5:00 AM to 6:00 AM) and evening (7:00 PM to 12:00 AM). Table B-5 outlines the observation periods for the study.

Table B-5. Observation periods—Airway Heights

	SR 2 Airway Heights between King and Lundstrom Streets	
	Before	**After**
Total Sample Size (N)	N = 303	N = 330
Hours of Observation	144 hours	159 hours
Dates of Observation	January - February 2006	June - July 2006

V. SR 2 —Spokane—Three Sites

In Spokane, pedestrian and vehicle behavior at the study locations was observed between 6:00 AM and 8:00 PM, Monday through Sunday. For these sites the "evening" time classification refers to 7:00 PM to 8:00 PM. Table B-6 includes details on the crossings observed during the study period.

Table B-6. Observations of crossings—Spokane

	SR 2 Spokane Division and Lacrosse (4-way unsignalized intersection, unmarked crosswalks)	SR 2 Spokane Division and Rowan (3-way signalized intersection, marked crosswalks)	SR 2 Spokane Division and Wellesley (4-way signalized intersection, marked crosswalks)
Total Sample Size (N)	N = 224	N = 301	N = 330
Hours of Observations	100 hours	79 hours	18 hours
Date of Observation	October - November 2006	November 2006	October 2006

NUMBER OF PEDESTRIAN CROSSINGS

The tables in the previous section displayed the number of hours of video collected at each site. The tables also included the number of crossings recorded in that time frame. These values were used to compute the average number of crossing events per hour at the sites before and after treatment. Table B-7 shows the results from the Spanaway site.

Table B-7. Average pedestrian crossings per hour—Spanaway

	SR 7 Spanaway at 180th Street		
	Before	**After — Phase I**	**After — Phase II**
Average crossings/hour	0.4	0.5	0.9

While the difference at this site between the *before* treatment and the first *after* treatment was not statistically significant, there was a statistically significant change between the *before* phase and the second *after* phase. This may be due to the timing of the data collection for the second *after* phase (during the winter holidays), which could have resulted in an increase in pedestrian traffic to the retail establishments in this area.

Table B-8 shows the results at the Shoreline site.

Table B-8. Average pedestrian crossings per hour—Shoreline

	SR 99 Shoreline at 152nd Street
Average crossings/hour	8.5

Table B-9 shows the results at the Kent site.

Table B-9. Average pedestrian crossings per hour (mid-block crossings only)—Kent

	SR 99 Kent at 240th Street	
	Before	**After**
Average crossings/hour	6.6	3.0

There was a statistically significant change in the number of pedestrians per hour crossing for the Kent study site. This is likely due to the relocation of one bus stop, the widening of the roadway, and the use of weekend video in the *after* analysis that was not present in the *before* analysis.

Table B-10 shows the results at the Airway Heights site.

Table B-10. Average pedestrian crossings per hour—Airway Heights

	SR 2 Airway Heights between King and Lundstrom Streets	
	Before	**After**
Average crossings/hour	2.1	2.1

There was no significant change in pedestrian crossings per hour between the *before* and *after* studies at this site.

Table B-11 shows the results at the Spokane sites.

Table B-11. Average pedestrian crossings per hour—Spokane

	SR 2 Spokane Division and Lacrosse (4-way unsignalized intersection, unmarked crosswalks)	SR 2 Spokane Division and Rowan (3-way signalized intersection, marked crosswalks)	SR 2 Spokane Division and Wellesley (4-way signalized intersection, marked crosswalks)
Average crossings/hour	2.2	3.8	18.3

TIME OF DAY OF CROSSINGS

The data were also analyzed for the time of day that crossings occurred. The results for the Spanaway site are shown below in Figure B-1. (Note that because of the wide variation of pedestrian volumes, different scales are used in the graphs in the following section.)

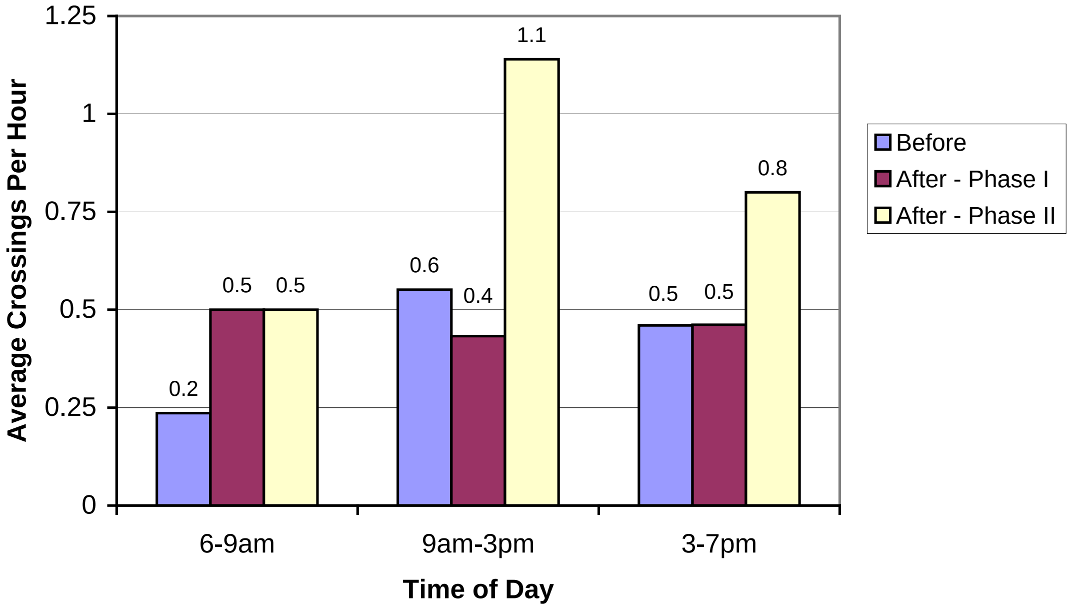


Figure B-1. Number of crossings per hour by time of day—Spanaway

Although there was no statistically significant difference in the data from the *before* and first phase of the *after* study in Spanaway, there was a statistically significant change between the *before* and second phase of the *after* study. Because the second phase of the *after* study was filmed during the holiday season, the increase in pedestrian activity during the day and evening hours may be attributed to shoppers visiting the retail stores in this area, rather than an overall change in pedestrian activity.

Figure B-2 shows the results at the Shoreline site. Figure B-3 shows the results at the Kent site.

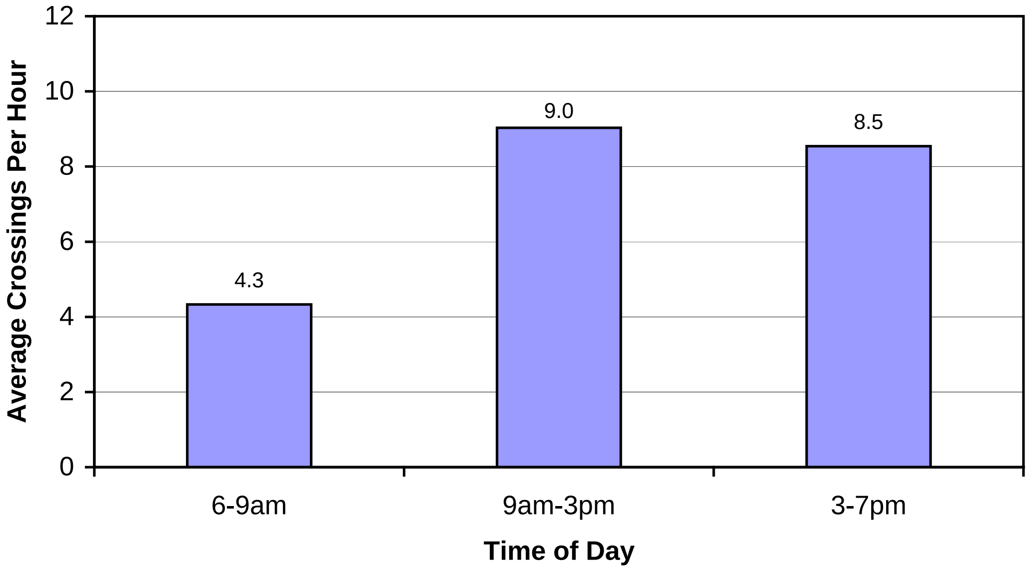


Figure B-2. Average pedestrian crossings per hour—Shoreline

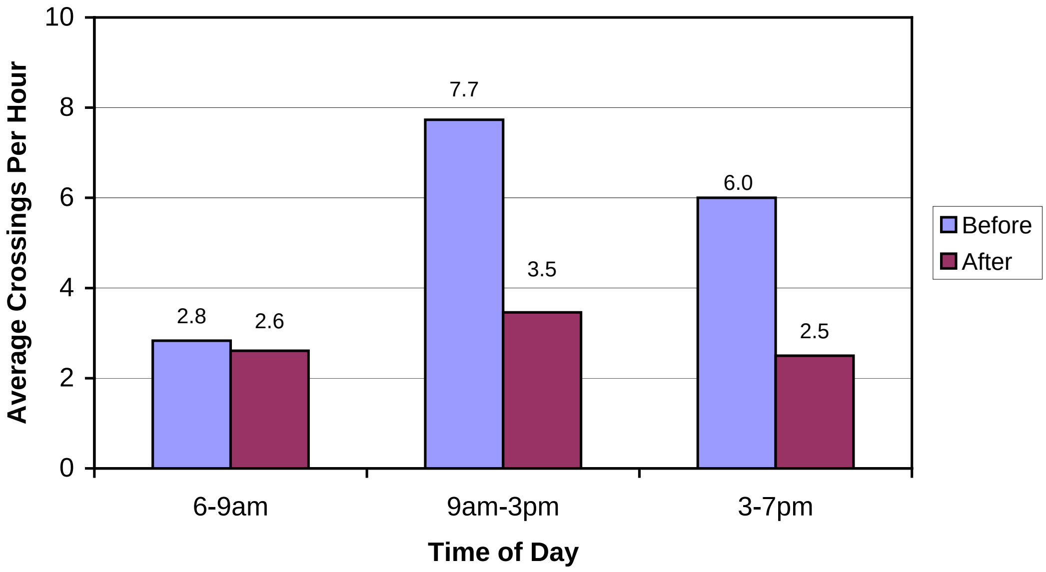


Figure B-3. Average pedestrian crossings per hour—Kent

The distribution of pedestrian traffic throughout the day in Kent may have been greatly influenced by the start and end times of classes at the adjacent Highline Community College, where, in general, about 10 percent of the classes began or ended during the morning peak period, about 75 percent began or ended during the midday period, and 15 percent began or ended during the PM peak period.

The reduction in pedestrian volumes was likely due to the relocation of one of the bus stops, the widening of the roadway, and the hours during which the video images were taken that were reviewed in this study. The stop for Route 166 was moved to an on-campus location. The new location made it possible for riders to board and alight directly to the Highline Community College campus, without having to cross any streets or large parking areas. The *after* study was also performed on a seven-lane roadway, as opposed to the five lanes that were present during the *before* study. This may have caused some pedestrians to cross at the signal rather than risk a mid-block crossing on such a wide road. In addition, the video data reviewed for the *after* study contained a larger proportion of weekend footage than that of the *before* study. Because most of the crossings involved pedestrians going to and from the college and few classes were offered on the weekends, this likely decreased the overall rate of pedestrian observations, as well.

Figure B-4 shows the results at the Airway Heights site. There was no statistically significant change in pedestrian volumes between the *before* and *after* studies at this site.

Figure B-5 through Figure B-7 show the results at the Spokane sites.

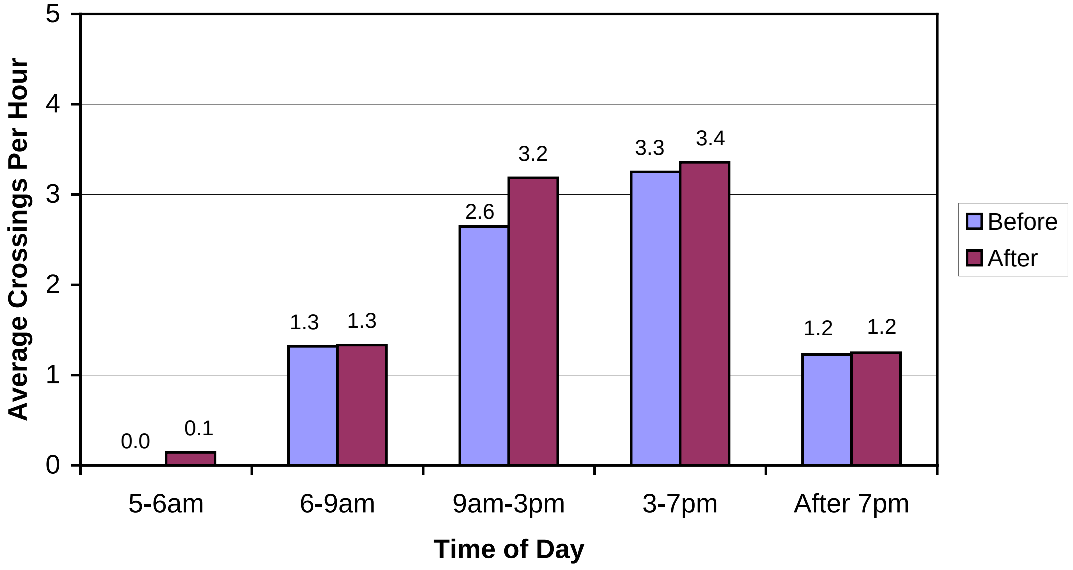


Figure B-4. Average pedestrian crossings per hour —Airway Heights

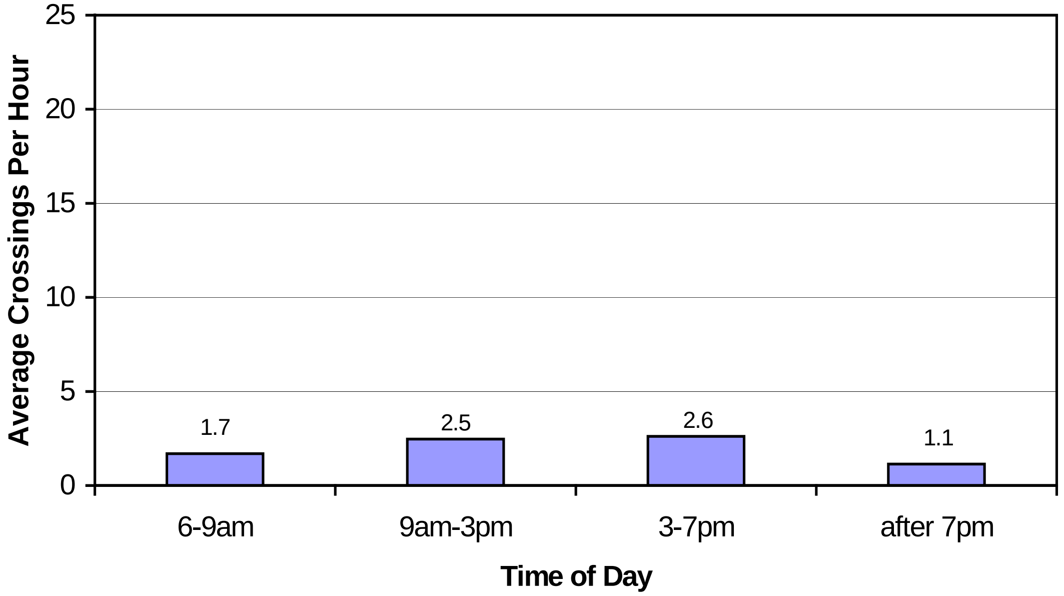


Figure B-5. Average pedestrian crossings per hour (Lacrosse Avenue)—Spokane

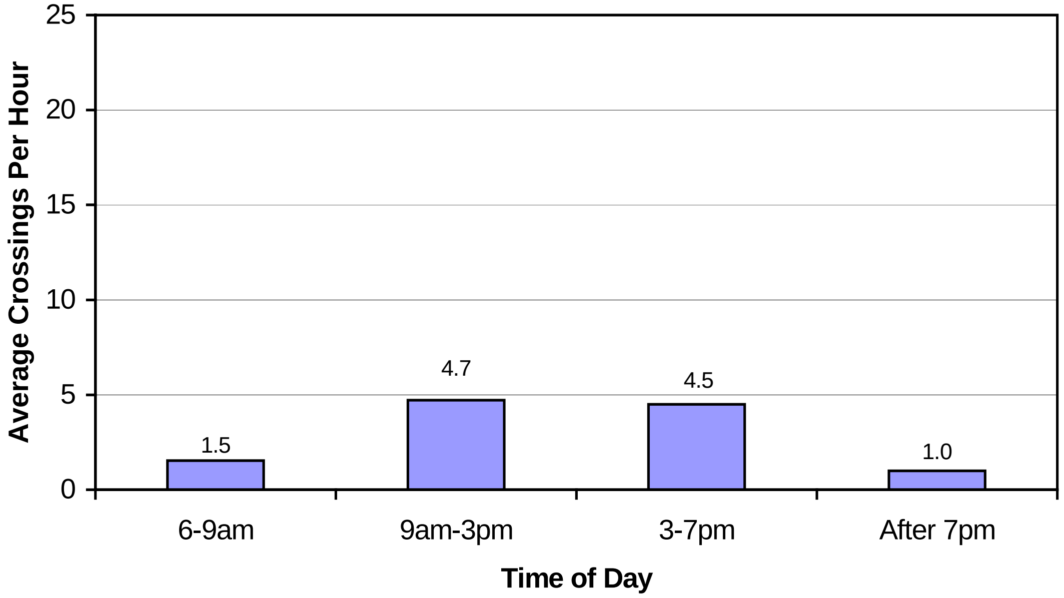


Figure B-6. Average pedestrian crossings per hour (Rowan Avenue)—Spokane

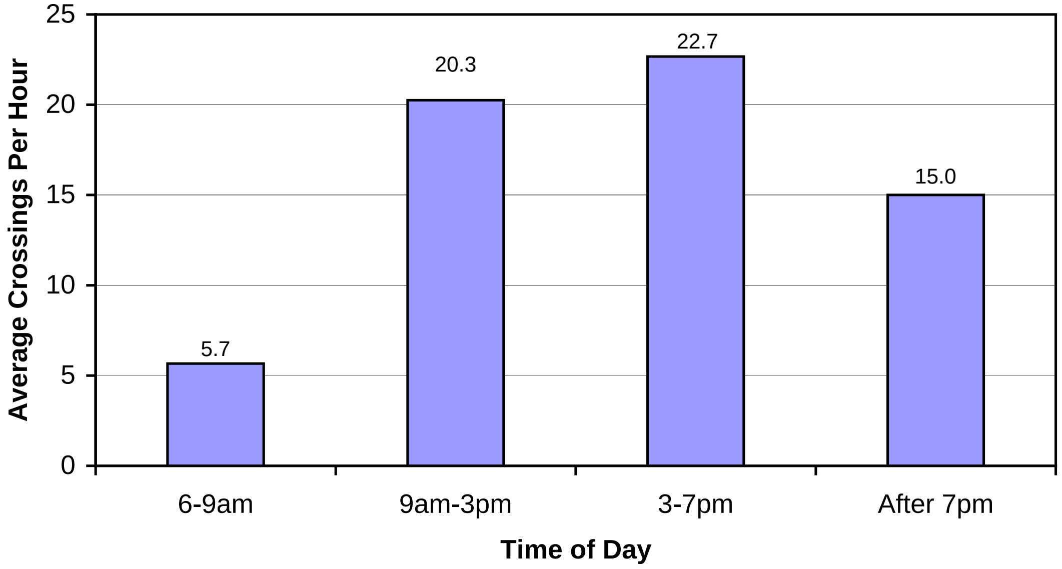


Figure B-7. Average pedestrian crossings per hour (Wellesley Avenue)—Spokane

PEDESTRIAN CROSSING PATHS

When each crossing was observed, the crossing path that the pedestrian or group of pedestrians took was also recorded. The intent was to discover the common paths used, origins and destinations of pedestrians, and potentially, the reasons for crossing at a particular place so that future crossings could better serve the needs of the pedestrians using the facilities. Those paths are displayed below for each site.

Figure B-8 and Figure B-9 display the crossing paths of the pedestrians in the *before* study near South 180th Street in Spanaway.

Figure B-8. Pedestrian crossing paths to the north of S. 180th Street—*before* condition (Spanaway) (Kopf and Hallenbeck 2005)

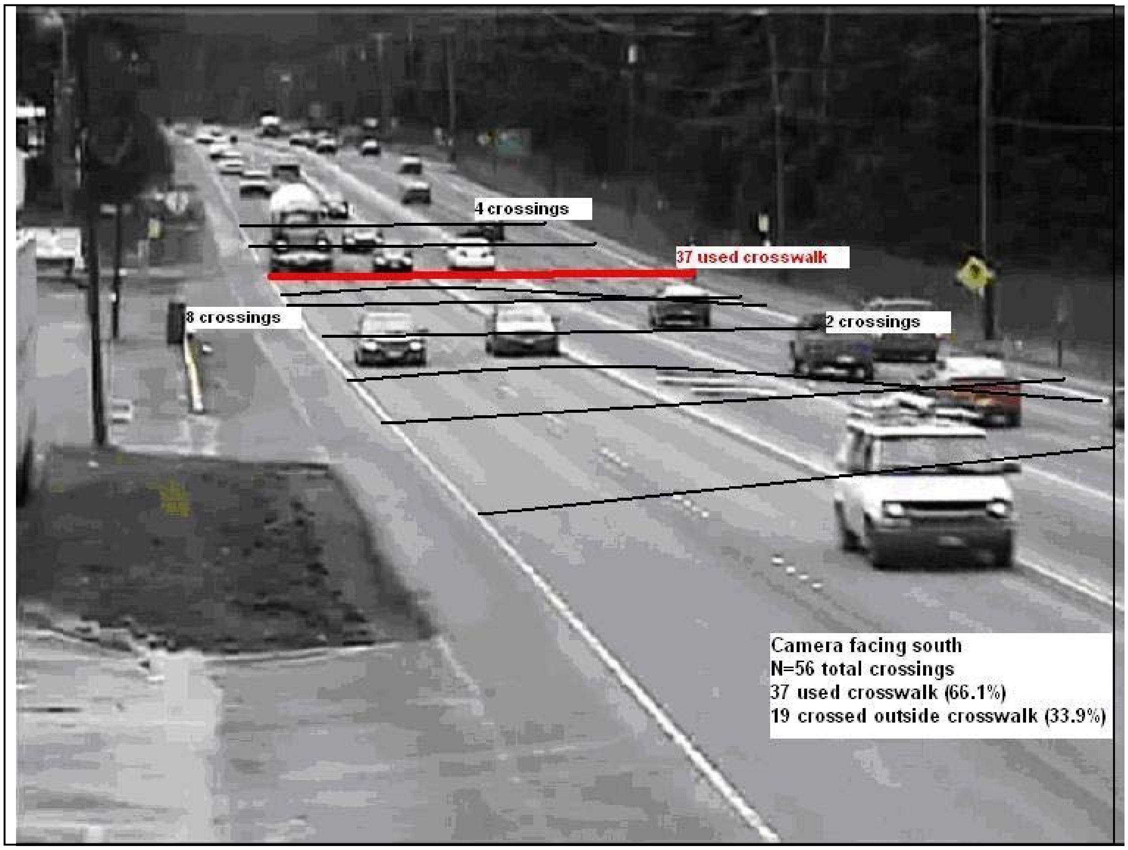


Figure B-9. Pedestrian crossing paths to the south of S. 180th Street—*before* condition (Spanaway) (Kopf and Hallenbeck 2005)

The paths are labeled with the number of crossings at that location. If a path is not labeled, it means that only one crossing occurred there. The factors that affected how pedestrians crossed included the origins and destinations of the observed pedestrians and whether there was a gap in traffic for crossing.

Figure B-10 displays the crossing paths after installation of the median. Note that an additional 15 percent of the crossings occurred just to the south of the median (path labeled “11 crossings” in Figure B-10).

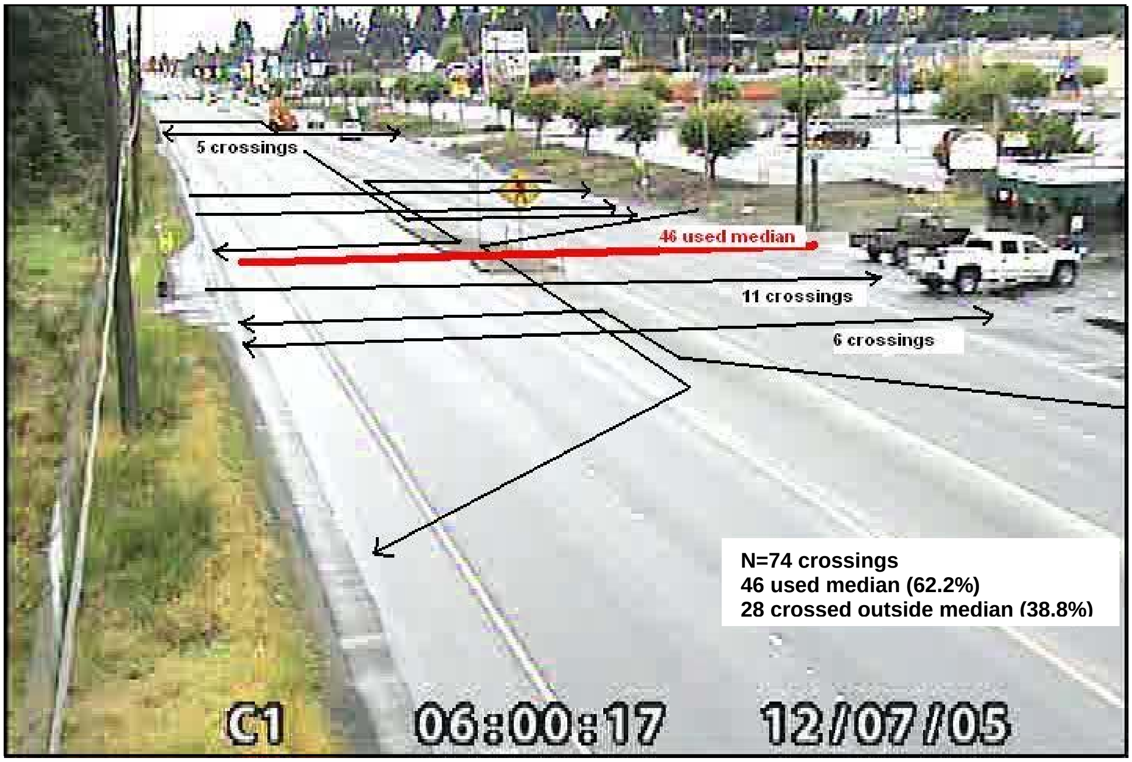


Figure B-10. Pedestrian crossing paths after median treatment —*after*—phase I condition (Spanaway) (Kopf and Hallenbeck 2005)

Figure B-11 displays the crossing paths after reinstallation of the crosswalk markings.

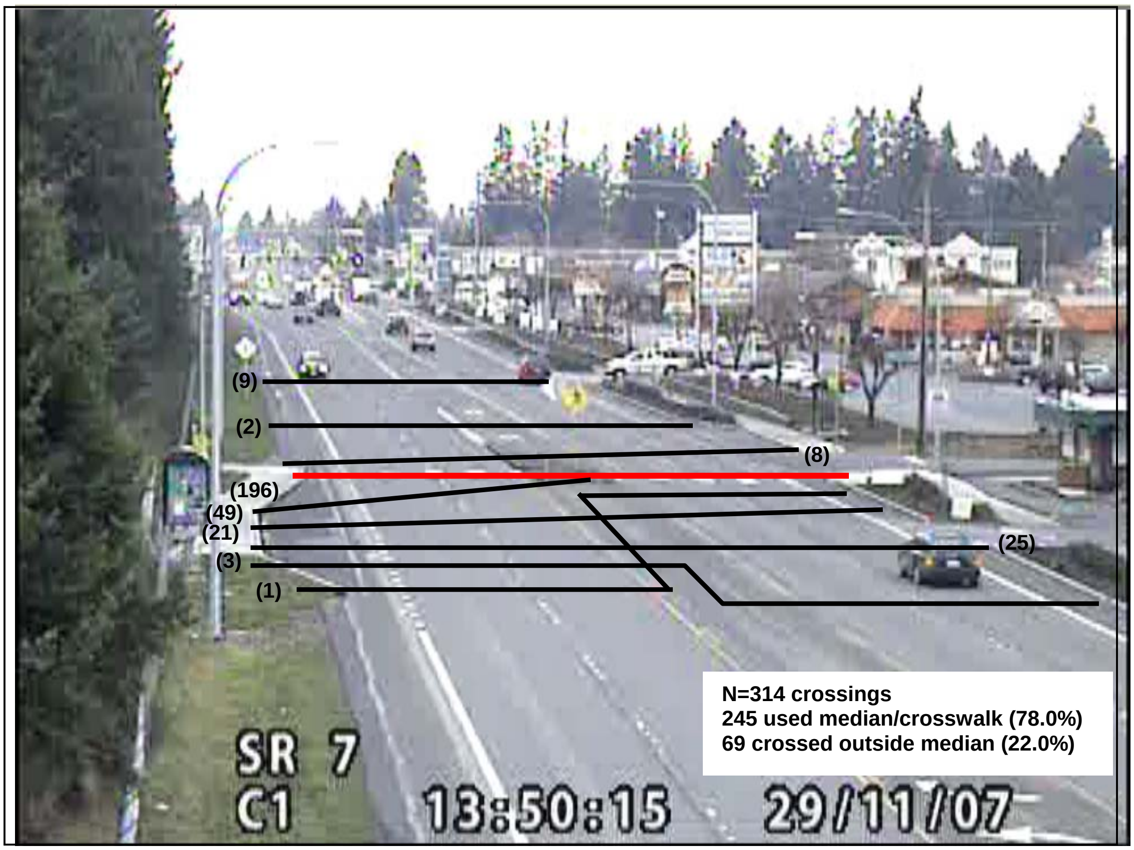


Figure B-11. Pedestrian crossing paths—*after*—phase II condition (Spanaway)

The study results revealed that pedestrians were less likely to use the median refuge after implementation than to use the marked crosswalks before the changes. When the crosswalk markings were reinstalled, crosswalk/median use returned to levels similar to those of the *before* study.

The *before* study showed that the majority of pedestrians crossed within the marked crosswalks. Over 85 percent of the crossings to the north of S. 180th Street were within the crosswalk. Over 65 percent of the crossings to the south of S. 180th Street were within that crosswalk. When the crossing data for both directions were combined, over 80 percent of the crossings were within the two marked crosswalks.

The installation of the pedestrian refuge did not funnel pedestrians to that crossing location. After the treatment had been implemented, only about 60 percent of pedestrians used the median refuge area. The transit stop on the west side of street was not parallel with the refuge area, and the additional 11 crossings occurred at the point where the pedestrians exited the bus. These pedestrians were protected somewhat by the median but did not follow the designated refuge path.

During the second phase of improvements, the crosswalk markings were reinstalled at South 180th Street. After those improvements, use of the crosswalk/median returned to levels that were not significantly different from those of the *before* study.

Figure B-12 displays the crossing paths at the Shoreline site.

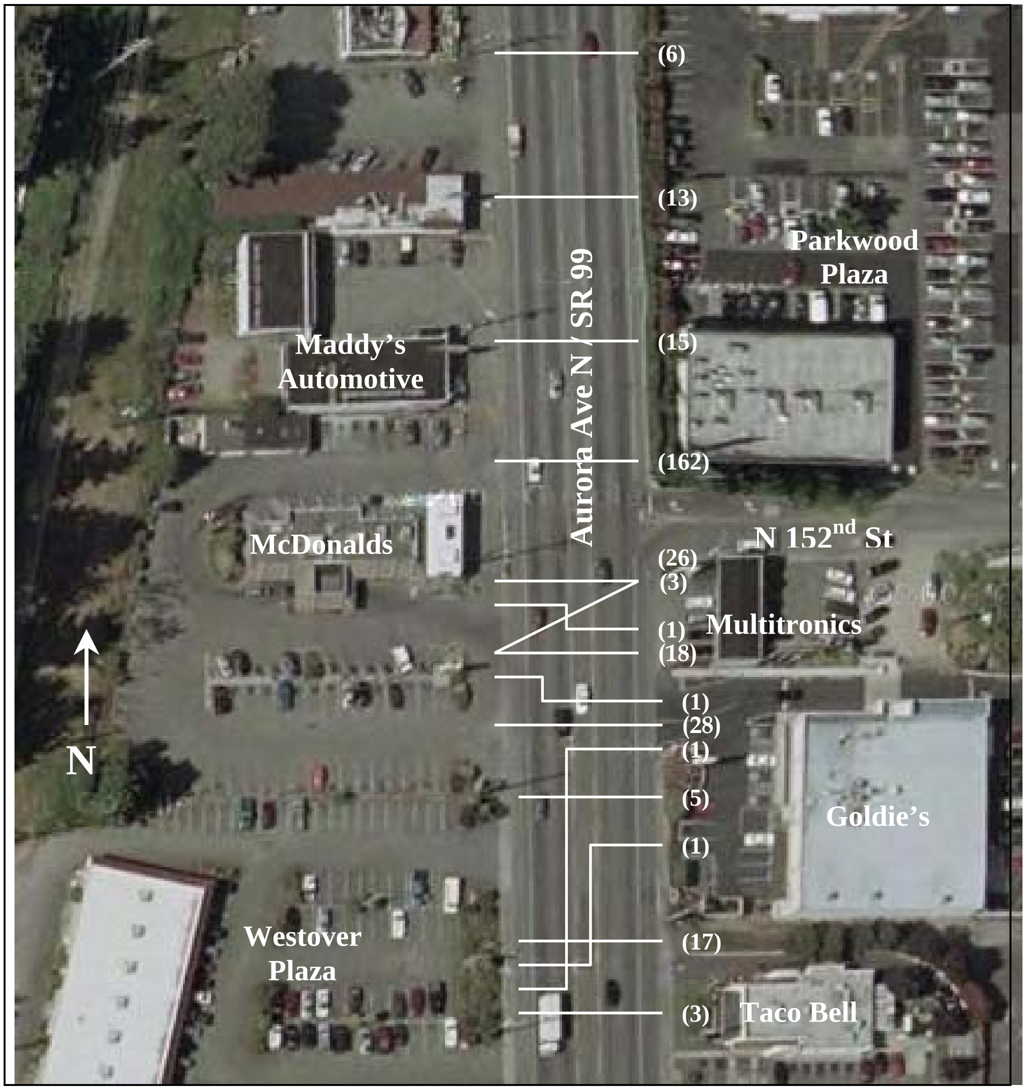


Figure B-12. Pedestrian crossing paths—Shoreline (Google Maps)

Figure B-13 displays the crossing paths at the Kent site, before improvements were made (includes only those pedestrians not using the signalized marked crosswalks).

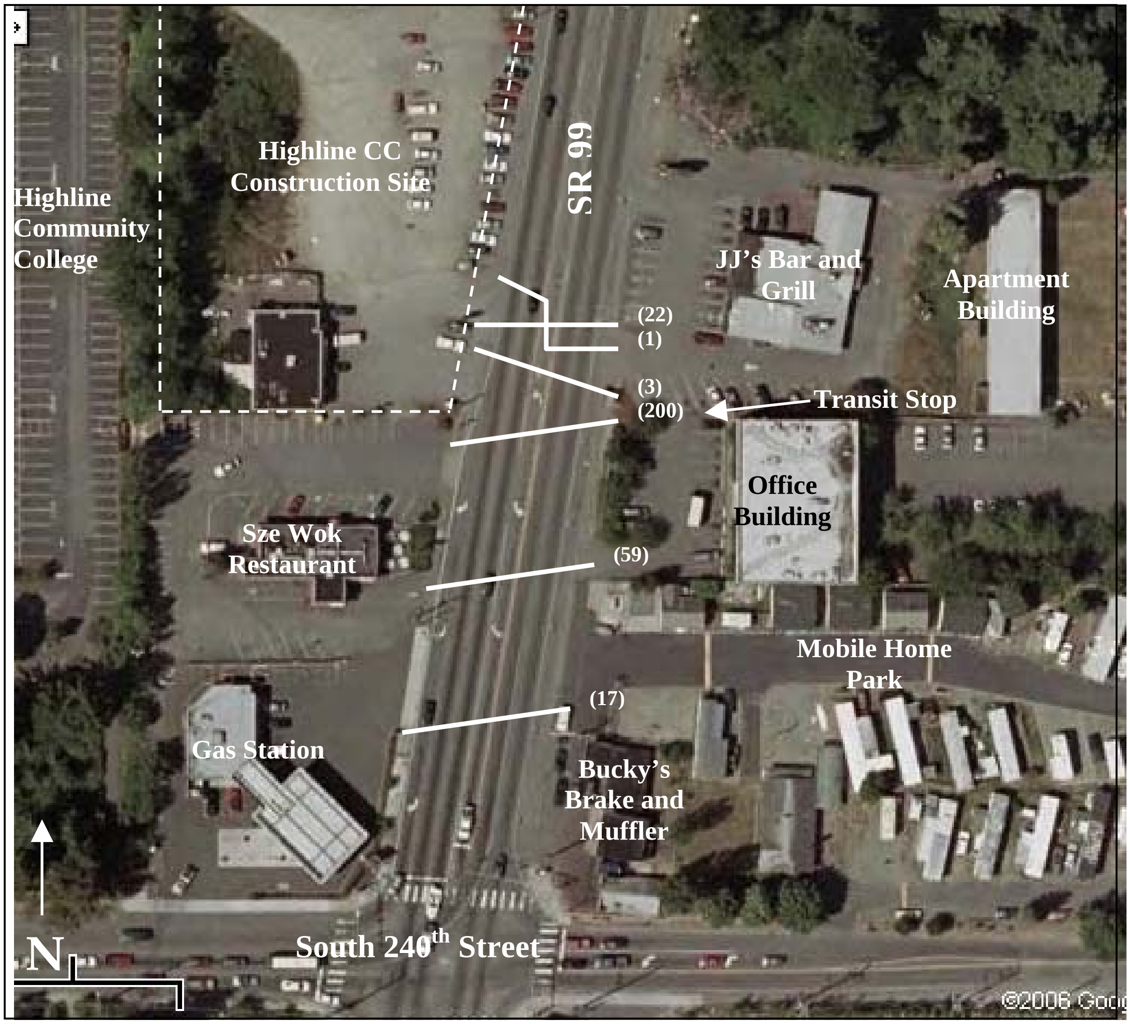


Figure B-13. Pedestrian crossing paths—*before* condition—Kent (Google Maps)

Figure B-14 shows the crossing paths used by pedestrians during the *after* portion of data collection. Again, this shows only those crossings made outside of the marked, signalized crosswalks.

Figure B-14. Pedestrian crossing paths—*after* condition—Kent (Google Maps)

In Kent, the crossings seemed to move toward the intersection at South 240th Street after the improvements were made. It is possible that this was due to pedestrians emerging near the Sze Wok Restaurant, seeing there was no opportunity to cross, making their way toward the traffic signal while checking for gaps as they walked, and then using any available gaps to cross.

Figure B-15 displays the crossing paths at the Airway Heights site, before improvements were made.

Figure B-15. Pedestrian crossing paths in the *before* analysis—Airway Heights (Google Maps)

Figure B-16 displays the crossing paths at the Airway Heights site, after improvements were made.

Figure B-16. Pedestrian crossing paths in the *after* analysis—Airway Heights (Google Maps)

In Airway Heights, there appears to have been very little change in the crossing paths of pedestrians from the *before* to the *after* study. This was the expected result because the changes made to the crossing treatment for the *after* condition were fairly minor and concentrated more on vehicle safety where they interacted with the pedestrians, rather than on channeling pedestrian movements to the crossing.

Figure B-17 through Figure B-19 display the crossing paths at the Spokane sites.

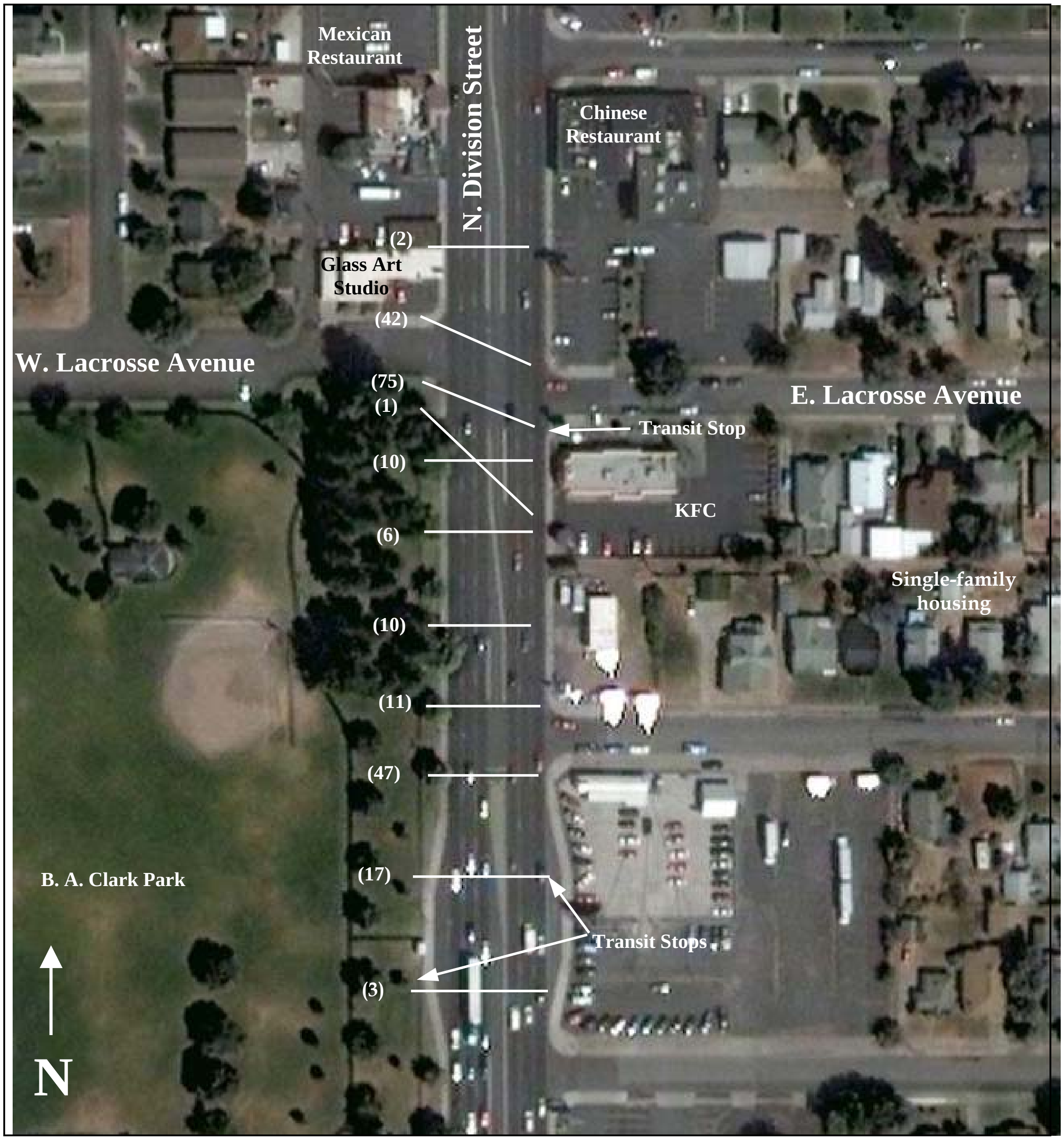


Figure B-17. Pedestrian crossing paths at Lacrosse Avenue—Spokane (Google Maps)

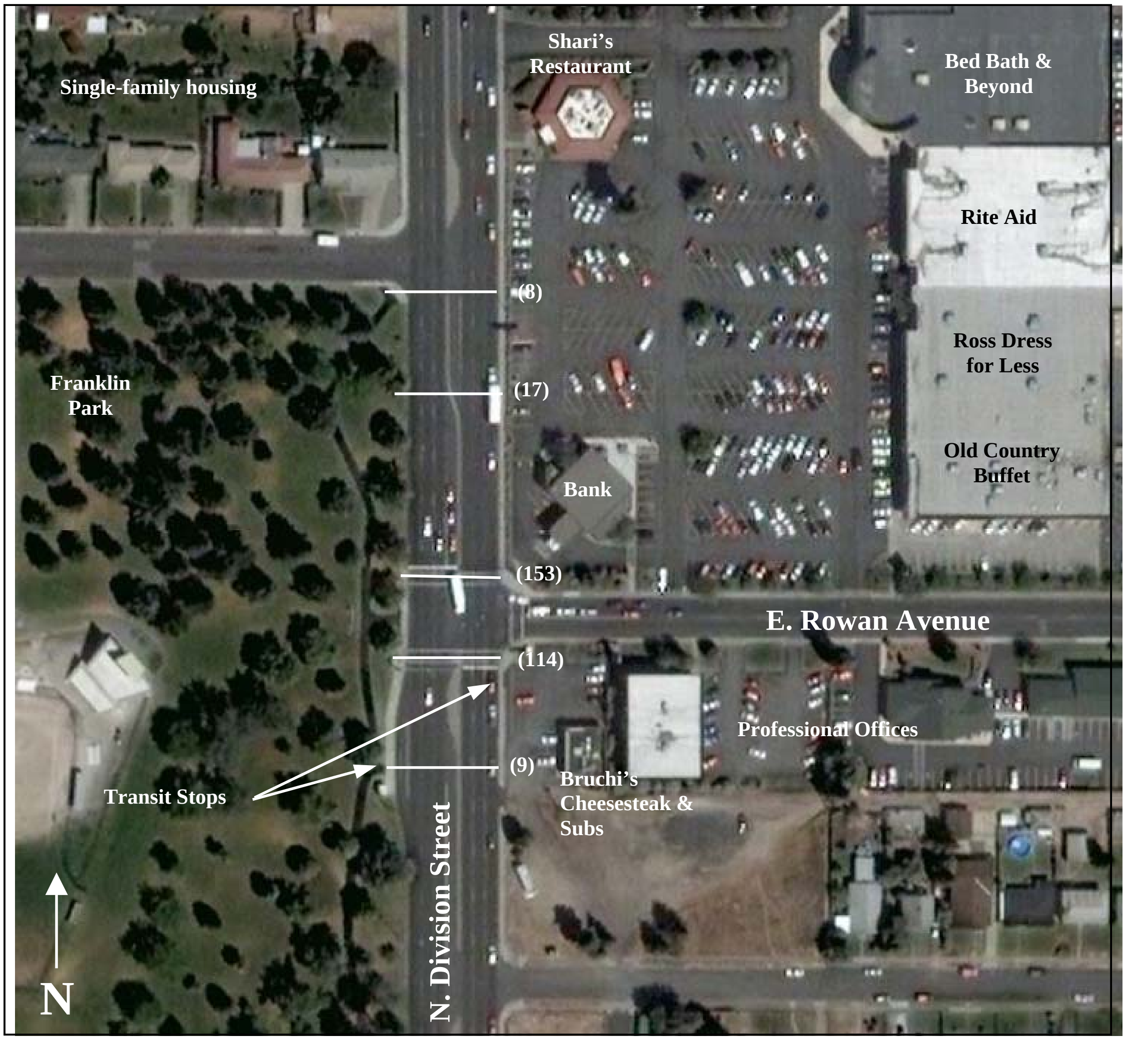


Figure B-18. Pedestrian crossing paths at Rowan Avenue—Spokane (Google Maps)

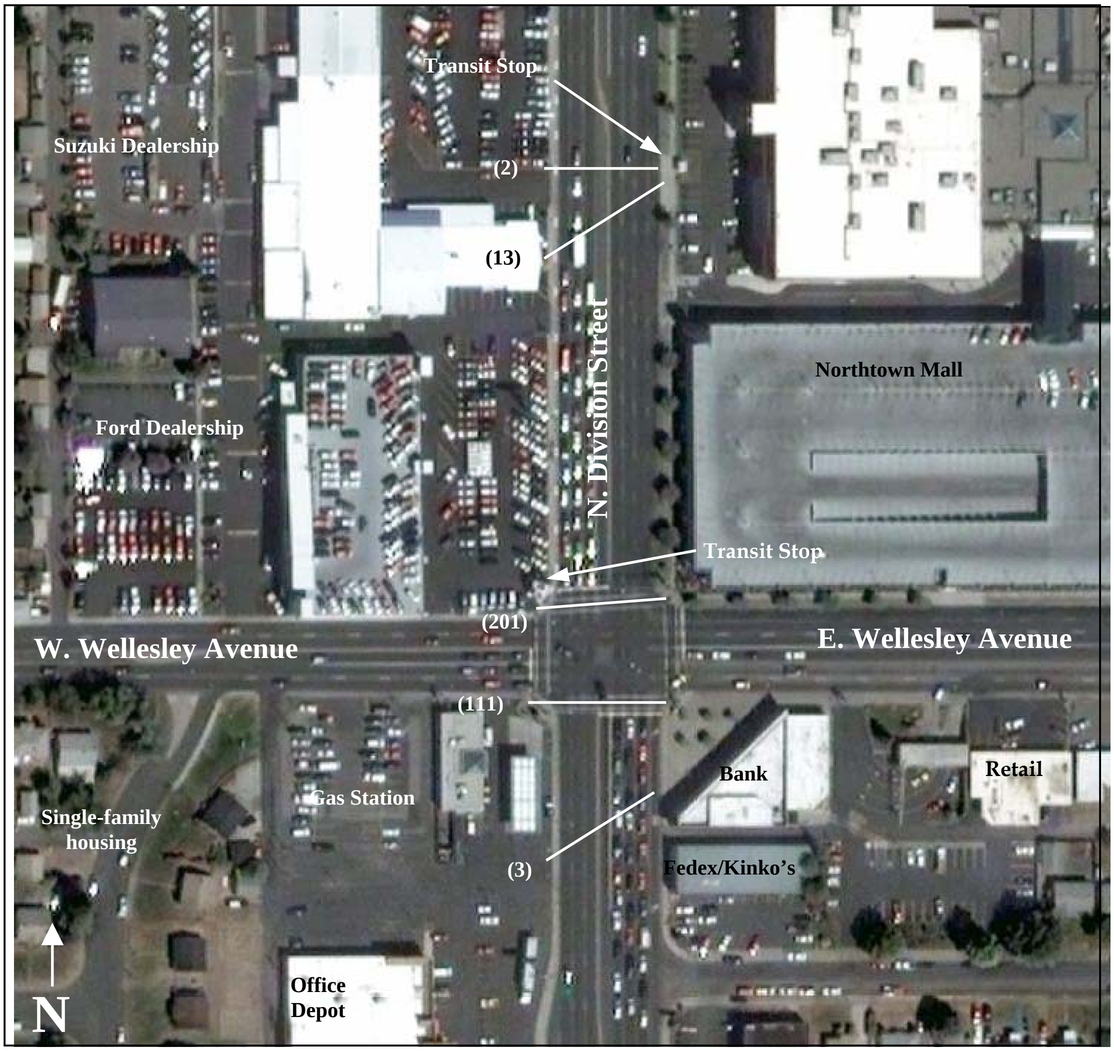


Figure B-19. Pedestrian crossing paths at Wellesley Avenue—Spokane (Google Maps)

Crosswalk Use

In general, pedestrians were fairly diligent about using the (marked or unmarked) crosswalks, with the possible exception of those using transit and crossing to get to and from bus stops. However, in all cases, a significant percentage (ranging from 5 to 20 percent) of all pedestrians crossed at locations not “officially designated” as crosswalks. Factors involved in this crossing location decision may have included the characteristics of the street, the origins and destinations of the pedestrians, and whether or not a gap opened in traffic to facilitate crossing at other locations. Table B-12 shows the results at the Spanaway site.

Table B-12. Use of the crosswalks and median refuge—Spanaway

	SR 7 Spanaway at South 180th Street		
	Before (N=220)	**After — Phase I (N=74)**	**After — Phase II (N=314)**
Used crosswalk / median	81.4% (179)	62.2% (46)	78.0% (245)
Crossed outside designated area	18.6% (41)	37.8% (28)	22.0% (69)

Shaded area – The change between the *before* phase and the *after* (phase I) treatment phase was significant at the 0.001 level.

The difference between the *before* treatment and the first *after* treatment in Spanaway was significant (shaded area), but there was no statistically significant difference between the *before* data and the data from the second phase of improvements.

Table B-13 shows the results at the Shoreline site.

Table B-14 shows the results at the Kent site. There was no statistically significant change in crosswalk use between the *before* and *after* studies in Kent.

Table B-15 shows the results at the Airway Heights site.

Table B-13. Use of the unmarked crosswalks—Shoreline

Description	SR 99 Shoreline at 152nd Street—no marked crosswalks (N=300)
Used unmarked crosswalk	62.7% (188)
Did not use crosswalk	37.3% (112)

Table B-14. Use of the signalized marked crosswalks—Kent

	SR 99 Kent at 240th Street	
	Before (N_1=252)	**After (N_1=220)**
Used marked, signalized crosswalk	74.6% (188)	81.8% (180)
Did not use crosswalk	25.4% (64)	18.2% (40)

Table B-15. Use of the crosswalk/median—Airway Heights

	U.S. 2 Airway Heights between King and Lundstrom Streets	
	Before	**After**
Used crosswalk / median	88.4% (268)	87.0% (287)
Did not use crosswalk	11.6% (35)	13.0% (43)

There was no statistically significant change in crosswalk use between the *before* and *after* studies in Airway Heights. This site shows that improvements in the available pedestrian amenities can influence behavior through design, but these designs do not override human behavior and the choices people make.

Table B-16 shows the results at the Spokane sites.

Table B-16. Use of the unmarked/marked crosswalks—Spokane

Description	SR 2 Spokane Division and Lacrosse (unsignalized)	SR 2 Spokane Division and Rowan (signalized)	SR 2 Spokane Division and Wellesley (signalized)
Used crosswalk / signal	79.9% (179)	88.0% (265)	94.5% (312)
Did not use crosswalk	20.1% (45)	12.0% (36)	5.5% (18)

MOTORIST YIELDING BEHAVIOR

Motorist yielding rates for each of the study areas are shown below. The tables detail the percentage of crossings when a vehicle traveling in the specified direction yielded for a pedestrian, including only those crossings made when vehicles were present.

Table B-17 shows the results for the Spanaway site.

Table B-17. Percentage of crossings when vehicles yielded for pedestrians—Spanaway (excludes crossings made with no vehicles present)

	Yielding instances (N)		
	Before	**After — Phase I**	**After — Phase II**
Southbound vehicle yielding	37.7% (52)	▨ 8.9% (4)	32.0% (58)
Northbound vehicle yielding	72.5% (100)	▨ 37.0% (17)	▨ 42.8% (107)

Shaded area—The change between the *before* phase and the *after* treatment phase(s) was significant at the 0.01 level.

The raised refuge island was designed to change pedestrians' behavior by improving their crossing environment. However, the analysis detailed in the previous section revealed that installation of the median did not increase pedestrian usage of designated crossing zones until the crosswalk markings were reinstalled. Further analysis was conducted to determine the effect of the median and median/crosswalk combination on the yielding behavior of vehicles.

In Spanaway, higher motorist yielding rates were observed during the *before* phase than after installation of the median (shaded area). Motorists in both the southbound and northbound directions yielded more frequently before installation of the median. After the median installation, yielding compliance decreased nearly 20 percent. When the crosswalk markings were reinstalled, yielding by southbound vehicles rebounded to their previous levels in the *before* study, but there was still a statistically significant difference in yielding by northbound vehicles between the *before* study and the second phase of the *after* study (at a 0.0001 level). In all phases of the study, the northbound vehicles had a statistically significant (at a 0.05 level or above) higher rate of yielding to pedestrians than the southbound vehicles.

Table B-18 shows the results for the Shoreline site.

Table B-18. Percentage of crossings where vehicles yielded for pedestrians—Shoreline (includes only those crossings where vehicles were present)

	Yielding instances (N)
Southbound vehicle yielding	20.8% (27)
Northbound vehicle yielding	24.5% (36)

There was no statistically significant difference in the yielding behavior between the northbound and southbound vehicles in Shoreline.

Table B-19 shows the results for the Kent site.

Table B-19. Percentage of crossings where vehicles yielded for pedestrians—Kent (includes only those crossings where vehicles were present)

	Yielding instances (N)	
	Before	**After**
Southbound vehicle yielding	14.5% (24)	17.6% (27)
Northbound vehicle yielding	7.1% (7)	8.7% (11)

In Kent, there was no statistically significant difference in the vehicle yielding rates observed in the *before* and *after* studies; however, the difference between southbound and northbound vehicle yielding was statistically significant (at the 0.05 level) in both the *before* and *after* studies.

Table B-20 shows the results for the Airway Heights site.

Table B-20. Percentage of crossings when vehicles yielded for pedestrians—Airway Heights (includes only those crossings where vehicles were present)

	Yielding instances (N)	
	Before	**After**
Eastbound vehicle yielding	86.0% (161)	▨ 65.5% (141)
Westbound vehicle yielding	84.4% (132)	▨ 62.2% (123)

Shaded area—The change between the *before* phase and the *after* treatment phase was significant at the 0.0001 level.

During the *after* phase of the project at Airway Heights, vehicle yielding behavior decreased by 20 percent (shaded area). There was no statistically significant difference in yielding behavior between the eastbound and westbound traffic.

Table B-21 shows the results for the Spokane sites.

Table B-21. Percentage of crossings where vehicles yielded for pedestrians—Spokane (excluding crossings made in gaps in traffic)

Description	SR 2 Spokane Division and Lacrosse (N=224)	SR 2 Spokane Division and Rowan (N=301)	SR 2 Spokane Division and Wellesley (N=330)
Southbound vehicle yielding	19.5% (29)	47.4% (9)	61.5% (8)
Northbound vehicle yielding	9.0% (12)	23.1% (3)	62.5% (5)

Shaded area—The change between the southbound and northbound vehicle yielding behavior was significant at the 0.05 level.

At the Lacrosse Avenue site, there was a statistically significant difference (at the 0.05 level) in the vehicle yielding behavior observed in the southbound direction in comparison to the northbound direction. At the Rowan and Wellesley Avenue sites, the sample sizes were too small to be examined.

Motorists Not Yielding

The response of vehicles to each crossing event was analyzed with additional detail. Vehicles at each site were tracked to determine how many vehicles passed a waiting pedestrian before either one or more yielded or a break in traffic opened for the pedestrian to cross. The following tables present the average number of vehicles that did not yield per crossing event. This value was also determined for each direction of traffic. The tables include only crossings made with vehicles present.

Table B-22 shows the results at the Spanaway site.

Table B-22. Average number of vehicles that did not yield per crossing event—Spanaway (excluding events with zero vehicles involved)

	Average number not yielding per crossing		
	Before	**After — Phase I**	**After — Phase II**
Southbound vehicles	5.4 (6.2) N=118	12.2 (17.3) N=45	9.4 (14.5) N=164
Northbound vehicles	5.0 (6.6) N=77	11.4 (16.5) N=37	6.2 (9.9) N=209

Shaded area – The change between the *before* phase and the *after* treatment phase(s) was significant at the 0.05 level.

The average number of vehicles that did not yield in Spanaway significantly increased (at a 0.05 level—shaded area) both after median installation and after the crosswalk markings were reinstalled (southbound vehicles only) in comparison to the *before* condition. For northbound vehicles, the number not yielding after the median installation increased significantly (0.05 level), but there was no significant difference between the *before* phase and the second phase of improvements.

Table B-23 shows the results at the Shoreline site.

Table B-23. Average number of vehicles not yielding per crossing event—Shoreline (excluding events with zero vehicles involved)

	Average number not yielding per crossing (Standard deviation)
Southbound vehicles	8.8 (10.1) N=130
Northbound vehicles	12.0 (18.0) N=147

There was no statistically significant difference in the number of vehicles traveling southbound that did not yield and the number of northbound vehicles that did not yield to pedestrians attempting to cross the roadway in Shoreline.

Table B-24 shows the results at the Kent site.

Table B-24. Average number of vehicles not yielding per crossing event—Kent (excluding events with zero vehicles involved)

	Average number not yielding per crossing (Standard deviation)	
	Before	**After**
Southbound vehicles	8.3 (11.1) N=161	7.8 (12.0) N=167
Northbound vehicles	7.7 (7.9) N=103	4.3 (5.5) N=120

Shaded area – The difference between the *before* and *after* data is statistically significant at the 0.0005 level.

There was a statistically significant difference in Kent in the number of northbound vehicles yielding from the *before* to the *after* study (shaded area—at a 0.0005 level). There was also a statistically significant difference (at a 0.001 level) between the number of southbound and northbound vehicles that did not yield in the *after* study.

Table B-25 shows the results at the Airway Heights site.

Table B-25. Average number of vehicles not yielding per crossing event—Airway Heights (excluding events with zero vehicles involved)

	Average number not yielding per crossing (Standard deviation)	
	Before	**After**
Eastbound vehicles	0.6 (1.0) N=185	1.0 (1.8) N=180
Westbound vehicles	1.0 (1.7) N=157	1.2 (2.2) N=167

Shaded area—The change between the *before* phase and the *after* treatment phase was significant at the 0.01 level.

The average number of eastbound vehicles that did not yield in Airway Heights significantly increased (at a 0.01 level) during the *after* phase of the project for eastbound vehicles (shaded area). There were also significantly (at a 0.01 level) more vehicles that did not yield to pedestrians in the eastbound direction than in the westbound direction in the *before* study.

Table B-26 shows the results at the Spokane sites.

Table B-26. Average number of vehicles not yielding per crossing event—Spokane (excluding crossings events made in gaps in traffic)

	Average number not yielding per crossing (Standard deviation)		
Description	SR 2 Spokane Division and Lacrosse	SR 2 Spokane Division and Rowan	SR 2 Spokane Division and Wellesley
Northbound vehicles	15.33 (20.7) N=111	4.23 (5.26) N=13	1.75 (2.49) N=8
Southbound vehicles	8.44 (12.0) N=142	6.00 (9.22) N=19	2.54 (4.67) N=13

There were significantly more vehicles (at a 0.01 level) that passed pedestrians waiting to cross the roadway in the northbound direction than in the southbound direction at the Lacrosse Avenue site in Spokane.

The number of vehicles not yielding to pedestrians attempting to cross the roadway was greater at intersections with fewer traffic controls (i.e., Lacrosse Avenue had the most vehicles that did not yield to crossing pedestrians, followed by Rowan Avenue, and finally Wellesley Avenue).

Effects of Crossing Paths on Vehicle Yielding

The following tables consider the effects of the crossing paths of pedestrians on vehicle yielding. The percentage of crossing events when a vehicle yielded was compared to whether the pedestrian crossed in the designated crossing area. These data were only explored for uncontrolled (i.e., unsignalized) crossing areas.

Table B-27 shows the results from the Spanaway site.

Table B-27. Percentage of vehicles yielding based on crossing paths—Spanaway (includes only those events where vehicles were present)

	Southbound vehicles	Northbound vehicles
Before		
Used crosswalk	41.0% (50)	75.4% (95)
Crossed outside of designated area	12.5% (2)	41.7% (5)
After – Phase I		
Used median	12.9% (4)	36.7% (11)
Crossed outside of designated area	0.0% (0)	37.5% (6)
After – Phase II		
Used median/crosswalk	32.2% (55)	45.5% (100)
Crossed outside of designated area	10.0% (3)	15.2% (7)

In the *after*—phase II study in Spanaway, motorist yielding (in both directions of travel) was significantly lower (at the 0.02 level) for those pedestrians not using the crosswalk/median. Sample sizes of crossings made outside of the designated area during the other phases of the study were not large enough for comparison.

For the *before* data, the designated crossing area was considered to be the marked crosswalks. For both phases of the *after* data, the designated crossing area was the path that included the median refuge. The above table shows that vehicles were significantly more likely to yield to pedestrians if they were in the marked crosswalk. For example, in the southbound direction before the treatment, 41 percent of vehicles yielded for pedestrians in the crosswalk, whereas only about 12 percent yielded when a pedestrian was outside of the crosswalk. However, in neither case was yielding a majority action. Many drivers do not yield to pedestrians attempting to cross arterials regardless of the design of the streetscape. In the second phase of the *after* treatment (with crosswalk markings), yielding was very similar to the *before* treatment for southbound vehicles but was significantly less (at a 0.0005 level) for northbound vehicles. Because the crosswalk markings were installed just days before data collection for that phase began, some motorists may have been unaware that the markings had been replaced. There also may have been some effects from the signalized intersection at South 176th Street. During red signals, the northbound direction of SR 7 routinely backed up to a point near the crosswalk, so drivers may have been concentrating on that rather than on seeing the new crosswalk markings.

Table B-28 shows the results from the Shoreline site.

Table B-28. Percentage of vehicles yielding based on crossing paths—Shoreline (includes only those events where vehicles were present)

	Southbound vehicles	Northbound vehicles
Used unmarked crosswalk	22.4% (19)	28.7% (29)
Crossed outside of designated area	17.8% (8)	16.3% (7)

There was no statistically significant difference between the percentage of vehicles yielding for pedestrians within the unmarked crosswalk and the percentage of vehicles yielding for those who crossed outside of the crossing area in Shoreline.

Because the crosswalks in Kent were located only at controlled intersections, no data were collected for this section.

Table B-29 shows the results from the Airway Heights site.

Table B-29. Percentage of vehicles yielding based on crossing paths—Airway Heights (includes only those events where vehicles were present)

	Eastbound vehicles	Westbound vehicles
Before		
Used median/crosswalk	85.9% (159)	83.4% (131)
Crossed outside of designated area	25.0% (2)	16.7% (1)
After		
Used median/crosswalk	59.3% (134)	54.5% (120)
Crossed outside of designated area	41.2% (7)	30.0% (3)

Shaded area—The change between the *before* phase and the *after* treatment phase was significant at the 0.0001 level.

At the Airway Heights site, there was a significant difference (at a 0.0001 level) in motorist yielding between the *before* and *after* studies. The data suggested that vehicles on SR 2 were more compliant when pedestrians crossed in the marked crosswalk in the *before* condition than in the *after* condition. The sample sizes of pedestrians crossing outside of the designated area during either phase of the study was not large enough to be able to conclude when motorists were more compliant under that condition.

Table B-30 shows the results from the Spokane–Lacrosse Avenue site.

Table B-30. Percentage of vehicles yielding based on crossing paths—Lacrosse Avenue, Spokane (includes only those events where vehicles were present)

	Northbound vehicles	Southbound vehicles
Used crosswalk	12.9% (12)	22.0% (26)
Crossed outside of designated area	0.0% (0)	10.8% (4)

There was no statistically significant difference in the percentage of vehicles yielding to pedestrians crossing in the crosswalk and the percentage of vehicles yielding to those crossing outside of the crossing area at Lacrosse Avenue.

The other two intersections that were studied in the Spokane SR 2 corridor had only controlled crosswalks; no data were collected for this section at those sites.

Pedestrian Wait Location

The following figures display the percentage of crossing events when a vehicle yielded as compared to where the pedestrian stood while waiting to cross (i.e., on the shoulder/sidewalk or in the center lane). This includes only the events in which vehicles were present.

Figure B-20 shows the results at the Spanaway site.

In each phase of the study at the Spanaway site, motorists were significantly more likely (at a 0.04 level) to yield to pedestrians in the center lane than those who had not yet begun to cross the roadway. The change between the *before* and *after* phases for vehicles yielding to pedestrians waiting on the sidewalk and in the center lane to cross was also significant (at a 0.02 level for sidewalk waiting and a 0.0001 level for center lane waiting). Yielding behavior after the reinstallation of the crosswalk markings was significantly higher (at a 0.001 level for center lane waiting) than it was with the median alone, but it had still not rebounded to the level observed in the *before* study. This may have been due to the markings being installed shortly before data collection began for the second phase of improvements. Motorists may not yet have become accustomed to the new crosswalk markings when the data collection was completed. It is also possible that the motorists were less forgiving to the pedestrians waiting in the median and may not have perceived a need to stop because the pedestrian was "safe enough" on the median.

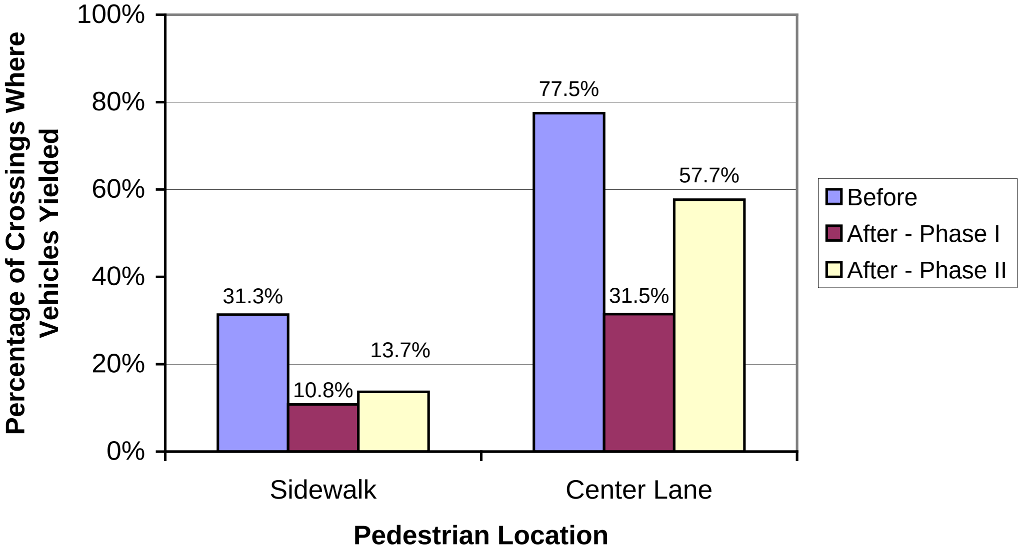


Figure B-20. Percentage of vehicles yielding based on wait location—Spanaway (includes only those events where vehicles were present)

Figure B-21 shows the results at the Shoreline site.

Although there was no statistically significant difference in yielding experienced by pedestrians waiting on the shoulder versus those on the sidewalk at Shoreline, the difference between both the crossings made from the sidewalk and shoulder experienced significantly lower (at a 0.005 level) yielding rates than those made from the center lane.

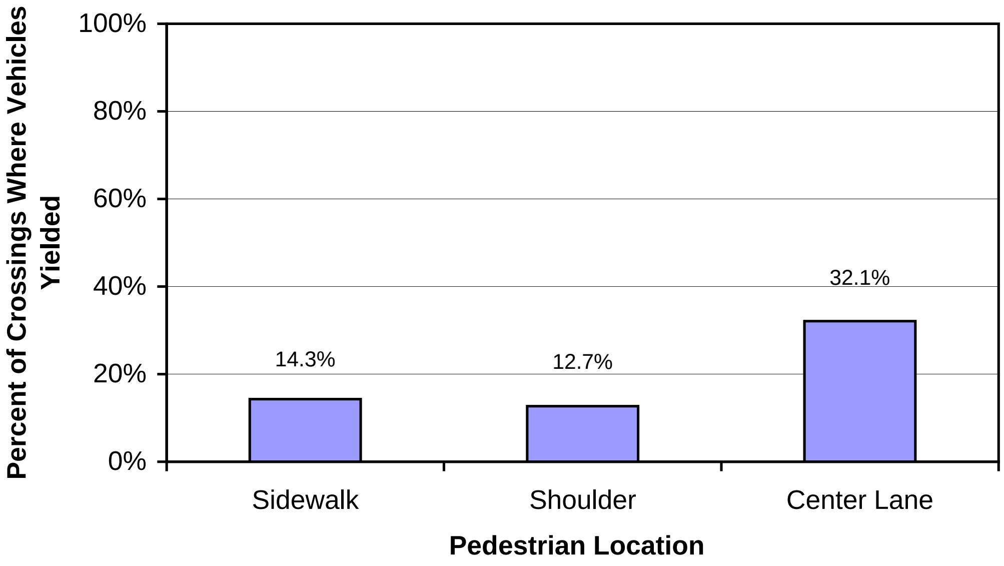


Figure B-21. Percentage of vehicles yielding based on wait location—Shoreline (includes only those events where vehicles were present)

Figure B-22 shows the results at the Kent site.

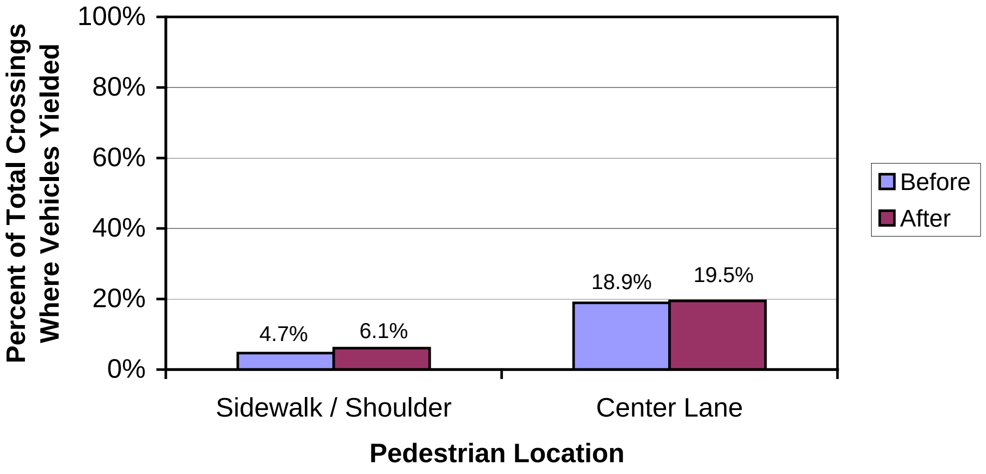


Figure B-22. Percentage of vehicles yielding based on wait location—Kent (includes only those events where vehicles were present)

Vehicles here were significantly more likely (at a 0.01 level) to yield for pedestrians who were waiting in the center lane than those who had not yet begun to cross the roadway (for both phases of the study at this site). Yielding behavior at the Kent site did not differ significantly between the *before* and *after* studies.

Figure B-23 shows the results at the Airway Heights site.

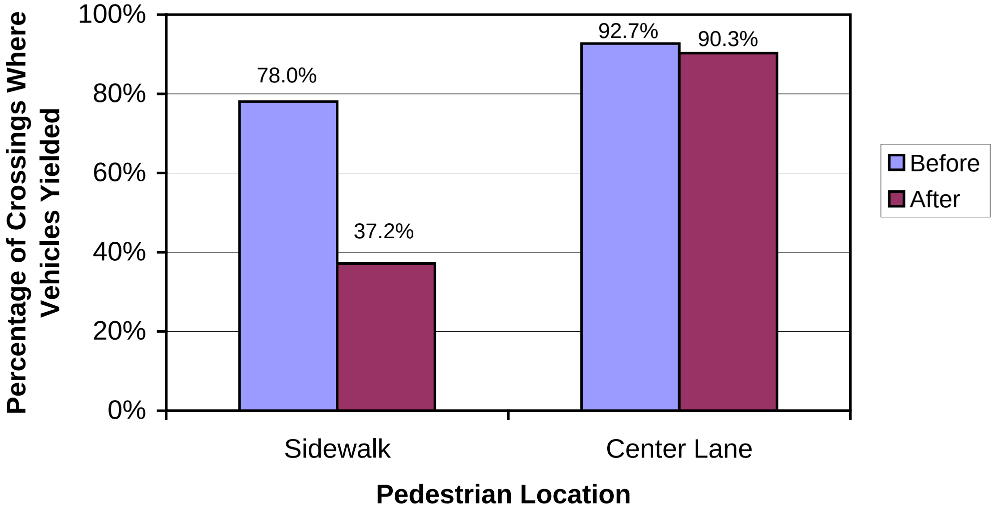


Figure B-23. Percentage of vehicles yielding based on wait location—Airway Heights (includes only those events where vehicles were present)

The change between the *before* and *after* phases for vehicles yielding to pedestrians waiting on the sidewalk to cross at Airway Heights was significant at the 0.0001 level. Yielding behavior related to those waiting in the center lane was largely unchanged. Again, there was a statistically significant difference (at a 0.0005 level) between vehicles yielding to pedestrians waiting on the sidewalk and vehicles yielding to those waiting in the center lane to cross the roadway.

Figure B-24 through Figure B-26 show the results at the Spokane sites.

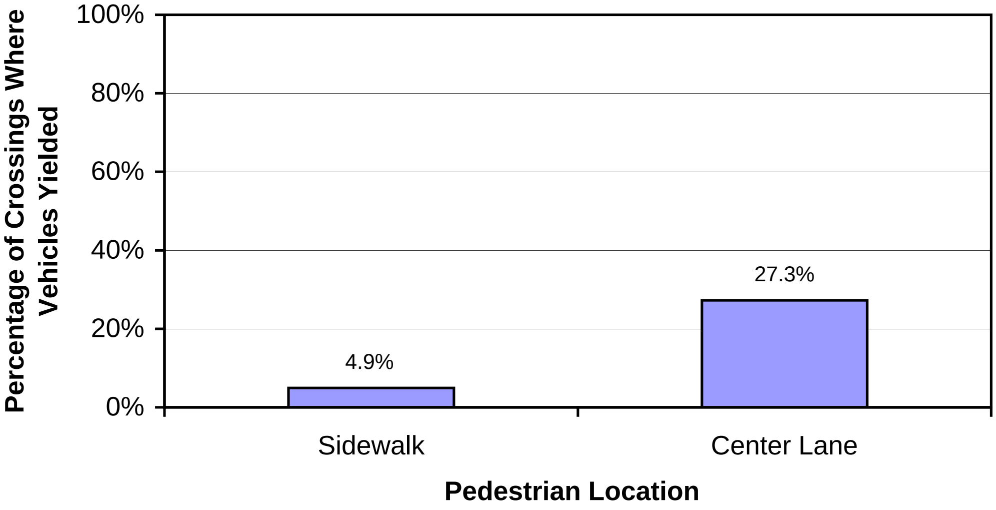


Figure B-24. Percentage of vehicles yielding based on wait location (Lacrosse Avenue)—Spokane (includes only those events where vehicles were present)

At the Lacrosse site, there was a statistically significant (at a 0.0001 level) difference between the yielding behavior experienced by the pedestrians waiting on the sidewalk and those waiting in the center lane.

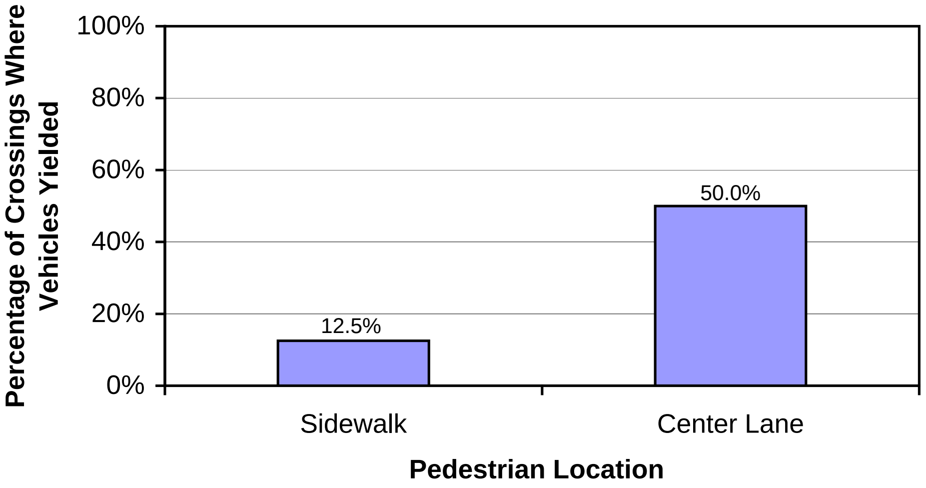


Figure B-25. Percentage of vehicles yielding based on wait location (Rowan Avenue)—Spokane (includes only those events where vehicles were present)

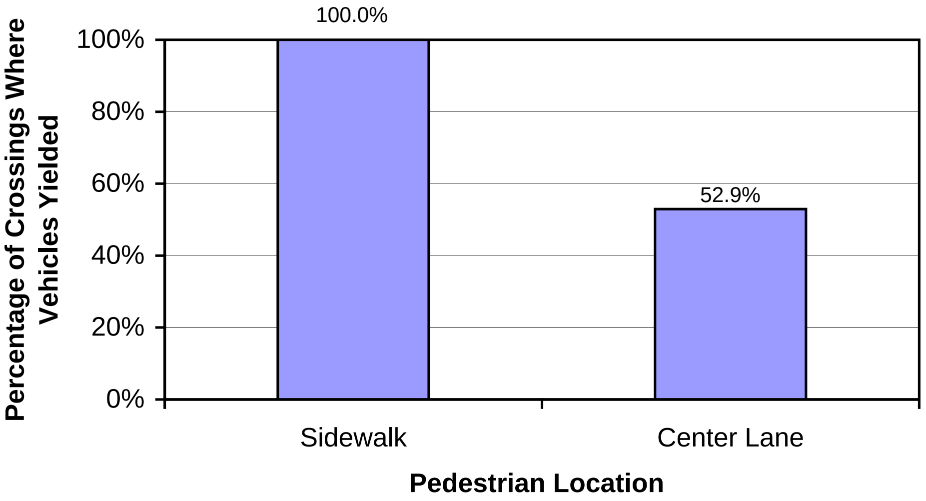


Figure B-26. Percentage of vehicles yielding based on wait location (Wellesley Avenue)—Spokane (includes only those events where vehicles were present)

At the Rowan and Wellesley Avenue sites in Spokane, the sample size of the crossings examined was too small to be able to evaluate the significance of the data collected.

Effects of Traffic Curbs on Vehicle Yielding

The Kent study site had a traffic curb on the east side of the center left turn lane. This feature appears to have had some effect on vehicle yielding. When a pedestrian was traveling westbound through the center lane, and therefore did not have the traffic curb between himself and the oncoming vehicles, the vehicles yielded 17.3 percent of the time (mean wait time = 2.1s) in the *before* study and 22.2 percent of the time (mean wait time = 3.2s) in the *after* study. Eastbound pedestrians, who did have the traffic curb between themselves and the vehicles, experienced vehicle yielding only 3.0 percent of the time (mean wait time = 5.5s) in the *before* study and 5.3 percent of the time (mean wait time = 7.1s) in the *after* study. The differences in motorist yielding behavior and pedestrian wait times were statistically significant (yielding at a level of 0.005 and wait times at a level of 0.002). This may have been due to a perception of safety on the part of the pedestrian and/or motorist. Motorists may feel as if the pedestrian is safer on the other side of this "barrier" than if they were to yield to him or that the pedestrian is safe, so the motorist does not "need" to stop. Pedestrians may feel the same way and be more likely to wait in the turn lane because of this security, rather than attempting to cross at a risky time.

Effects of Overhead Lighting on Vehicle Yielding

Overhead lighting was added at the Spanaway and Kent study sites. For both studies, the data from the *before* and *after* phases were analyzed to determine whether the overhead lighting added during the *after* phases would increase yielding behavior or decrease pedestrian wait times and/or conflicts with vehicles. Because of an insufficient number of crossings made with vehicles present during dark conditions at both study sites, no conclusions could be drawn.

Effects of Natural Lighting Conditions on Vehicle Yielding

At the Airway Heights study location, motorist yielding behavior was examined as it related to the natural lighting conditions. This was defined as the amount of natural light available, at street level, to the drivers and pedestrians when each crossing occurred. The results are shown in Figure B-27 and Figure B-28.

These figures suggest similar yielding behavior in Airway Heights for all light levels in both the *before* and *after* conditions and a marked decrease in yielding behavior in the *after* condition. The change between the *before* and *after* phases for vehicles yielding to pedestrians crossing from the sidewalk in both daylight and dark conditions was significant at the 0.0001 level. (Crossings made during dusk/dawn conditions were not numerous enough to determine statistical significance.)

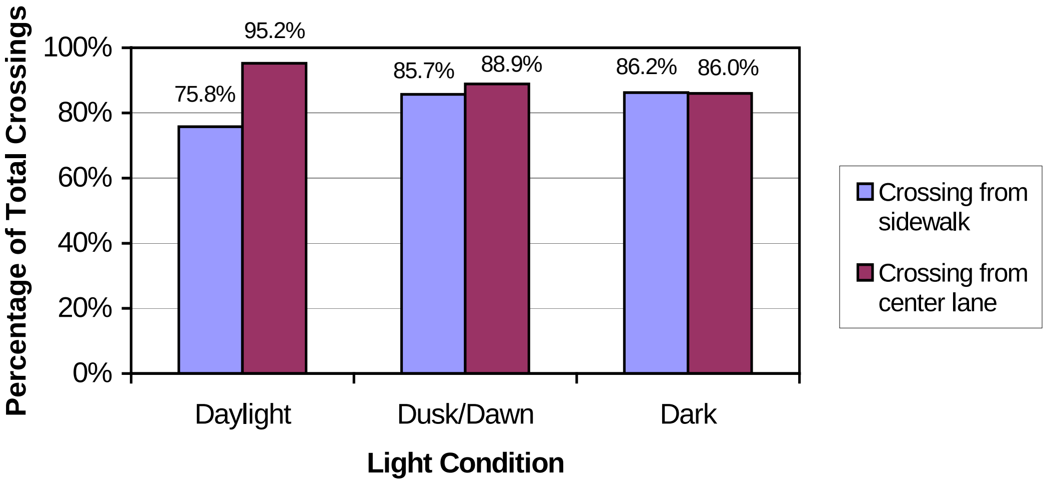


Figure B-27. Percentage of vehicles yielding based on light condition—*before* conditions—Airway Heights

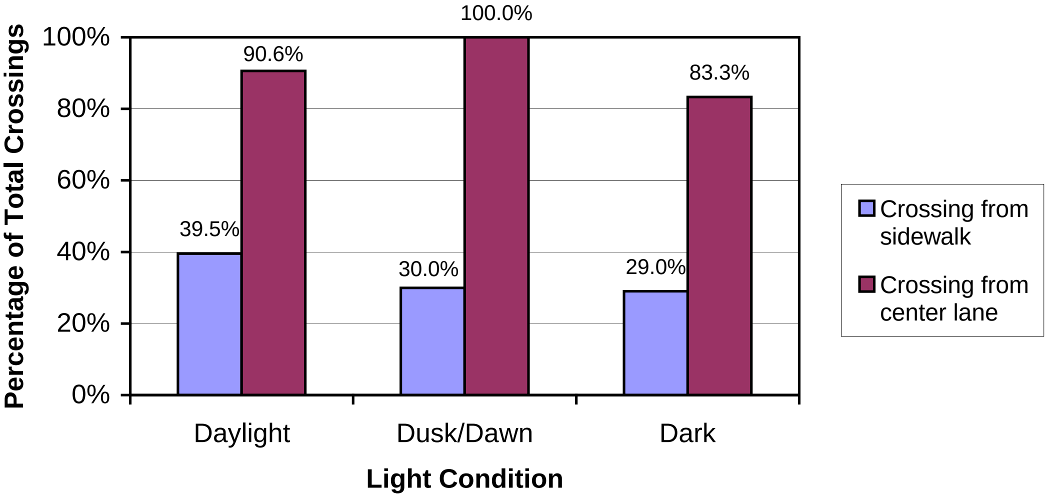


Figure B-28. Percentage of vehicles yielding based on light condition—*after* conditions—Airway Heights

Effects of Crossing Location and In-Pavement Flasher Use on Vehicle Yielding

Vehicle yielding at the Airway Heights site was also examined in relation to crossing location and use of the flashers. Figure B-29 and Figure B-30 show these results.

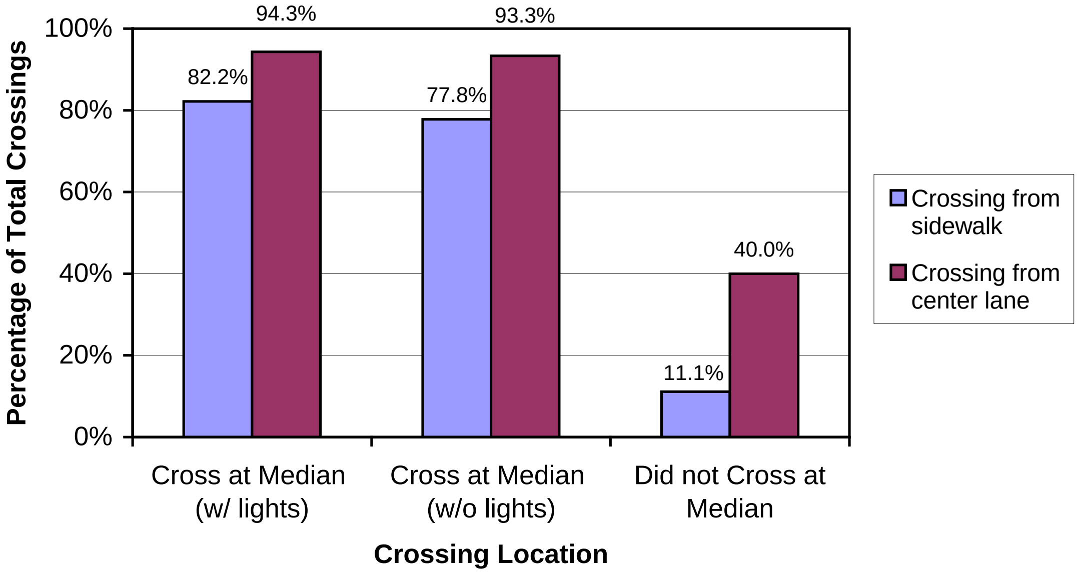


Figure B-29. Percentage of vehicles yielding based on crossing location/flasher use—*before* condition—Airway Heights

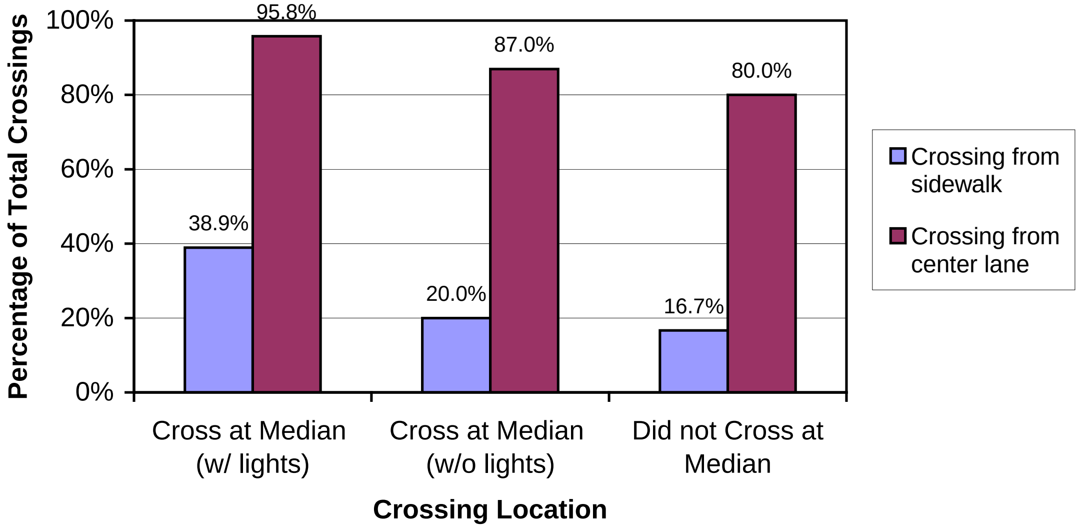


Figure B-30. Percentage of vehicles yielding based on crossing location/flasher use—*after* condition—Airway Heights

There was a statistically significant change in the number of vehicles yielding to pedestrians using the median and lights in Airway Heights between the *before* and *after* phase of the study (at the 0.0001 level). Crossings made by using the median and not the lights and crossings made without using the median were of small sample size in both the *before* and *after* phases, so those results may not be considered statistically significant.

PEDESTRIAN DELAY

Because all of the study sites were located on heavily traveled corridors and vehicle yielding was limited, pedestrians often had to wait for an extended period before beginning to cross the roadway. The waiting times presented below were measured from the time the pedestrian appeared to commit to crossing the roadway to the time the pedestrian actually began crossing.

Figure B-31 displays the wait times of the pedestrians at the Spanaway site.

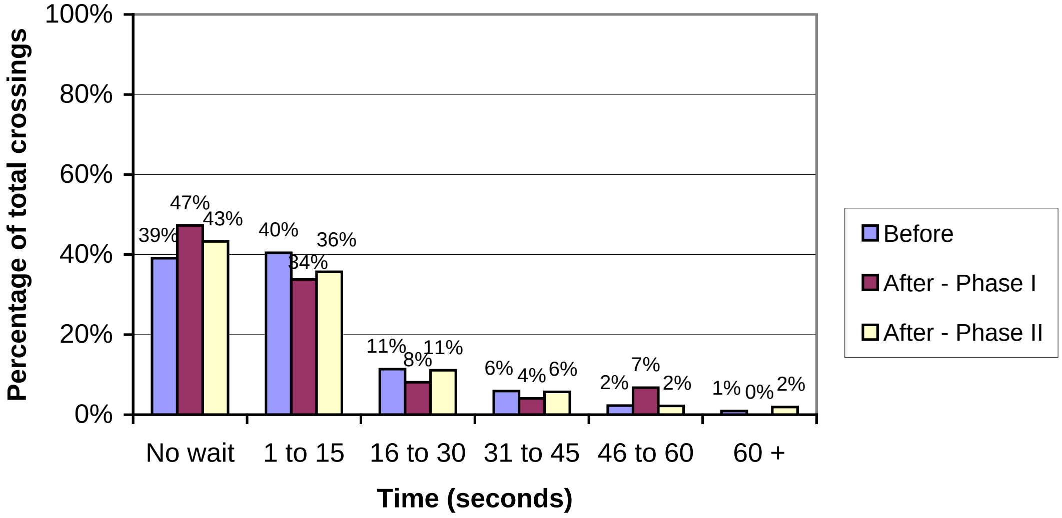


Figure B-31. Pedestrian wait time before crossing—Spanaway

The wait times in Spanaway are comparable for the three data sets. Before installation of the improvements, the average wait before crossing was just over 9 seconds. After the median had been installed, the average wait time was about 10 seconds. When the crosswalk markings were again installed, the average wait time was

10.6 seconds. The installation of the median and new crosswalk markings did not appear to have affected the initial waiting time of pedestrians.

Before phase: The average wait time at Spanaway for all crossings was 9.1 seconds (N=220). The zero wait times occurred most often (N=72) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 14.0 seconds (N=134). In nine cases, there was a zero wait time due to vehicle yielding. If only the crossing cases exhibiting yielding are considered, the average wait time was 14.8 seconds (N=42).

After phase I: The average wait time at Spanaway for all crossings was 10.0 seconds (N=74). The zero wait times occurred most often (N=34) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 19.4 seconds (N=37). In no cases was a zero wait time due to vehicle yielding. If only the crossing cases exhibiting yielding are considered, the average wait time was 10.75 seconds (N=4).

After phase II: The average wait time at Spanaway for all crossings was 10.6 (N=314). The zero wait times occurred most often (N=124) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 17.8 seconds (N=187). In three cases, there was a zero wait time due to vehicle yielding. If only the crossing cases exhibiting yielding are considered, the average wait time was 18.0 seconds (N=26).

Figure B-32 displays the wait times of the pedestrians at the Shoreline site.

The average wait time at Shoreline for all crossings was 12.9 seconds (N=300). The zero wait times occurred most often (N=148) because there was no traffic or a gap in traffic. In only 10 cases was there a zero wait time due to vehicle yielding. If only the crossing cases exhibiting yielding are considered, the average wait time was 20.1 seconds (N=19).

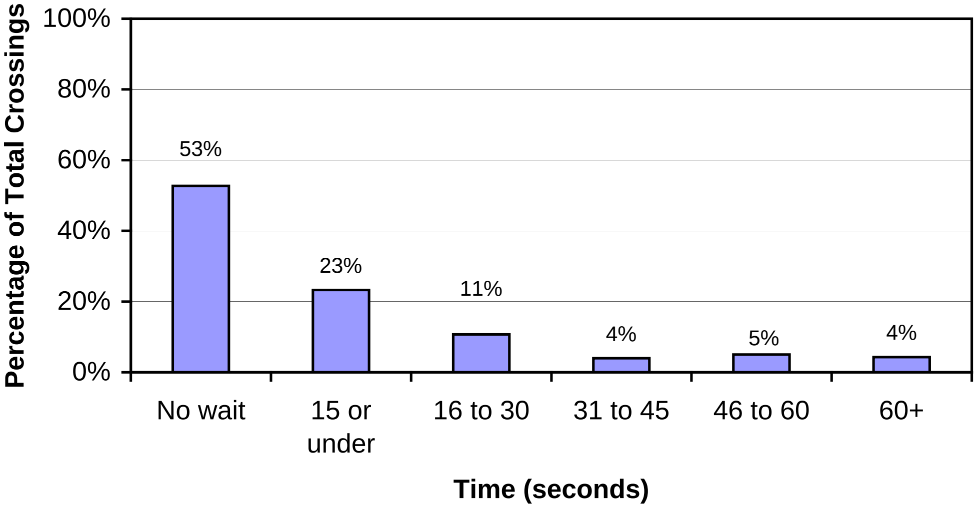


Figure B-32. Pedestrian wait time before crossing—Shoreline

Figure B-33 displays the wait times of the pedestrians at the Kent site.

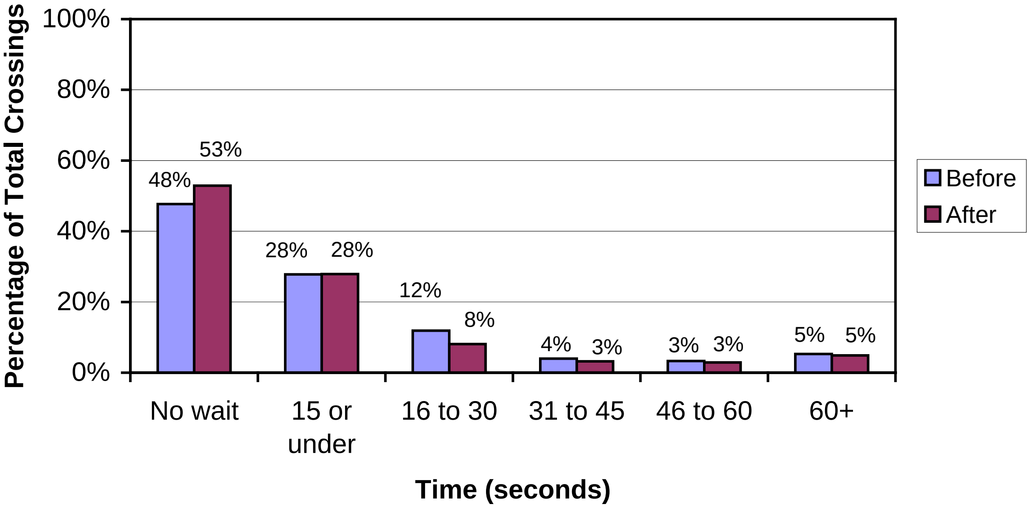


Figure B-33. Pedestrian wait time before crossing (mid-block crossings only)—Kent

Before condition: The average wait time at Kent for all mid-block crossings was 12.6 seconds (N=302). The zero wait times occurred most often (N=144) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 24.0

seconds (N=158). In only four cases was there a zero wait time due to vehicle yielding. If only the crossing cases exhibiting yielding are considered, the average wait time was 24.6 seconds (N=7).

After condition: The average wait time at Kent for all mid-block crossings was 10.8 seconds (N=308). The zero wait times occurred most often (N=141) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 21.2 seconds (N=153). In four cases there was a zero wait time due to vehicle yielding. If only the crossing cases exhibiting yielding are considered, the average wait time was 21.9 seconds (N=10).

There was no statistically significant change in average wait times from the *before* study to the *after* study in Kent.

Figure B-34 displays the wait times of the pedestrians at the Airway Heights site.

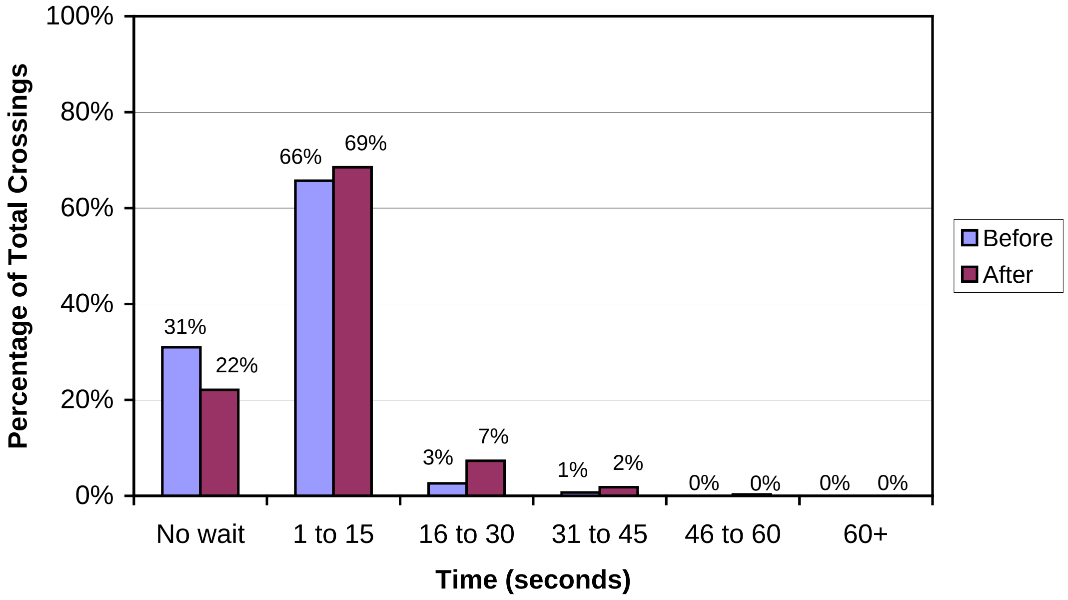


Figure B-34. Pedestrian wait time before crossing—Airway Heights

Before phase: The average wait time at Airway Heights for all crossings was 4.0 seconds (N=303). The zero wait times occurred most often (N=78) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 5.4 seconds (N=225). In 13 cases, there was a zero wait time due to vehicle yielding. If only the crossing cases exhibiting yielding are considered, the average wait time was 6.0 seconds (N=129). There were also 37 crossings (with an average wait time of 10.6 seconds) where the pedestrian waited—far off of the street or sidewalk—for a gap in traffic, prior to activating the flashers.

After phase: The average wait time at Airway Heights for all crossings was 6.0 seconds (N=330). The zero wait times occurred most often (N=69) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 7.6 seconds (N=261). In three cases, there was a zero wait time due to vehicle yielding. If only the crossing cases exhibiting yielding are considered, the average wait time was 8.6 seconds (N=100). There were also 49 crossings (with an average wait time of 12.4 seconds) where the pedestrian waited—far off of the street or sidewalk—for a gap in traffic, prior to activating the flashers.

The change in overall mean wait times between the *before* and *after* phases was statistically significant at the 0.0005 level at Airway Heights.

Figure B-35 through Figure B-37 display the wait times of the pedestrians at the Spokane sites.

The average wait time at Lacrosse Avenue for all crossings was 18.8 seconds (N=224). All of the zero wait times occurred (N=60) because there was no traffic or a gap in traffic. If these are excluded, the average wait time is 25.7 seconds (N=164). If only the crossing cases exhibiting yielding are considered, the average wait time was 18.7 seconds (N=9). In 121 of the observed crossings, the wait was terminated because of a gap in traffic.

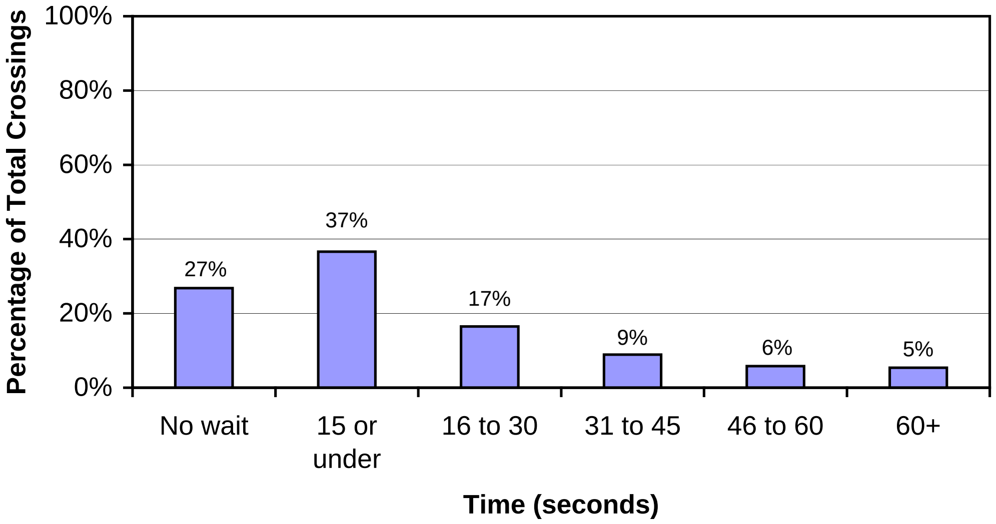


Figure B-35. Pedestrian wait time before crossing at Lacrosse Avenue—Spokane

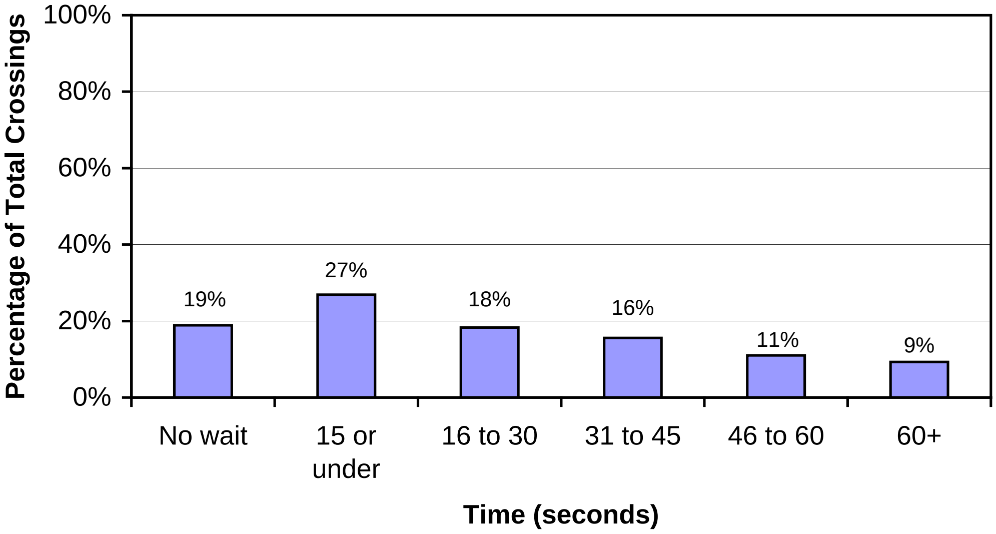


Figure B-36. Pedestrian wait time before crossing at Rowan Avenue—Spokane

The average wait time at Rowan Avenue for all crossings was 25.2 seconds (N=301). All of the zero wait times occurred (N=57) because there was no traffic or a gap in traffic (often due to the traffic signal (N=30)). If these are excluded, the average wait time was 31.1 seconds (N=244). If only the crossing cases exhibiting yielding are considered, the average wait time was 69.0 seconds (N=1).

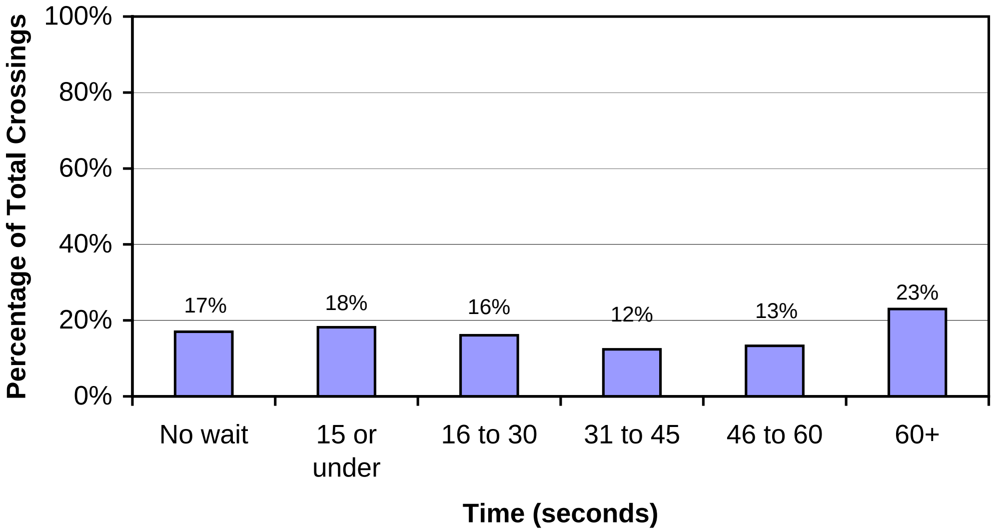


Figure B-37. Pedestrian wait time before crossing at Wellesley Avenue—Spokane

The average wait time at the Wellesley Avenue location for all crossings was 34.6 seconds (N=330). The zero wait times occurred most often (N=50) because there was no traffic or a gap in traffic (often due to the traffic signal (N=35)). If these are excluded, the average wait time was 44.2 seconds (N=280). In only two cases was there a zero wait time due to vehicle yielding. If only the crossing cases exhibiting yielding are considered, the average wait time was 23.5 seconds (N=4).

Signal Delay

The figures below show the wait times for pedestrians crossing with the signal at the marked, signalized crosswalks. (No data are presented for the study sites that did not contain signalized intersections: Spanaway, Shoreline, Airway Heights, and Lacrosse Avenue in Spokane).

Figure B-38 displays the signal wait times of the pedestrians at the Kent site.

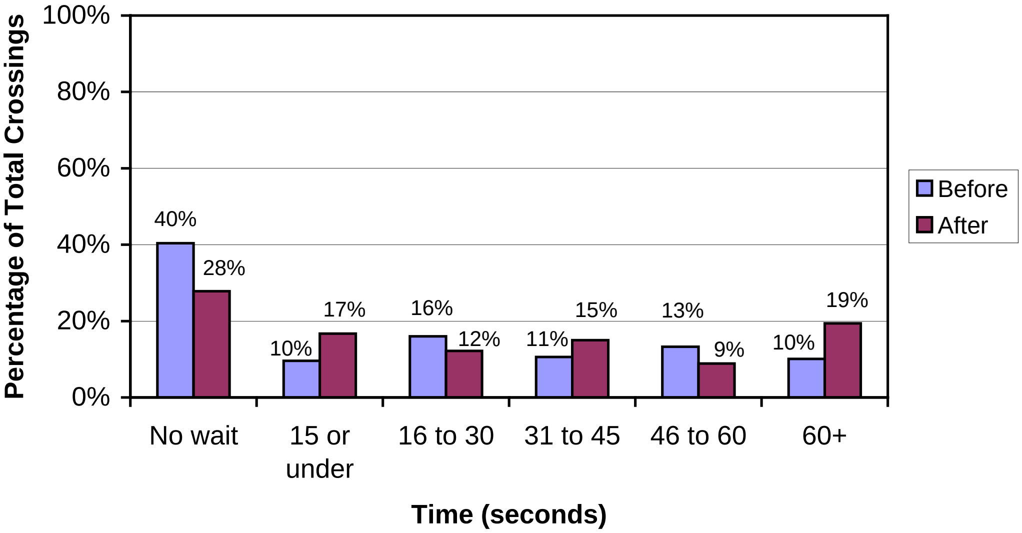


Figure B-38. Pedestrian wait time before crossing (marked, signalized crosswalks only)—Kent

Before condition: The average wait time at Kent for all such crossings was 25.0 seconds (N=188). The zero wait times (N=76) occurred when pedestrians arrived at the intersection during the portion of the signal timing plan that allows pedestrian crossings in that direction. If these are excluded, the average wait time was 42.0 seconds (N=112).

After condition: The average wait time at Kent for all such crossings was 30.3 seconds (N=180). The zero wait times (N=50) occurred when pedestrians arrived at the intersection during the portion of the signal timing plan that allows pedestrian crossings in that direction. If these are excluded, the average wait time was 41.9 seconds (N=130).

Figure B-39 and Figure B-40 display the signal wait times of the pedestrians at the Spokane sites.

The average wait time for pedestrians crossing with the signal at Rowan Avenue was 29.1 seconds (N=240) (the average wait to cross at unsanctioned locations was 5.3 seconds (N=36)). The zero wait times (N=30) occurred when pedestrians arrived at the intersection during the portion of the signal timing plan that allows pedestrians to cross in that direction. If these are excluded, the average wait time was 33.3 seconds (N=210). The traffic signal cycle length was 75 seconds at this intersection.

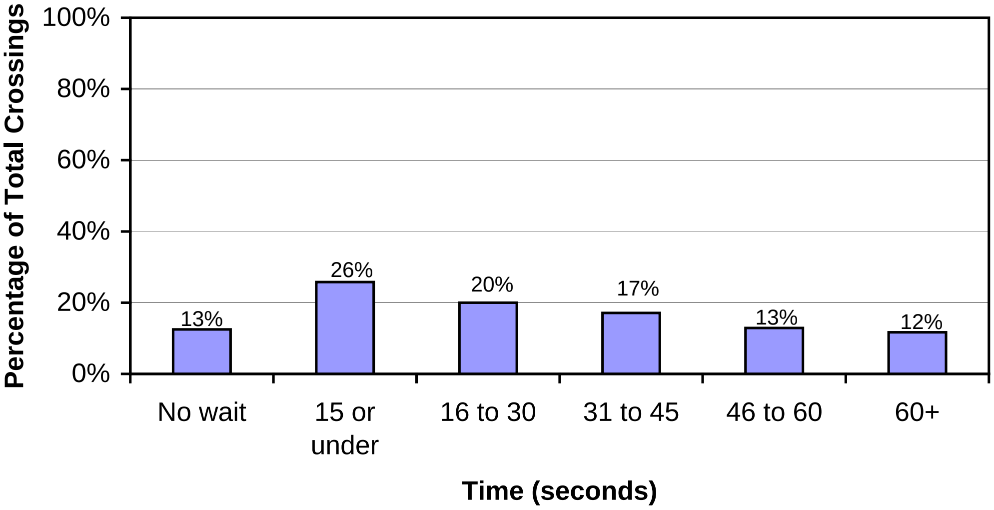


Figure B-39. Pedestrian wait time before crossing (marked, signalized crosswalks only)—Rowan Avenue (Spokane)

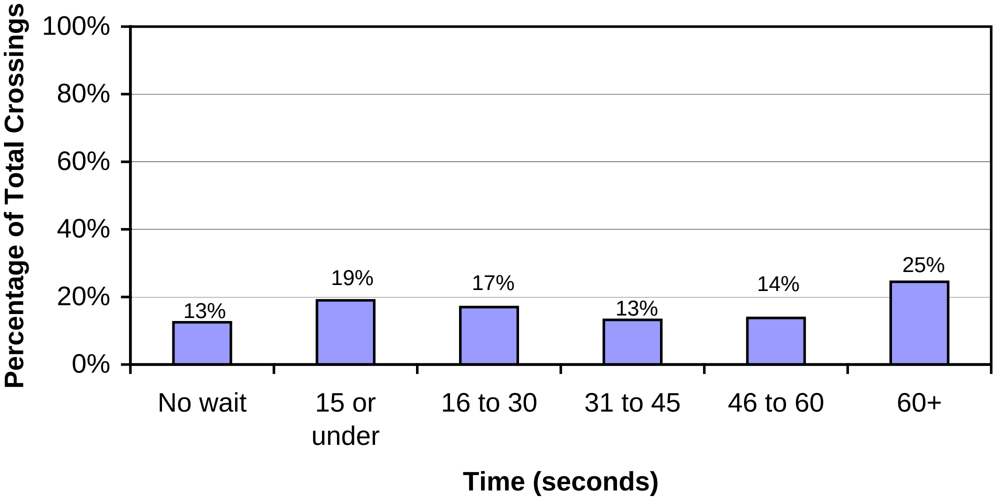


Figure B-40. Pedestrian wait time before crossing (marked, signalized crosswalks only)—Wellesley Avenue (Spokane)

The average wait time for pedestrians crossing with the signal at Wellesley Avenue was 39.6 seconds (N=311) (the average wait to cross at unsanctioned locations was 3.1 seconds (N=18)). The zero wait times (N=39) occurred when pedestrians arrived at the intersection during the portion of the signal timing plan that allowed pedestrians to cross in that direction. If these are excluded, the average wait time was 45.3 seconds (N=272). The traffic signal cycle length was 120 seconds at this intersection.

Signal Delay Conclusion. As mentioned above, most pedestrians observed in this study actually experienced shorter wait times while crossing at an unsanctioned mid-block location than at a traffic signal. This perception of and personal experience with this difference in crossing wait times may entice pedestrians to cross high volume arterials at locations other than the signalized, marked crossing, regardless of the safety issues inherent in that decision, especially if a gap in traffic is observed.

Center Lane Waiting

The significant number of vehicles in both directions at each of the study sites made it difficult for pedestrians to get completely across the roadway in one motion. Occasionally, pedestrians were required to wait in the center lane or in the median refuge before completing their crossing.

Figure B-41 displays pedestrian wait times in the center lane or median refuge at the Spanaway site.

The installation of the median and new crosswalk markings at the Spanaway site resulted in a significant increase (at the 0.001 level) in mid-crossing delay: the average wait time increased from approximately 2 seconds to about 15 seconds during the first phase of improvements. This decreased to 5.7 seconds in the second phase of the *after* study. The statistically significant increase (at the 0.0001 level) in the percentage of pedestrians who had to wait in the center lane or median after the median installation may correspond to a decrease in motorist yielding in the first *after* phase. It is also possible that some pedestrians felt more comfortable taking their time while waiting in the median refuge than while standing in the center left turn lane.

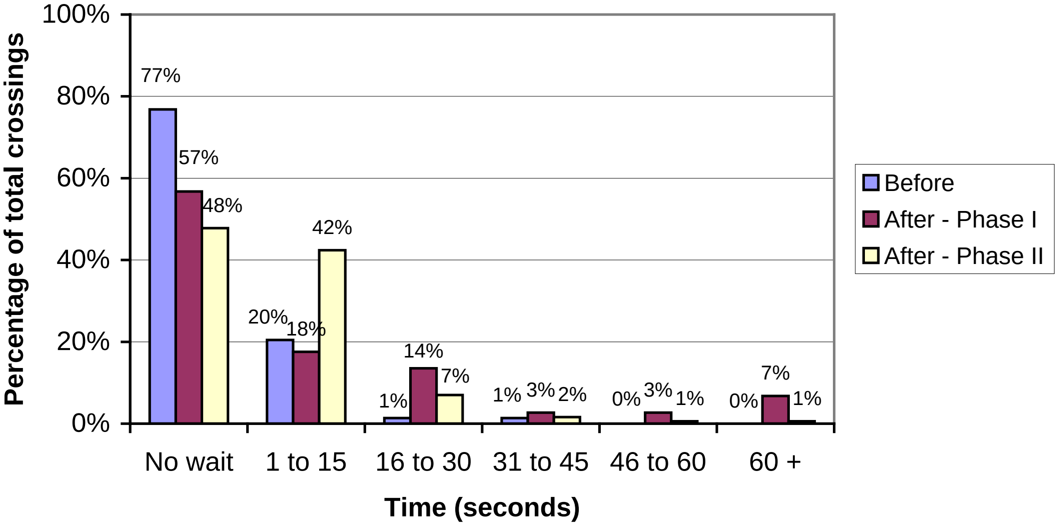


Figure B-41. Pedestrian wait time in the center lane/median—Spanaway

Before phase: The average center lane wait time for all crossings in Spanaway was 1.9 seconds (N=220). Again, the zero wait times occurred often (N=74) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 2.9 seconds (N=142). In 72 cases, there was a zero wait time because of vehicle yielding. When only the crossing cases involving yielding to pedestrians in the center lane are considered, the average wait time was 2.3 seconds (N=110).

After—phase I: The average center lane wait time for all crossings in Spanaway was 14.9 seconds (N=74). The zero wait times occurred most often (N=18) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 19.6 seconds (N=55). In 11 cases, there was a zero wait time because of vehicle yielding. When only the crossing cases involving yielding to pedestrians in the center lane are considered, the average wait time was 6.4 seconds (N=17).

After—phase II: The average center lane wait time for all crossings in Spanaway was 5.7 seconds (N=314). The zero wait times occurred most often (N=77) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 7.6 seconds (N=235). In 49 cases, there was a zero wait time because of vehicle yielding. When only the crossing cases involving yielding to pedestrians in the center lane are considered, the average wait time was 5.2 seconds (N=135).

Figure B-42 displays pedestrian wait times in the center lane at the Shoreline site.

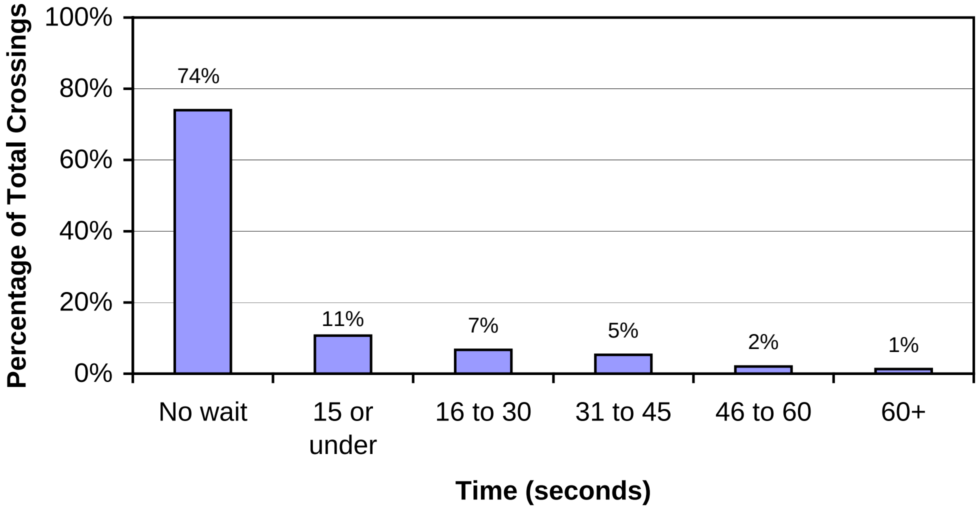


Figure B-42. Pedestrian wait time in the center lane—Shoreline

The average center lane wait time for all crossings in Shoreline was 6.9 seconds (N=300). Again, the zero wait times occurred most often (N=132) because there was no traffic or a gap in traffic. In 26 cases, there was a zero wait time because of vehicle yielding. When only the crossing cases involving yielding to pedestrians in the center lane are considered, the average wait time was 11.6 seconds (N=44).

Figure B-43 displays pedestrian wait times in the center lane at the Kent site.

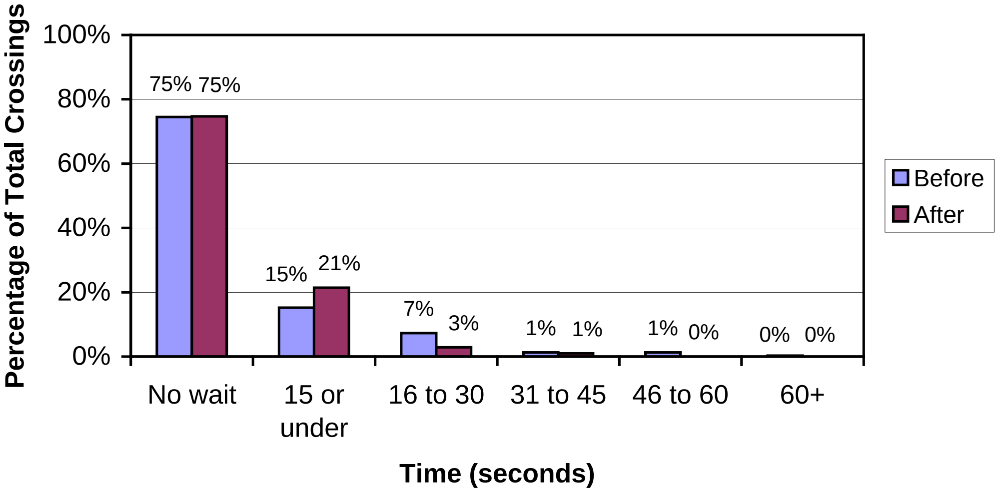


Figure B-43. Pedestrian wait time in the center lane—Kent

Before condition: The average center lane wait time for all crossings in Kent was 4.3 seconds (N=302). Again, the zero wait times occurred most often (N=225) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 16.9 seconds (N=77). In 23 cases, there was a zero wait time because of vehicle yielding. When only the crossing cases involving yielding to pedestrians in the center lane are considered, the average wait time was 1.3 seconds (N=24).

After condition: The average center lane wait time for all crossings in Kent was 2.5 seconds (N=308). The zero wait times occurred most often (N=156) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 5.0 seconds (N=149). In 18 cases, there was a zero wait time because of vehicle yielding. When only the crossing cases involving yielding to pedestrians in the center lane are considered, the average wait time was 3.8 seconds (N=29).

Center lane waiting times decreased at a statistically significant level (0.01) from the *before* to the *after* study in Kent. This could be due to the presence of some long center lane wait times in the *before* data or an increase in aggressive crossing behavior by pedestrians during the *after* study.

Figure B-44 displays pedestrian wait times in the center lane or median refuge at the Airway Heights site.

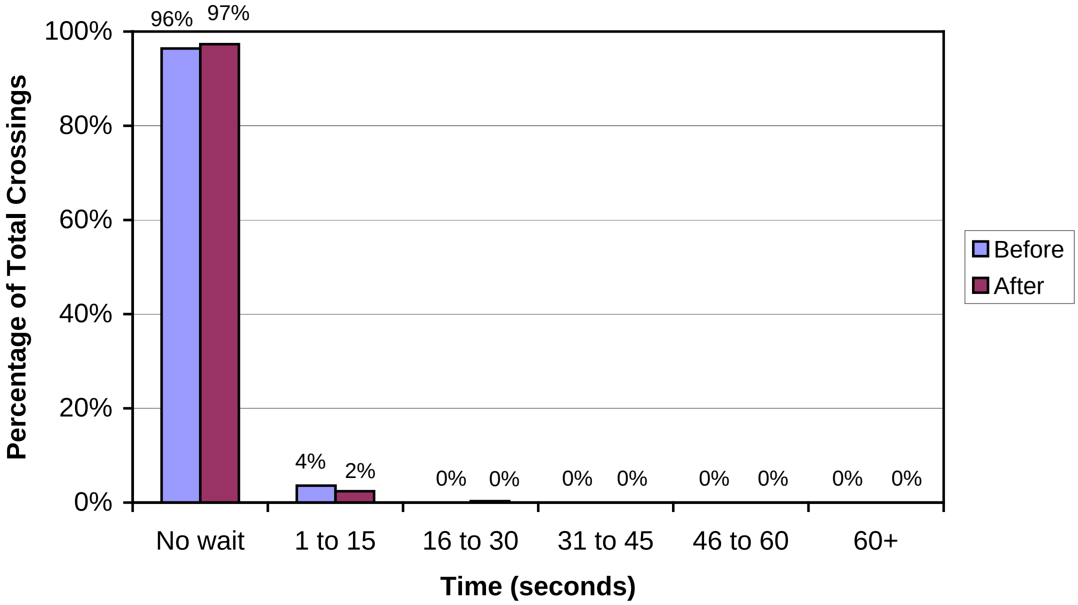


Figure B-44. Pedestrian wait time in the center lane/median—Airway Heights

Before phase: The average center lane wait time for all crossings in Airway Heights was 0.2 seconds (N=303). Again, the zero wait times occurred often (N=124) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 0.3 seconds (N=179). In 157 cases, there was a zero wait time because of vehicle yielding. When only the crossing cases involving yielding to pedestrians in the center lane are considered, the average wait time was 0.24 seconds (N=168).

After phase: The average center lane wait time for all crossings in Airway Heights was 0.2 seconds (N=330). The zero wait times occurred most often (N=44) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 0.2 seconds (N=286). In 22 cases, there was a zero wait time because of vehicle yielding. When only the crossing cases exhibiting yielding to pedestrians in the center lane are considered, the average wait time was 0.5 seconds (N=177).

There was no significant change in center lane/median wait times from the *before* phase to the *after* phase of the study in Airway Heights.

Figure B-45 through Figure B-47 display pedestrian wait times in the center lane at the Spokane sites.

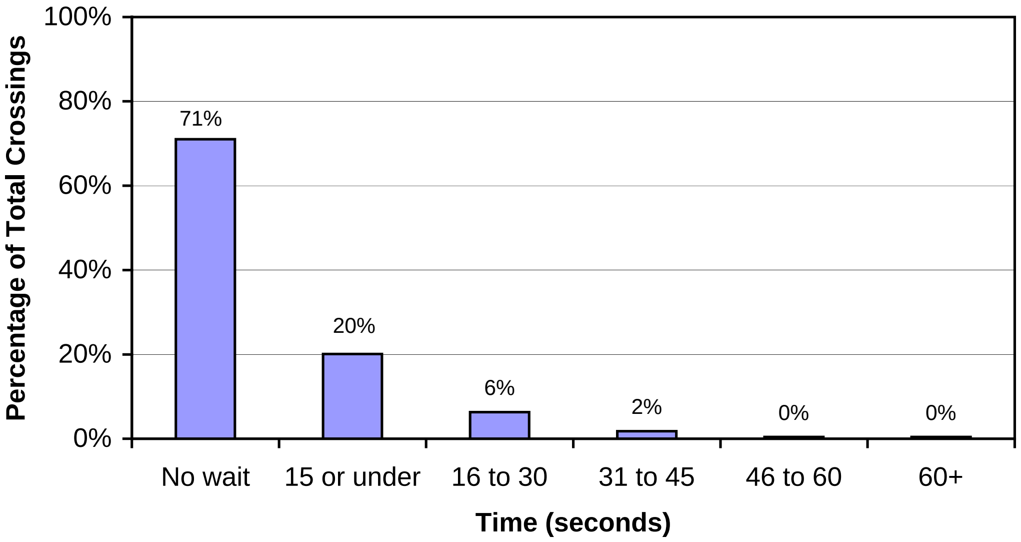


Figure B-45. Pedestrian wait time in the center lane/median (Lacrosse Avenue)—Spokane

The average center lane wait time for all crossings at the Lacrosse Avenue site was 4.2 seconds (N=224). Again, the zero wait times occurred most often (N=103) because there was no traffic or a gap in traffic. If these are excluded, the average wait time was 7.7 seconds (N=121). In 12 cases, there was a zero wait time because of vehicle yielding. When only the crossing cases involving yielding to pedestrians in the center lane are considered, the average wait time was 5.6 seconds (N=33). In 42 of the observed crossings, the center lane wait was terminated because of a gap in traffic.

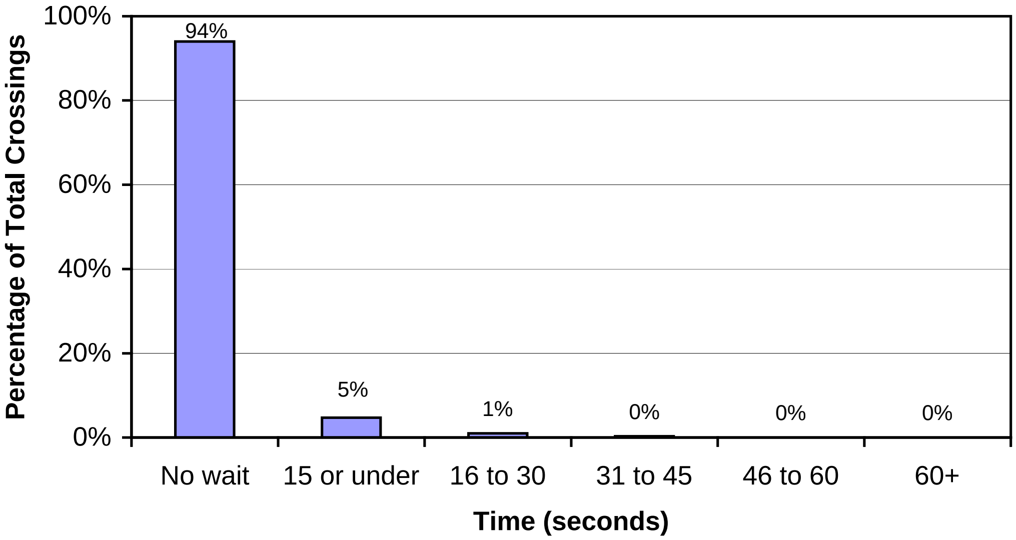


Figure B-46. Pedestrian wait time in the center lane/median (Rowan Avenue)—Spokane

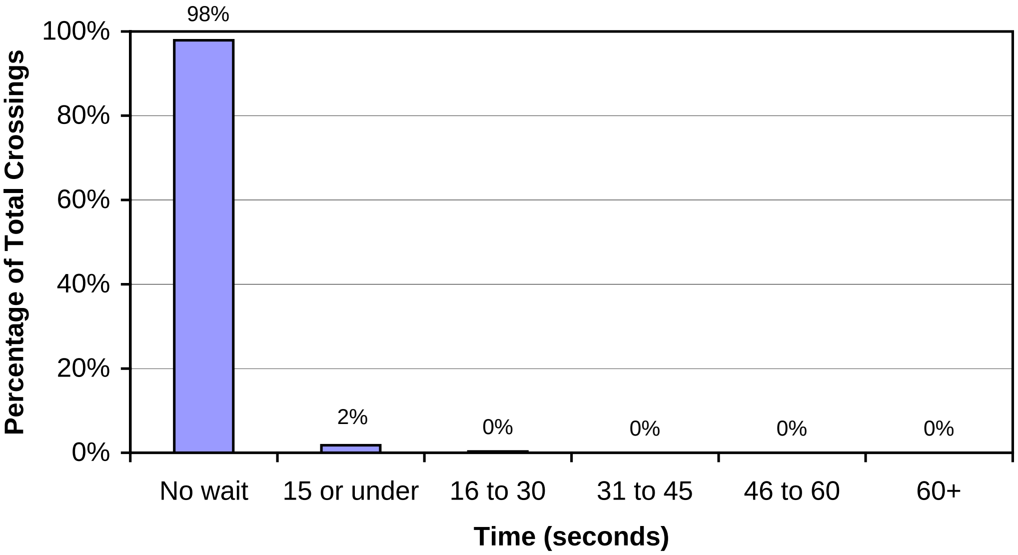


Figure B-47. Pedestrian wait time in the center lane/median (Wellesley Avenue)—Spokane

The average center lane wait time for all crossings at the Rowan Avenue site was 0.6 seconds (N=301). Again, the zero wait times occurred most often (N=261) because there was no traffic or a gap in traffic (often provided by the traffic signal (N=226)). If these are excluded, the average wait time was 4.8 seconds (N=40). In seven cases, there was a zero wait time because of vehicle yielding. When only the crossing cases involving yielding to pedestrians in the center lane are considered, the average wait time was 6.0 seconds (N=12). In ten of the observed crossings, the center lane wait was terminated because of a gap in traffic.

The average center lane wait time for all crossings at the Wellesley Avenue site was 1.8 seconds (N=330). Again, the zero wait times occurred most often (N=293) because there was no traffic or a gap in traffic (often provided by the traffic signal (N=289)). If these are excluded, the average wait time was 1.9 seconds (N=37). In eight cases, there was a zero wait time because of vehicle yielding. When only the crossing cases involving yielding to pedestrians in the center lane are considered (and excluding zero wait time cases), the average wait time was 3.4 seconds (N=10). In seven of the observed crossings, the center lane wait was terminated because of a gap in traffic.

Center lane waits were positively affected by intersection controls at the Spokane sites. When crossing with a signal, pedestrians rarely, if ever, needed to stop in the center turn lane before finishing their crossing. At Wellesley Avenue, 2.1 percent of pedestrians waited in the center lane; at Rowan Avenue, 5.7 percent waited; and at Lacrosse, 29 percent waited in the center lane. Fortunately, the average center lane wait at all sites was under 5 seconds.

Effects of In-Pavement Flasher Use of Pedestrian Delay

The only study site that used in-pavement flashers was Airway Heights. At that site, pedestrian use of the flashers was very high; in the *before* analysis, of the 268 crossings that used the median, 242 also used the flashers (90.3 percent of those using the median, 79.9 percent of all crossings). In the *after* analysis, 287 used the median and 248 used the flashers (86.4 percent of those using the median, 75.2 percent of all crossings). These lights flashed for approximately 35 seconds per activation. Because some pedestrians would wait for a break in traffic before activating the lights and because there is a wide variation in walking speeds, data were collected on how long the lights flashed before the pedestrian entered the marked crosswalk and also on how long the lights continued to flash once the crossing had been completed.

Figure B-48 shows the distribution of pedestrian waiting times once the flashers had been activated.

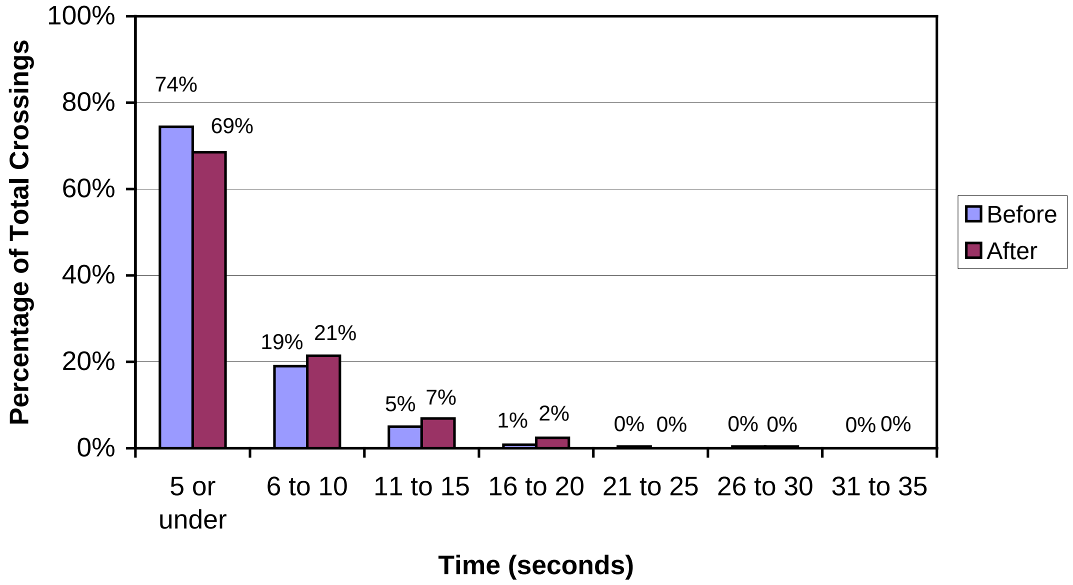


Figure B-48. Pedestrian wait time with flashers activated—Airway Heights

The mean wait time for pedestrians once the flashers had been activated in Airway Heights was 4.1 seconds (N=242) for the *before* study and 4.7 seconds (N=248) for the *after* study. This was not a statistically significant change.

Figure B-49 shows the distribution of times that the flashers continued to light after the pedestrian had finished crossing.

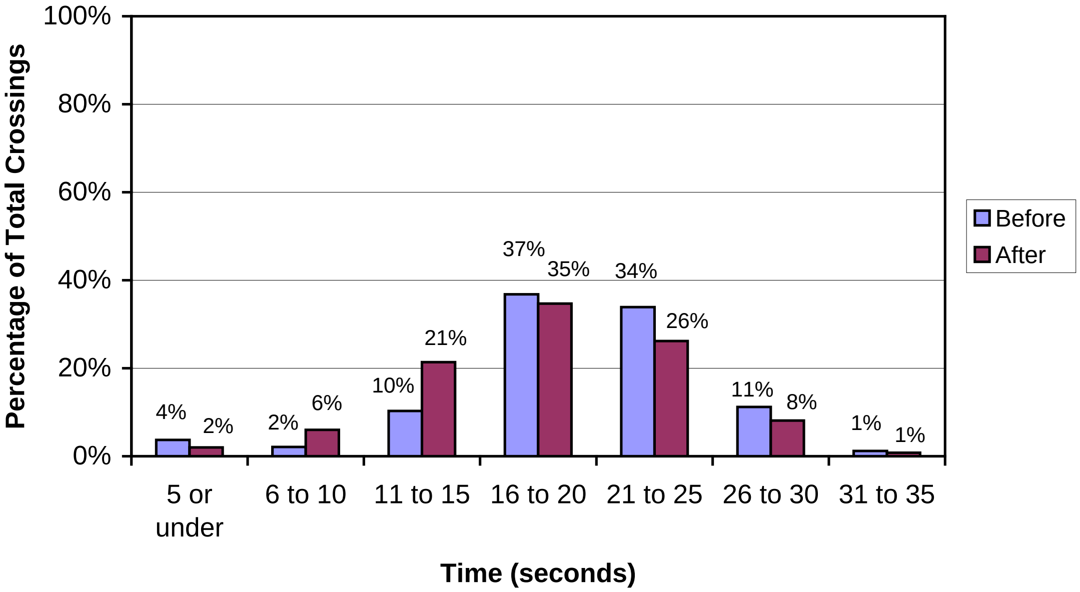


Figure B-49. Amount of time that flashers remained lit after crossing was completed—Airway Heights

The crossing lights remained lit for an average of 19.8 seconds in Airway Heights after each crossing had been completed in the *before* study (in three crossings, the pedestrians had not yet finished crossing when the lights stopped flashing). In the *after* study, the lights remained lit for an average of 18.6 seconds (in two crossings, the pedestrians had not yet finished crossing when the lights stopped flashing). Although it is understood that a variety of walking speeds must be accommodated with a treatment of this type, this lengthy period of flashing lights with no pedestrians in the crosswalk may, over time, contribute to indifference to the lights and to potential problems when more than one group of pedestrians attempts to cross the highway at approximately the same time (much as multiple trains crossing a roadway near the same time can be dangerous to motorists who believe the tracks are clear and the crossing lights can be ignored).

Also examined were wait times in relation to on crossing location and whether or not the flashers were used. These results are shown in Figure B-50 and Figure B-51.

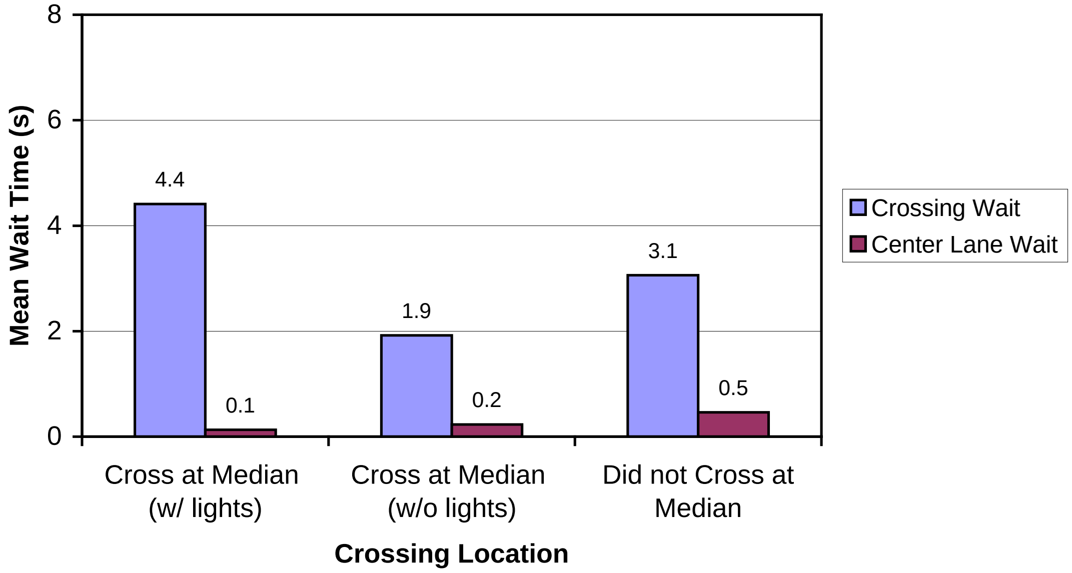


Figure B-50. Wait times based on crossing location and flasher use—*before* phase—Airway Heights

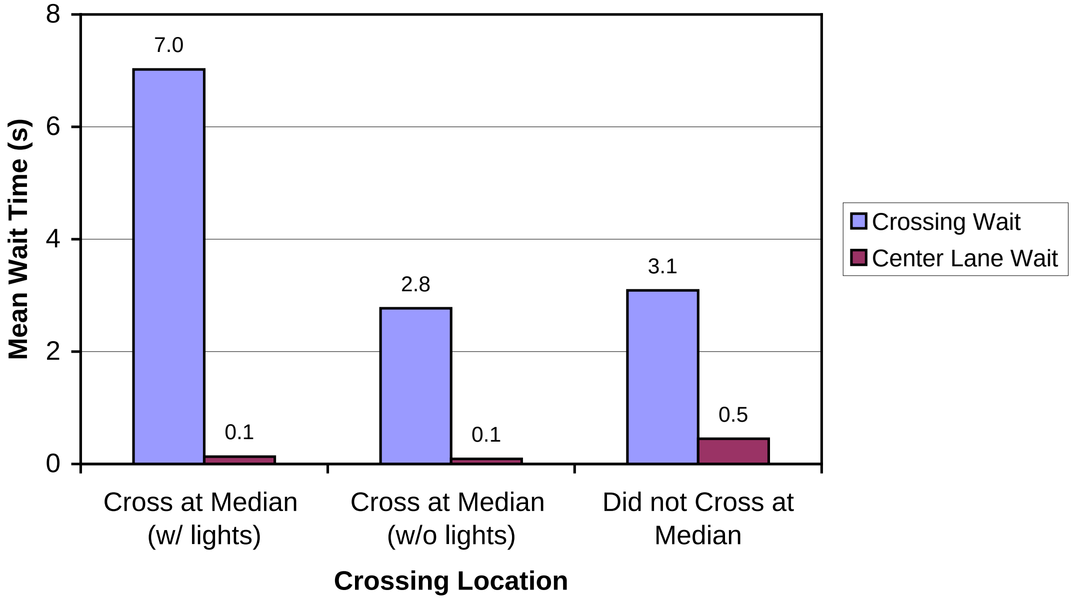


Figure B-51. Wait times based on crossing location and flasher use – *after* phase—Airway Heights

In the *after* analysis, the wait time for pedestrians crossing from the sidewalk using the median and lights almost doubled at Airway Heights, while wait times for crossing at other locations and/or with other strategies remained fairly consistent with previous levels. This change while using the median and flashers was significant at the 0.0001 level.

Wait times were also examined in relation to natural lighting conditions at Airway Heights. Figure B-52 shows wait times for crossings made using the median and flashers for various light conditions.

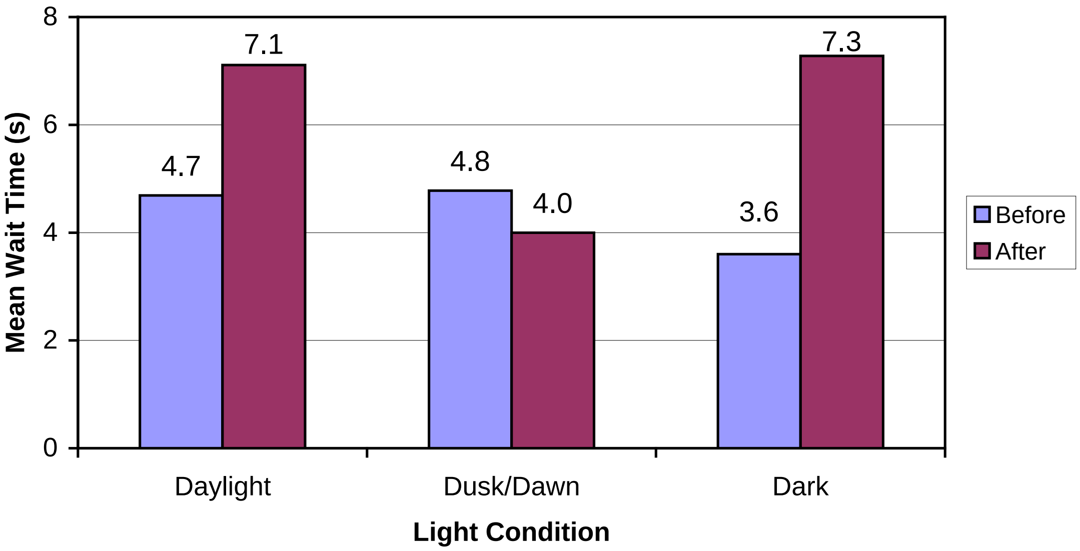


Figure B-52. Wait times by lighting condition (crossings using median and lights only)—Airway Heights

The changes in wait times from the *before* condition to the *after* condition were significant for the daylight and dark light conditions. (The dusk/dawn sample size was too small for statistical significance comparison). The change in daylight wait times was significant at the 0.0001 level. The change in wait times during dark conditions was significant at the 0.04 level.

STOP BAR COMPLIANCE

In the *after* phase of the study at Airway Heights, stop bars were added to the roadway 20 feet in advance of the marked crosswalk. These markings can give motorists better sight of the crosswalk and can allow pedestrians to see approaching traffic better while crossing. Of course, motorist compliance with the markings is required to be able to achieve these safety benefits.

Table B-31 shows the proportion of motorists who stopped their vehicles behind the stop bar while a pedestrian was crossing the roadway. This table is organized by direction of travel and includes only the vehicles that were nearest to the stop bar (i.e., those that were "second in line" to the stop bar were not considered). "Behind the stop bar" was defined as the entire vehicle (front bumper, tires, etc.) being behind the line when the pedestrian crossed in front of it.

Table B-31. Stop bar compliance by motorists—Airway Heights

	Vehicles stopping behind the stop bar	
	Before	**After**
Eastbound	N/A	81.4%
Westbound	N/A	66.1%

The difference in compliance between the two directions of travel is significant at the 0.005 level. However, because compliance with the stop bar was so high, pedestrians had a better understanding overall of where most vehicles would be stopping and could react more readily to potential threats or conflicts.

PEDESTRIAN CROSSING (CONFLICT AVOIDANCE) STRATEGIES

Because each corridor was often busy and hard to cross, pedestrians employed a variety of conflict avoidance strategies to improve their chances of crossing the roadway safely. Some used the shoulder as a waiting area to be closer to the cars, and hopefully more visible; some only crossed half of the roadway at a time; and some ran across all or part of the roadway.

At the Spanaway site, these data were collected only during the *after—phase II* evaluation. The results are displayed in Figure B-53.

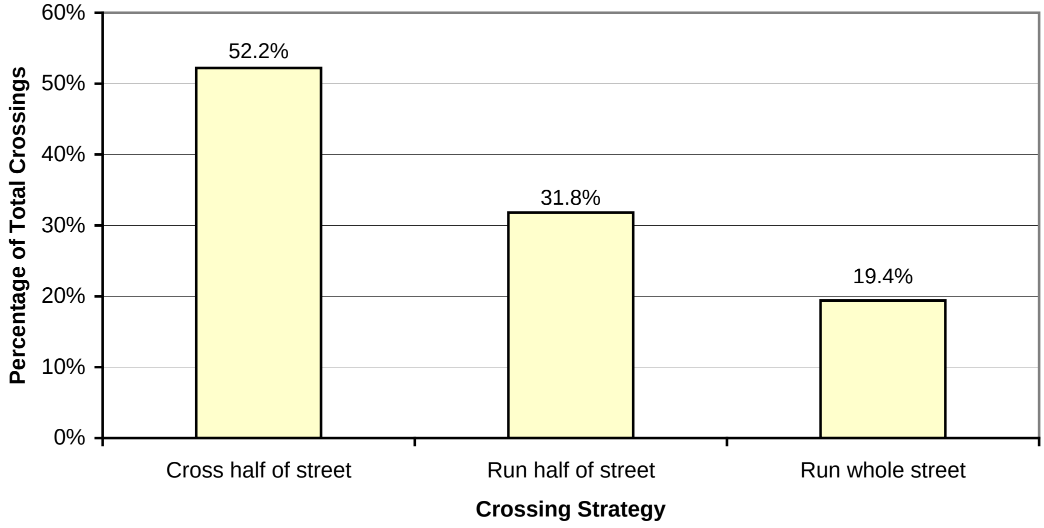


Figure B-53. Usage of different pedestrian crossing strategies—Spanaway—*after—phase II* only

The results for the Shoreline site are shown in Figure B-54. In comparing the data from Shoreline, no significant difference was found in the side of the street that was more often crossed by pedestrians while running or walking

The results for the Kent site are shown in Figure B-55.

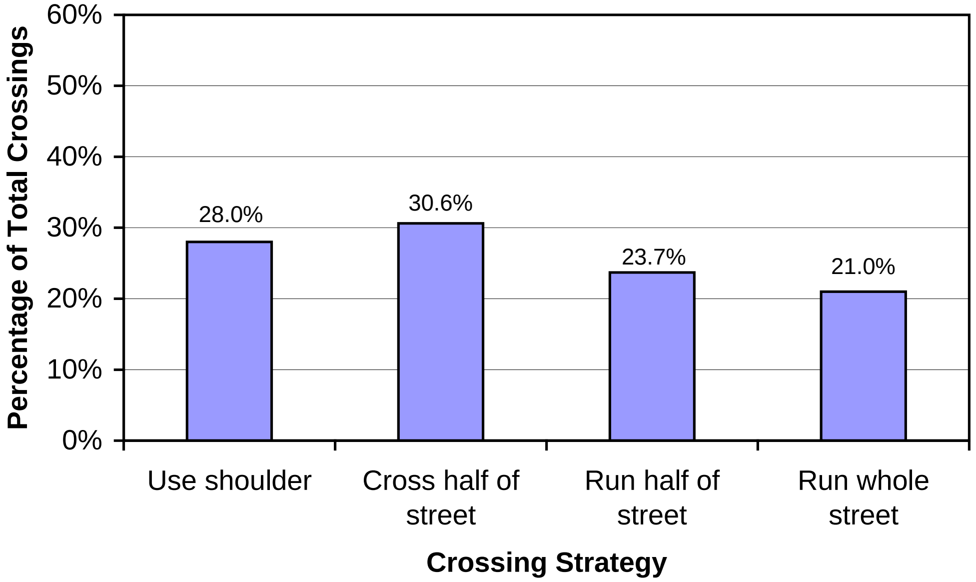


Figure B-54. Usage of different pedestrian crossing strategies—Shoreline

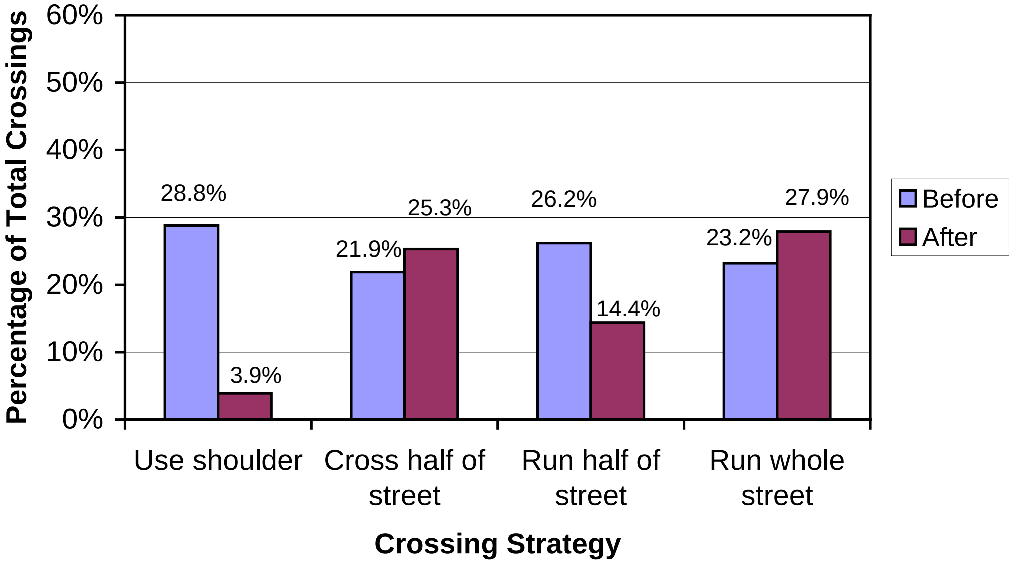


Figure B-55. Usage of different pedestrian crossing strategies—Kent

The proportion of pedestrians who ran across half of the roadway, as well as those who used the shoulder to wait, decreased significantly (at the 0.0005 level for running across half of the street and at the 0.0001 level for shoulder use) in the *after* study at

Kent. The shoulders were technically eliminated with the addition of the bus/HOV lane in the *after* study; however, the pedestrians who chose to wait in the new lane were classified as having used the shoulder. The fact that this area was now part of the roadway used by traffic likely deterred most pedestrians from using it as a waiting area.

The results for the Airway Heights site are shown in Figure B-56.

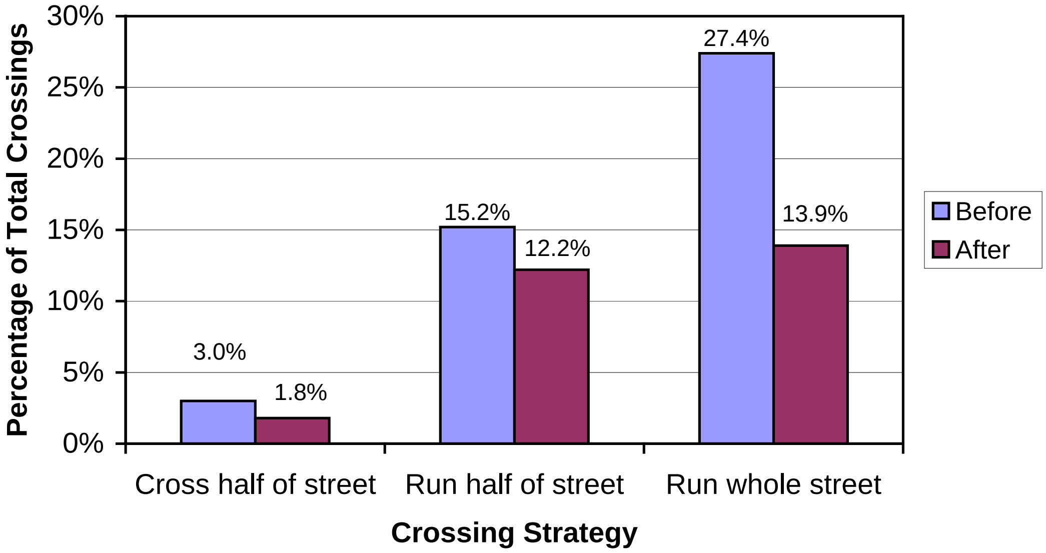


Figure B-56. Usage of different pedestrian crossing strategies—Airway Heights

The change in running across both sides of the roadway was statistically significant at the 0.0001 level between the *before* and *after* phases of the study at Airway Heights. This increase may have been due to the addition of the stop bar. It allowed pedestrians to see where vehicles should be stopped for their crossing and, because it was set back from the crosswalk, gave them more reaction time to decide to run if an approaching vehicle did not appear to be able to stop in time.

The results for the Spokane sites are shown in Figure B-57 through Figure B-59.

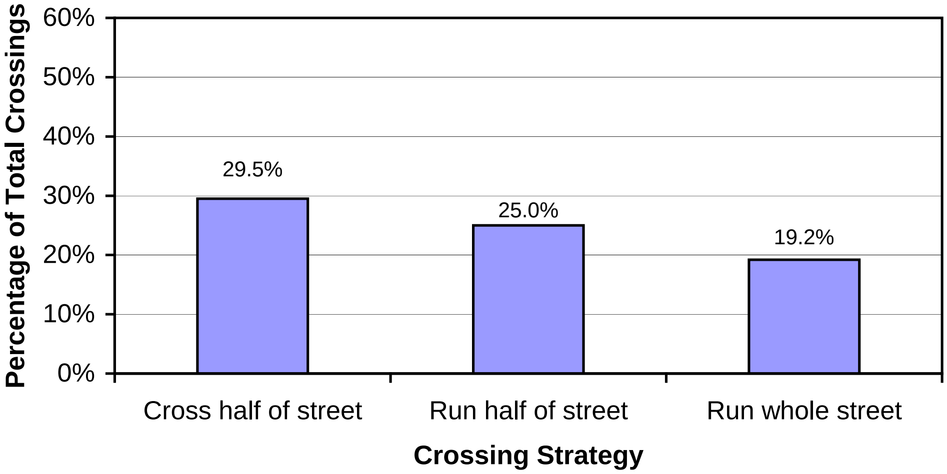


Figure B-57. Usage of different pedestrian crossing strategies at Lacrosse Avenue—Spokane

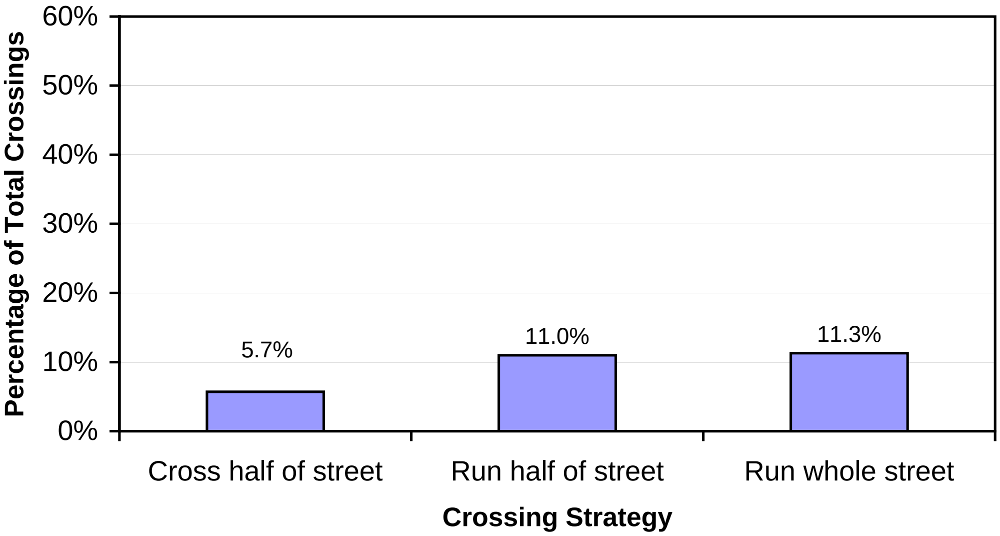


Figure B-58. Usage of different pedestrian crossing strategies at Rowan Avenue—Spokane

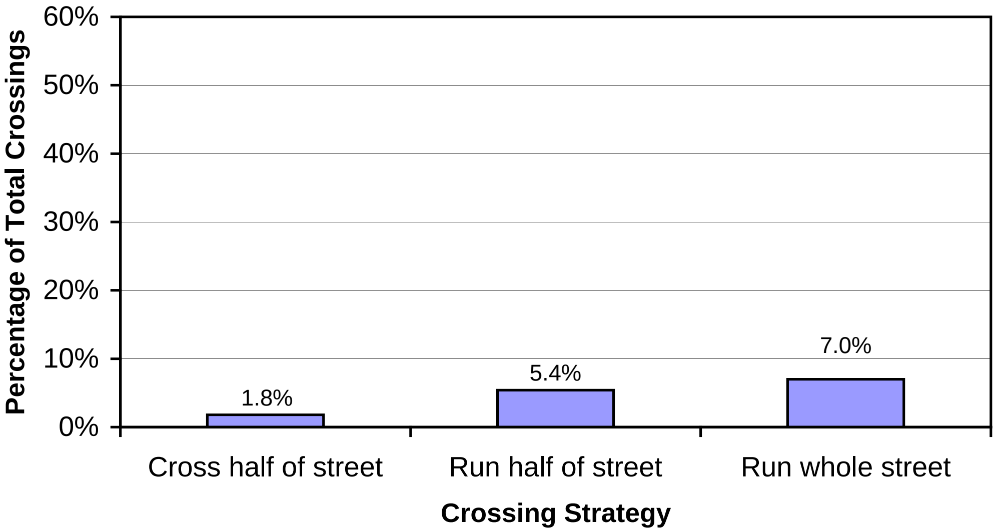


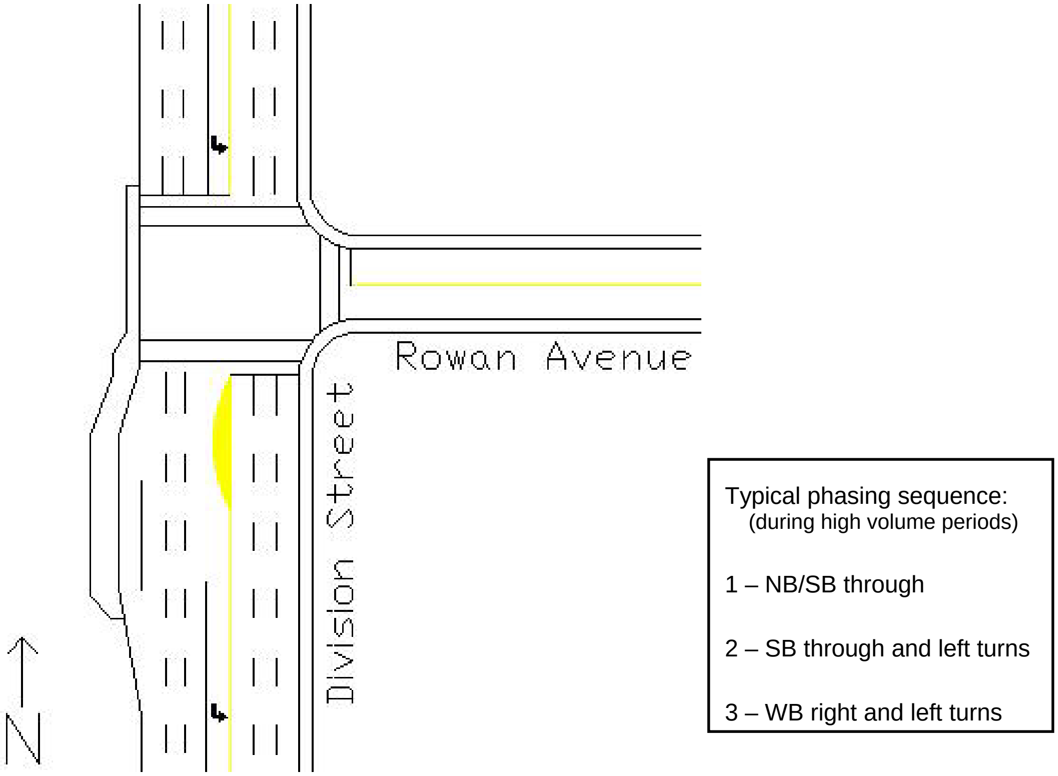
Figure B-59. Usage of different pedestrian crossing strategies at Wellesley Avenue—Spokane

Signalization of the intersections seemed to play a large role in the crossing strategies used by pedestrians in Spokane. At the unsignalized intersection at Lacrosse Avenue, crossing in stages (first one half of the street and then the other), as well as running, were very common, with the number of pedestrians employing each strategy accounting for 20 percent or more of the crossings. At signalized intersections, such as Rowan Avenue, running behavior was lower by about 50 percent, and staged crossings were lower by about 80 percent. At Wellesley Avenue, where there were not only a signal but also protected left turns at all approaches, running behavior was lower by another 50 percent in comparison to Rowan Avenue (which had permissive left turns) and staged crossings were lower by about two-thirds.

In comparing the Spokane data, there did not appear to be any consistency in which side of the street or direction of pedestrian travel caused these strategies to be employed.

Signal-Related Pedestrian Behavior

In addition to the crossing strategies mentioned above, there were also instances of pedestrians crossing against the traffic signals at the Spokane sites of Rowan Avenue and Wellesley Avenue. Specifically, pedestrians were observed crossing against the signal 9.8 percent of the time (N=26) at Rowan Avenue and only 1.5 percent of the time (N=5) at Wellesley Avenue. At Rowan Avenue, this occurred most often (64 percent of the time, N=16) because of “early starting” pedestrians, that is, people leaving the curb before their approach received a “Walk” indication. This appeared to be affected by the signal phasing of the intersection: 1) both the north- and southbound directions received a green light, 2) then if southbound vehicles were waiting to turn left onto Rowan, the northbound direction was stopped and southbound vehicles (straight and left turns) were given the green light, 3) finally, traffic from Rowan Avenue was given green time for vehicles to turn left or right (see Figure B-60 for intersection and signal phase details). In the early start cases, pedestrians were crossing as soon as they saw the northbound traffic signal turn red. This put them in danger of being struck by the southbound vehicles that were traveling straight at Rowan, and, depending upon which side of the street they were crossing, they might also be in the path of the left turning vehicles. This occurred once as a result of a pedestrian attempting to reach a transit vehicle that was at the stop on the opposite side of the street.



Typical phasing sequence:
(during high volume periods)

1 – NB/SB through

2 – SB through and left turns

3 – WB right and left turns

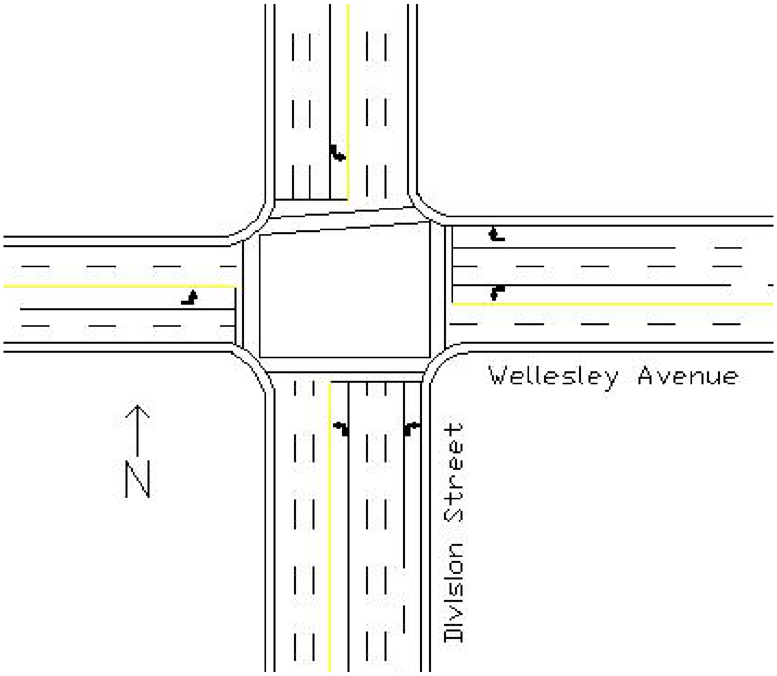
Figure B-60. Intersection diagram and signal phasing sequence for Rowan Avenue—Spokane

Other behavior at Rowan Avenue included simple disregard for the signals, crossing late, and anticipation of the signal change. Signal disregard normally occurred when there were gaps in the traffic on Division Street. Pedestrians might or might not push the actuation button, but if there was an acceptable gap, they might make the crossing against the signal. This occurred in 28 percent (N=7) of the “against signal” crossings, once because of a transit vehicle approaching the bus stop on the opposite side of the street. Crossing late was defined as a pedestrian leaving the curb well into the green indication and finishing the crossing after the traffic on Division Street had already received the green signal. This happened twice during the study. There was also one incident in which a pedestrian left the curb during the red clearance interval (about 2 seconds before he would have received the green signal). This was the least serious of the behaviors classified as being “against the signal.”

At Wellesley Avenue, the most serious occasion of a pedestrian crossing against the signal was due to disregard of the signal (N=1). In this case, the northbound through and left turn movements had the green signal as he approached (see Figure B-61 for intersection/phasing details). Before he stepped from the curb, the left turn phase had ended and the southbound through-movement green phase had begun. He stepped in front of these three lanes of traffic, which waited for him to cross, but then he had to wait on the small, two-foot wide median to allow the northbound vehicles to proceed before he could complete his crossing.

The other four instances of crossing against the signal were all pedestrians who arrived at the intersection after the vehicle green time for that direction had begun. They each began their crossings, presumably with a “Don’t Walk” pedestrian signal indication (but a green vehicle indication), and ended their crossings out of phase, that is, the north- or southbound vehicles had to stop and wait for the pedestrians to complete their crossings before proceeding through the intersection.

There was one other signal-related observation at Rowan Avenue. This was the dismissal that the pedestrian actuation buttons sometimes received. Although the placement of the cameras did not allow the researchers to see the pedestrian signal indications at this intersection, many pedestrians who wished to cross Division Street were observed to arrive during the green phase for Rowan Avenue. Instead of pushing the button and waiting through an entire signal cycle to receive the “Walk” indication, they crossed on the green vehicle signal, when “Don’t Walk” was being shown on the pedestrian signal. This behavior is thought to be due, at least in part, to the lower vehicle volumes on Rowan Avenue and the lower perceived complexity of this T-intersection versus a standard, four-legged intersection. This behavior was not seen at the intersection of Division Street and Wellesley Avenue, a four-way intersection where vehicle volumes were much higher (especially on the cross street, Wellesley) and the signal phasing for the intersection was much more complex.



Typical phasing sequence:
(during high volume periods)

1 – NB/SB left turns

2 – NB/SB through

3 – EB/WB left turns

4 – EB/WB through

Figure B-61. Intersection diagram and signal phasing sequence for Wellesley Avenue—Spokane

SHIELDING CONFLICTS

A shielding conflict occurs when a vehicle in the lane closest to a pedestrian yields while vehicles in adjacent travel lane(s) continue. These conflicts often result in some of the most severe pedestrian injuries or death.

The shielding conflicts were categorized as follows:

- **Type I**

  Subtype (a): The pedestrian is crossing the second half of the street, in the crosswalk. The vehicle in the left lane stops. The vehicle in the right lane continues and then must brake hard or swerve to avoid the pedestrian. In this case, the vehicle in the left lane is larger (i.e., a full-size pick up truck or van) than the vehicle in the right lane (i.e., a small passenger car or small sport utility vehicle).

  Subtype (b): Same as subtype (a), but the shielded vehicle is the same size or larger than the shielding vehicle.

<u>Subtype (c)</u>: Same as subtype (a), except the vehicle in the right lane yields, while the vehicle in the left lane proceeds.

- **<u>Type II</u>**

  <u>Subtype (a)</u>: The pedestrian is crossing the first half of the street, in the crosswalk. The vehicle in the right lane stops. The vehicle in the left lane continues through the crossing while braking slightly. In this case the vehicle in the right lane is larger (i.e., a full-size sedan or minivan), while the vehicle in the left lane is smaller (i.e., a compact or sports car).

  <u>Subtype (b)</u>: Same as subtype (a), but the shielded vehicle is the same size or larger than the shielding vehicle.

  <u>Subtype (c)</u>: Same as subtype (a), except the vehicle in the left lane yields, while the vehicle in the right lane proceeds.

I. SR 7—Spanaway

Pedestrians crossing in the Spanaway study site experienced the following shielding conflicts:

Type I a: *Before* phase, N=4; *After – phase I*, N=1; *After – phase II*, N=12
Type I b: *Before* phase, N=5; *After – phase I*, N=0; *After – phase II*, N=16
Type I c: *Before* phase, N=0; *After – phase I*, N=0; *After – phase II*, N=8
Type II a: *Before* phase, N=0; *After – phase I*, N=0; *After – phase II*, N=1
Type II b: *Before* phase, N=2; *After – phase I*, N=0; *After – phase II*, N=4
Type II c: *Before* phase, N=1; *After – phase I*, N=0; *After – phase II*, N=3

In general, the incidences of this were fairly rare in the *before* study in Spanaway (5.5 percent of all crossings, N=12), the *after—phase I* study (1.4 percent of all crossings, N=1), and the *after—phase II* study (13.1 percent of all crossings, N=41). There was a statistically significant change in the number of shielding conflicts from the *before* study to the second phase of the *after* study (at the 0.005 level). This may have been due to the relative newness of the crosswalk markings, in that some motorists were not yet accustomed to them, or simply to the increased number of hours of darkness during this phase of the study in comparison to the other two phases that were performed in spring and summer months.

These conditions might be improved by additional engineering treatments: actuated flashers on the signs in the raised median and on the shoulder or in the pavement itself. Overhead lighted signage or flashers (preferably actuated) to call attention to the crosswalk could be beneficial. Stop bars could be added in advance of the crosswalks to give drivers and pedestrians more opportunity to see one another before a conflict occurs.

II. SR 99—Shoreline

Pedestrians crossing in the Shoreline study site experienced the following shielding conflicts:

Type I a: N=4
Type I b: N=1
Type I c: N=0
Type II a: N=1
Type II b: N=1
Type II c: N=1

Shielding incidences were rare at the Shoreline study site (2.7 percent of all crossings (N=8)).

III. SR 99—Kent

Pedestrians crossing in the Kent study site experienced the following shielding conflicts:

Type I a: *Before* phase, N=1; *After* phase, N=2
Type I b: *Before* phase, N=1; *After* phase, N=5

Type I c: *Before* phase, N=0; *After* phase, N=0
Type II a: *Before* phase, N=0; *After* phase, N=0
Type II b: *Before* phase, N=0; *After* phase, N=0
Type II c: *Before* phase, N=0; *After* phase, N=0

Shielding incidences were very rare at the Kent study site (0.7 percent of all crossings (N=2) in the *before* study and 2.3 percent of all crossings (N=7) in the *after* study). There was no statistically significant difference between the numbers of shielding conflicts in the *before* and *after* studies.

Because shielding conflicts were rare at this location, specific recommendations to decrease them are difficult. The placement of the northbound bus stop should be considered. If pedestrians are given convenient, safe crossing routes, they will likely use them. The current crossing paths to the bus stop (unsanctioned, mid-block) save time and are much closer than using the signalized crossing. Other options include adding signage to alert drivers to the possibility of crossing pedestrians, studying the placement of lighting to ensure that it is optimal for drivers to see pedestrians at their preferred crossing routes, or adding a sanctioned mid-block crossing at this location.

IV. SR 2—Airway Heights

Pedestrians crossing in the Airway Heights study site experienced the following shielding conflicts:

Type I a: *Before* phase, N=3; *After* phase, N=1
Type I b: *Before* phase, N=0; *After* phase, N=0
Type I c: *Before* phase, N=0; *After* phase, N=0
Type II a: *Before* phase, N=2; *After* phase, N=2
Type II b: *Before* phase, N=0; *After* phase, N=6
Type II c: *Before* phase, N=0; *After* phase, N=2

In general, the incidences of this were rare in both the *before* study (1.7 percent of all crossings, N=5) and the *after* study (3.3 percent of all crossings, N=11) at Airway Heights. There was not a statistically significant change.

These conditions might be improved by additional lighting (i.e., flashers on the signs in the raised median/turn lane) or a more complex system of lighting the crosswalk, in which the lights would start flashing on the side of the street where the pedestrian began his crossing and then move to the other side of the street as the pedestrian moved.

Stop bars are also thought to help with shielding problems. By stopping vehicles in advance of the crosswalk, they give both the vehicles in other lanes and the pedestrians a better view of the roadway and should increase safety as a result. Figure B-62 shows the shielding instances observed categorized by whether the vehicles stopped behind the painted stop bar.

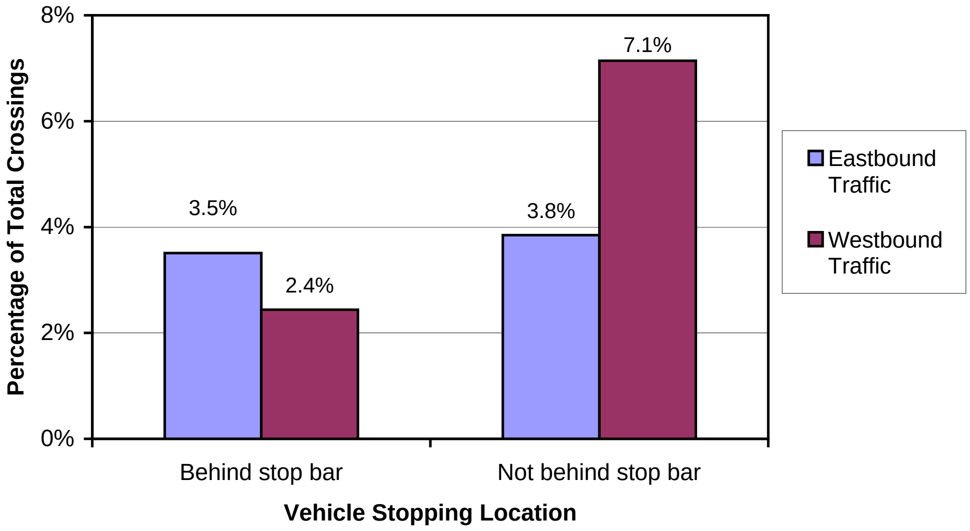


Figure B-62. Shielding instances based on vehicle stopping location

Because the sample size of shielding cases was quite small (N=11) at Airway Heights, the results are not statistically significant. Further research into the effectiveness of this simple treatment could be warranted on this or other multilane roadways, especially since shielding conflicts normally account for most of the more severe collisions involving pedestrians.

V. SR 2—Spokane

Pedestrians crossing in the Spokane study sites experienced shielding conflicts only at the Lacrosse Avenue site. Those pedestrians experienced the following shielding conflicts:

Type I a: N=5

Type I b: N=0

Type I c: N=3

Type II a: N=0

Type II b: N=5

Type II c: N=0

In general, the incidences of this were rare in the Spokane study (5.4 percent of crossings at Lacrosse Avenue (N=13); there were no incidences at Rowan Avenue or Wellesley Avenue).

It appears that Type I c and II b shielding conflicts are both likely due to inattention on the part of the drivers. Clues visible to drivers (i.e., applying fresh crosswalk markings, if appropriate/warranted, or adding signs to alert drivers to the possibility of pedestrians crossing at this intersection) may be helpful.

PEDESTRIAN AND VEHICLE CONFLICTS

A number of pedestrian-vehicle conflicts were thought to be possible in the study areas. They included pedestrian evasive action, vehicle evasive action, near miss, pedestrian pressured to run, center lane wait, center lane conflict, turning movement conflict.

Pedestrian evasive behavior was defined as pedestrians jumping or stepping back to avoid a vehicle, or running to avoid being struck. Vehicle evasive action was defined as vehicles abruptly braking or swerving to avoid striking a pedestrian. Pedestrians observed during this study were generally cautious about crossing the street, and most pedestrians crossing at the study locations showed extreme caution, even when they were crossing in a legal marked or unmarked crosswalk. Many waited for a gap in traffic to cross the street without stopping at the center turn lane; others crossed one direction of the roadway at a time, waiting in the center turn lane for another gap to complete the crossing. Therefore, pedestrian and vehicle evasive behaviors were relatively infrequent during the study.

Another commonly observed behavior was classified as “pedestrians pressured to run.” This performance measure was recorded when a pedestrian appeared anxious about a crossing and ran across the street, even if vehicles yielded for the crossing.

“Near miss” was a performance measure that described when a pedestrian-vehicle collision almost occurred.

A center lane *wait* was defined as any crossing in which the pedestrian had to wait in the center turn lane for more than 5 seconds while waiting for a safe gap in which to cross.

A center lane *conflict* was defined as any crossing in which a vehicle had to stop or alter its course to avoid a pedestrian standing in the center turn lane.

A turning conflict was defined as an occurrence when a turning vehicle had to stop or alter its course to avoid a pedestrian crossing the roadway.

Figure B-63 displays the percentage of occurrences of these performance measures per total pedestrian crossings at the Spanaway site.

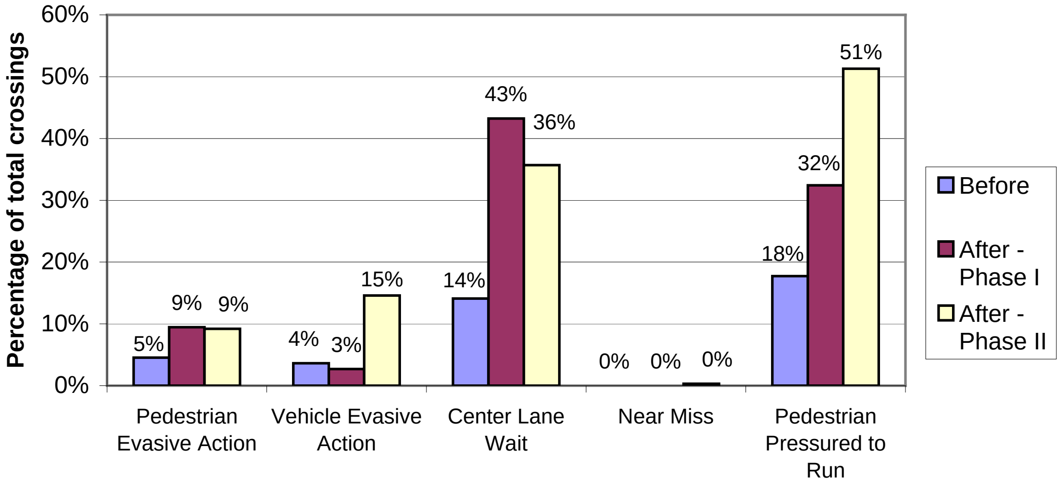


Figure B-63. Pedestrian and vehicle conflicts—Spanaway

At the Spanaway site, pedestrian and vehicle evasive actions were relatively infrequent because pedestrians were very cautious. However, the data suggest that pedestrians were more likely to wait in the center lane (likely due to the security of the raised median) and felt more pressured to run after the median had been installed.

One near miss was observed at Spanaway. It was observed during the second phase of the *after* study. The pedestrian was walking eastbound and used the crosswalk/raised median. While crossing the second half of the roadway, the vehicle in the left lane (medium size sedan) stopped. The vehicle in the right lane (full size sedan) appeared to make a decision to continue through the crosswalk. The pedestrian started to run to avoid a conflict. The vehicle in the right lane braked and narrowly missed the pedestrian as he completed his crossing. There was no stop bar in advance of the crosswalk at this location.

Figure B-64 displays the percentage of occurrences of pedestrian-vehicle conflicts per pedestrian crossings at the Shoreline site.

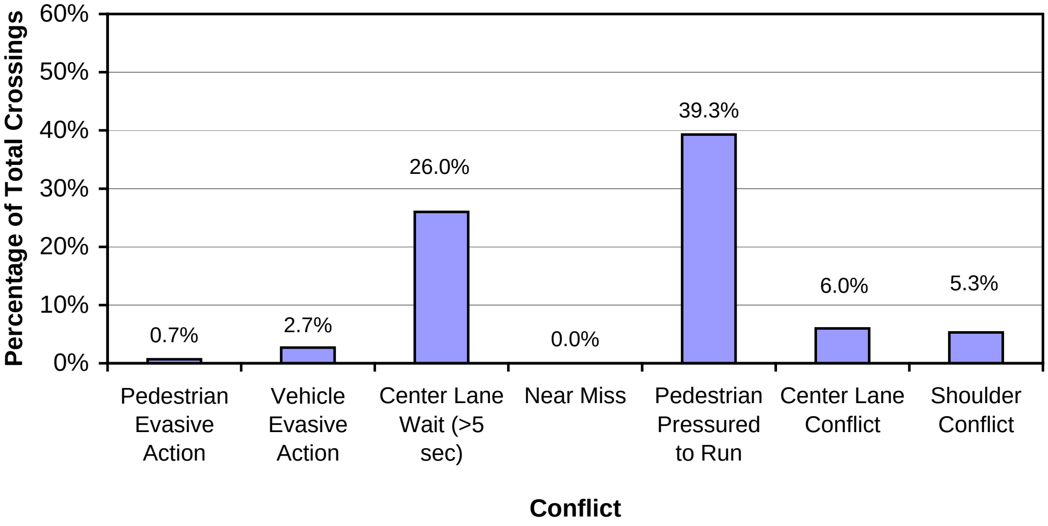


Figure B-64. Pedestrian and vehicle conflicts—Shoreline

There were no near misses at the Shoreline study site and very few evasive action conflicts. The comparatively large number of center lane waits and running behavior is indicative of a site where pedestrians were very cautious about crossing the roadway.

Figure B-65 displays the percentage of occurrences of pedestrian-vehicle conflicts per pedestrian crossings at the Kent site.

At the Kent site, pedestrian and vehicle evasive action conflicts, as well as center lane conflicts, increased at a statistically significant level (0.04 or better), while center lane waits and pedestrians who were pressured to run actually decreased in the *after* study. Pedestrian and vehicle evasive action conflicts were much more common during the *after* study in groups of two or more pedestrians (sometimes as many as 20 pedestrians) than when just one person was crossing the roadway. It appeared that the groups were using their size to cross at times when it was not safe to do so. This was not observed during the *before* study. The increase in center lane conflicts seems to be due to the increased length of the left turn pocket. In the *before* study, pedestrians crossed at the point where vehicles would enter the lane, so it was easier for the vehicles to simply delay their entry to the lane to avoid the pedestrians. In the *after* study, the vehicles had already entered the lane at the point where pedestrians were crossing, thereby making it a more dangerous situation. The decrease in center lane waits may be related to the increase in evasive action: pedestrians (especially groups) seemed to become less patient and acted more aggressively when crossing and, therefore, were less likely to wait in the center turn lane for a safe gap in which to continue crossing.

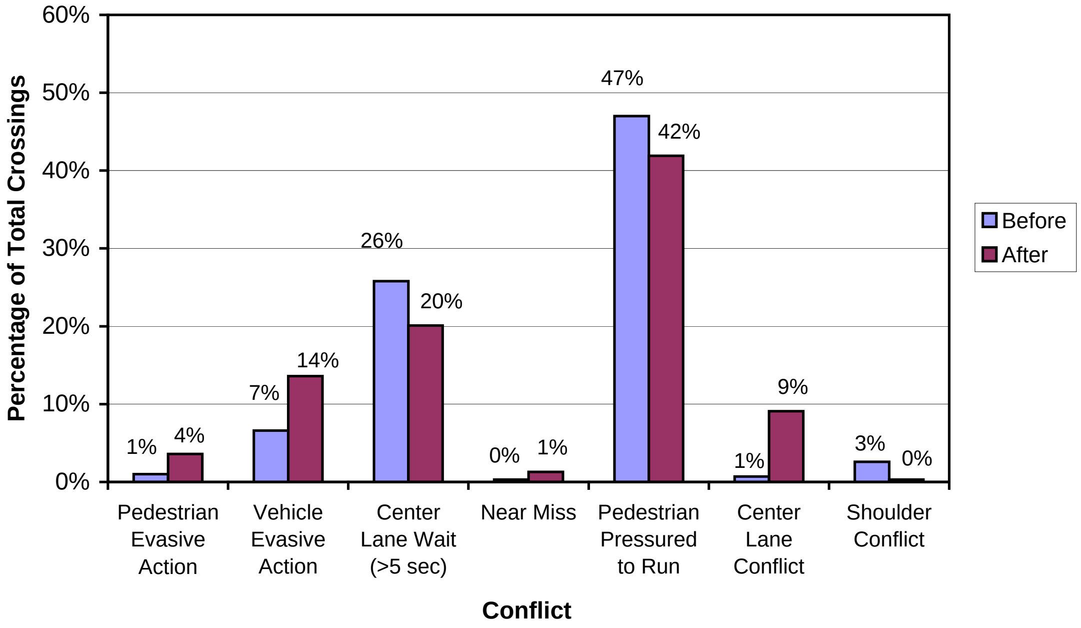


Figure B-65. Pedestrian and vehicle conflicts—Kent

One near miss was observed during the *before* phase of the study and two during the *after* phase at the Kent study site. Each of the near misses appeared to be precipitated by the pedestrian.

In the *before* study, the near miss occurred when an eastbound pedestrian crossed on a dark and rainy evening. The pedestrian walked, at an even pace, across the southbound lanes (at an unsanctioned, mid-block crossing location). The vehicle that was traveling in the leftmost through-lane was able to identify the pedestrian in its lane and began to brake and swerve into the left turn lane at a distance away of about four car lengths. It was able to barely avoid the pedestrian, who continued, uninterrupted, across the remainder of the roadway.

In the *after* study, there were two “near miss” conflicts. The first involved two eastbound pedestrians crossing on a dark but dry evening. They were seen running through the gas station near the corner of SR 99 and South 240th Street. When they reached SR 99, they continued running into the street, causing a delivery truck to brake abruptly to avoid them. In the second conflict, an eastbound pedestrian was waiting to cross SR 99 on a sunny, dry day. After waiting for approximately 30 seconds, he appeared to tire of waiting and proceeded to walk through a platoon of vehicles that were slowing for the red traffic light at South 240th Street. Two vehicles in the middle lane actually swerved and drove past him while he was standing in that lane. Both of the near misses in the *after* study involved crossings made to the transit stop. In neither case was the bus present nor in view when the crossings took place.

Figure B-66 displays the percentage of occurrences of pedestrian-vehicle conflicts per pedestrian crossings at the Airway Heights site.

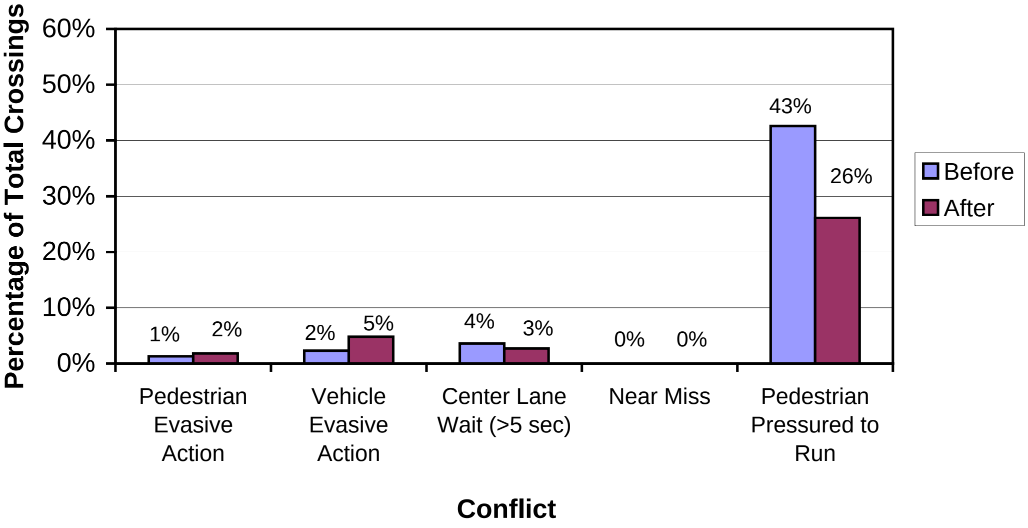


Figure B-66. Pedestrian and vehicle conflicts—Airway Heights

No near misses were observed at this site in either phase of the study at Airway Heights.

The only change between the *before* and *after* phases of the project at Airway Heights that was statistically significant was a decrease in crossings in which the pedestrian was pressured to run (significant at the 0.0001 level).

Figure B-67 through Figure B-69 display the percentage of occurrences of pedestrian-vehicle conflicts per pedestrian crossings at the Spokane sites.

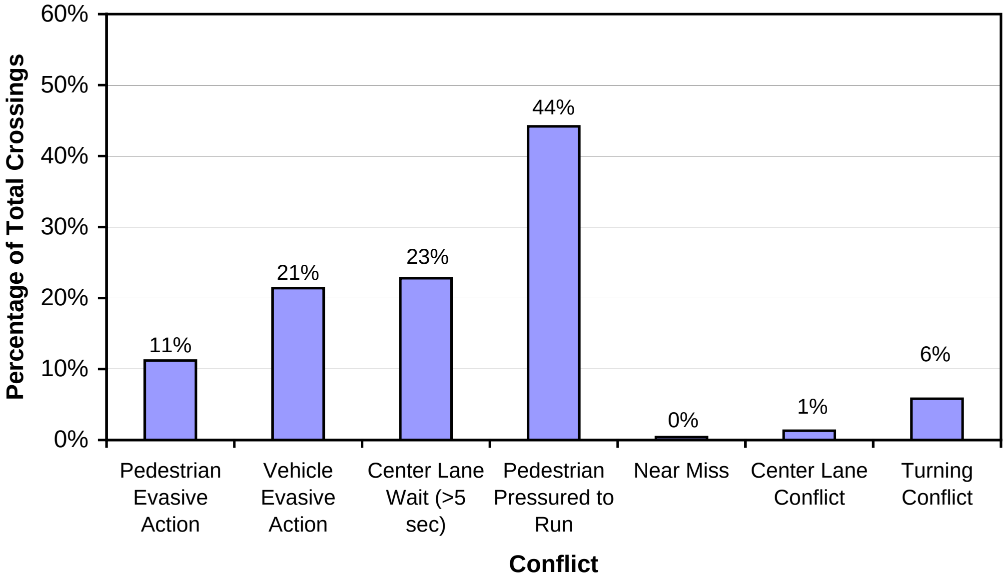


Figure B-67. Pedestrian and vehicle conflicts at Lacrosse Avenue—Spokane

One near miss was observed at the Lacrosse Avenue site. The conflict involved a westbound pedestrian crossing on a dry and overcast afternoon. The pedestrian made it safely across the northbound portion of the roadway and waited in the center lane for a gap in southbound traffic. The vehicle in the leftmost lane appeared to be slowing to yield for the pedestrian, but when the pedestrian crossed in front of the vehicle, it was unprepared to stop. This resulted in an emergency stop by the vehicle, leaving it very close to the path of the crossing pedestrian. The vehicle in the middle lane failed to stop at all, and the pedestrian had to stop abruptly to avoid it. In the right lane, the first vehicle passing the pedestrian did not stop, and the pedestrian ran in front of the next vehicle, causing it to have to brake to avoid a collision. There was a "near miss" situation in each of the southbound lanes of this crossing.

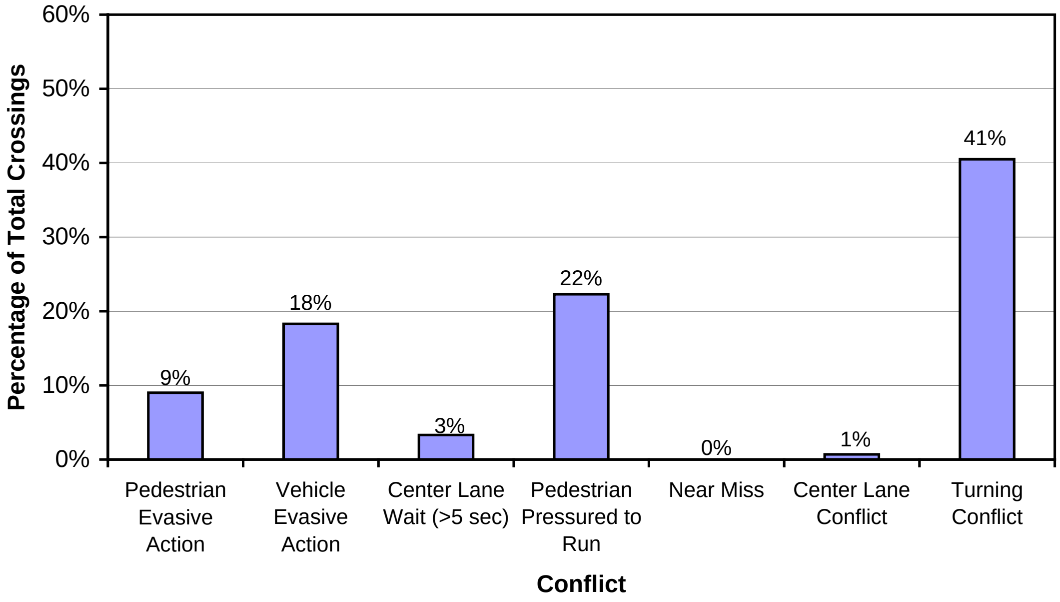


Figure B-68. Pedestrian and vehicle conflicts at Rowan Avenue—Spokane

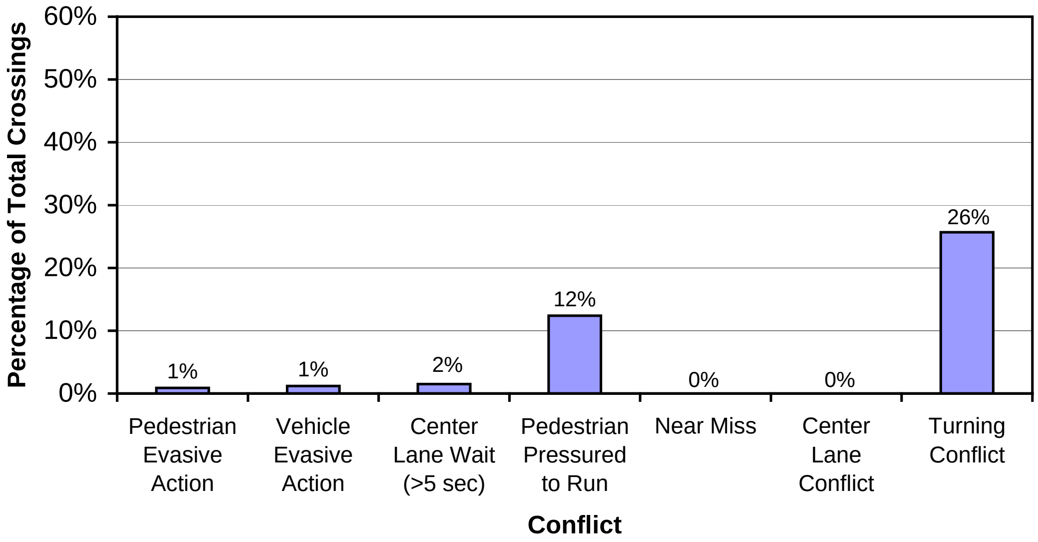


Figure B-69. Pedestrian and vehicle conflicts at Wellesley Avenue—Spokane

Again, signalization appeared to play a key role in the frequency and type of conflicts observed at the Spokane sites. The unsignalized intersection at Lacrosse Avenue experienced higher pedestrian and vehicle evasive behavior, more running, and more center lane waits, but fewer turning conflicts than the signalized intersections. The signalized intersection with permissive left turns at Rowan Avenue had many more turning conflicts than the other two intersections but had lower incidences of evasive action, running, and staged crossings. Wellesley Avenue (signalized, with protected left turns) had fewer incidences in all categories than the other intersections, except for turning conflicts, of which it had many more than at Lacrosse Avenue but still fewer than at Rowan Avenue.

Turning Conflicts

Turning conflicts were also examined at the Spokane study sites. The number of observed turning conflicts were quite varied from intersection to intersection. In an effort to more fully understand the specifics of what was happening, these conflicts were analyzed in more detail for each of the study sites, shown in Figure B-70 through Figure B-75. The direction of the each turn that exhibited a conflict is displayed (i.e., right or left turn), as well as whether the turn was taking the vehicle on to or off of SR 2 at the time of the conflict.

Lacrosse Avenue (unsignalized) had relatively few turning conflicts, and they were evenly split between right and left turns. Rowan Avenue (signalized, permissive left turns) had a large number of conflicts for both right and left turns, but left turn conflicts were significantly more frequent (at the 0.01 level). Wellesley Avenue (signalized, protected left turns) experienced almost exclusively right turn conflicts. At all of the Spokane study locations, the vast majority of conflicts occurred with vehicles from the minor street turning onto Division Street/SR 2. Presumably this occurred because of the longer delay (shorter green time or fewer/smaller gaps) experienced on the minor streets. This forced pedestrians and vehicles to use the same gaps for crossings and turns, which can easily result in conflicts.

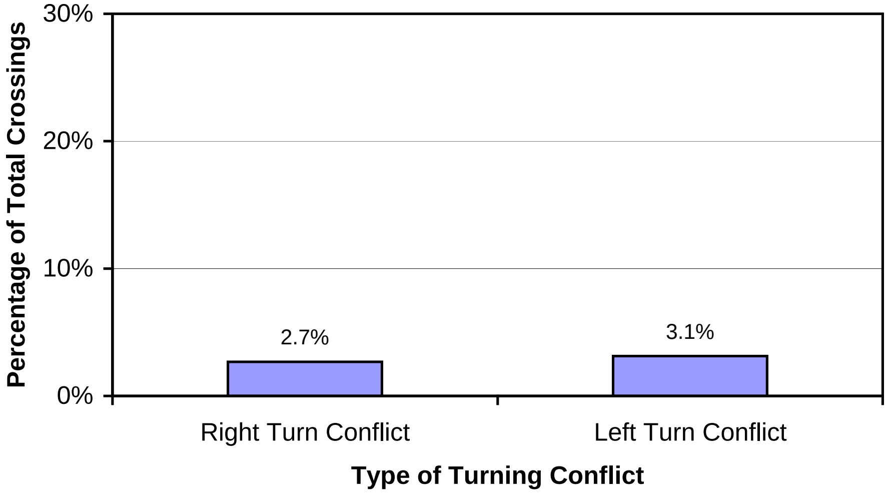


Figure B-70. Types of turning conflicts at Lacrosse Avenue—Spokane

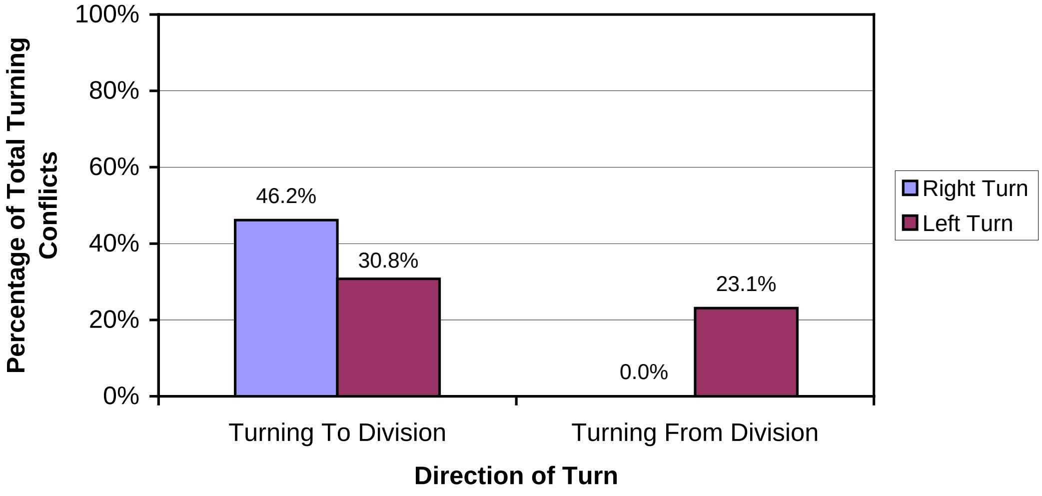


Figure B-71. Direction of turning conflicts at Lacrosse Avenue—Spokane

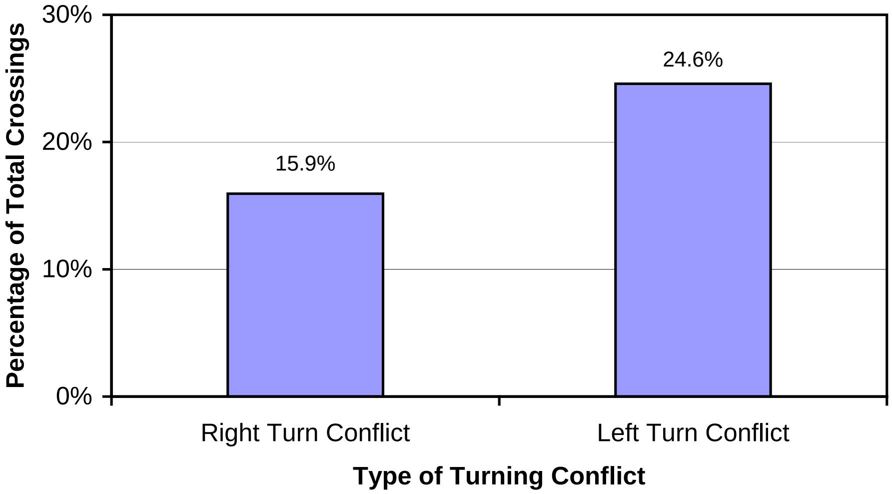


Figure B-72. Type of turning conflicts at Rowan Avenue—Spokane

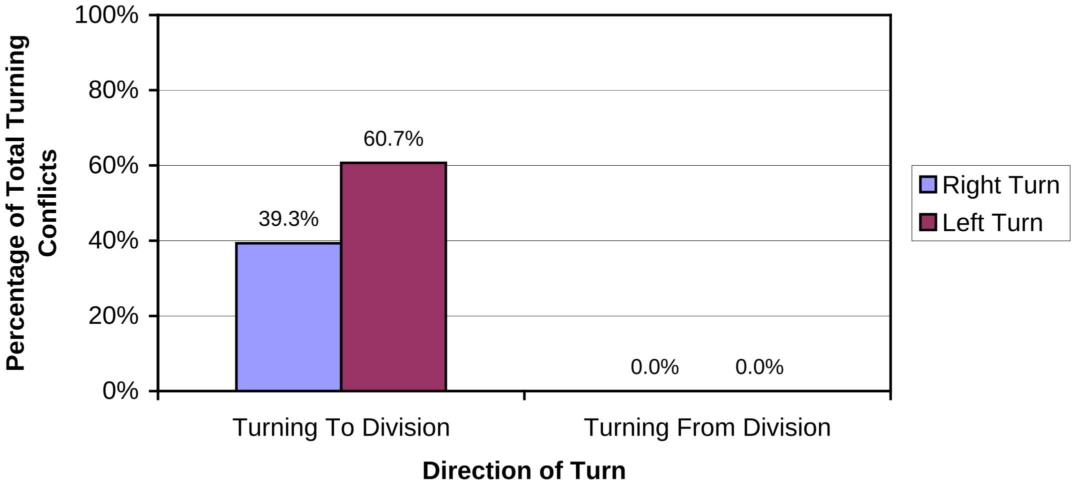


Figure B-73. Direction of turning conflicts at Rowan Avenue—Spokane

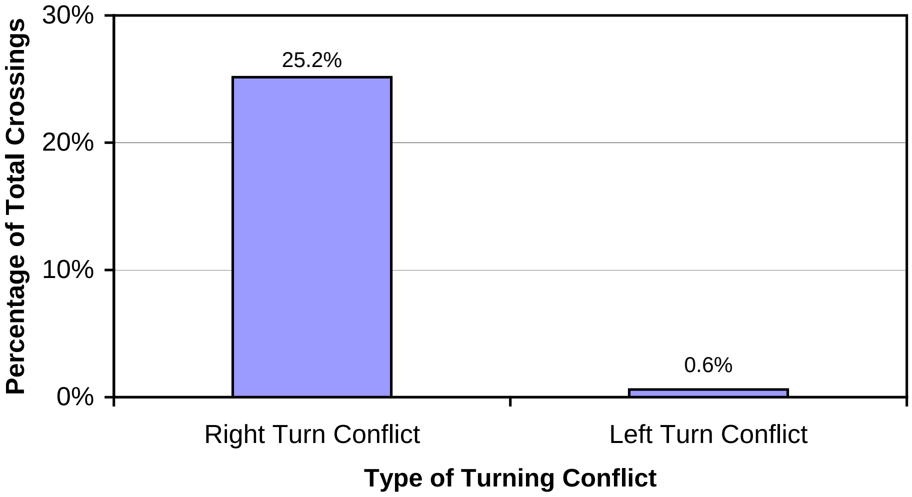


Figure B-74. Type of turning conflicts at Wellesley Avenue—Spokane

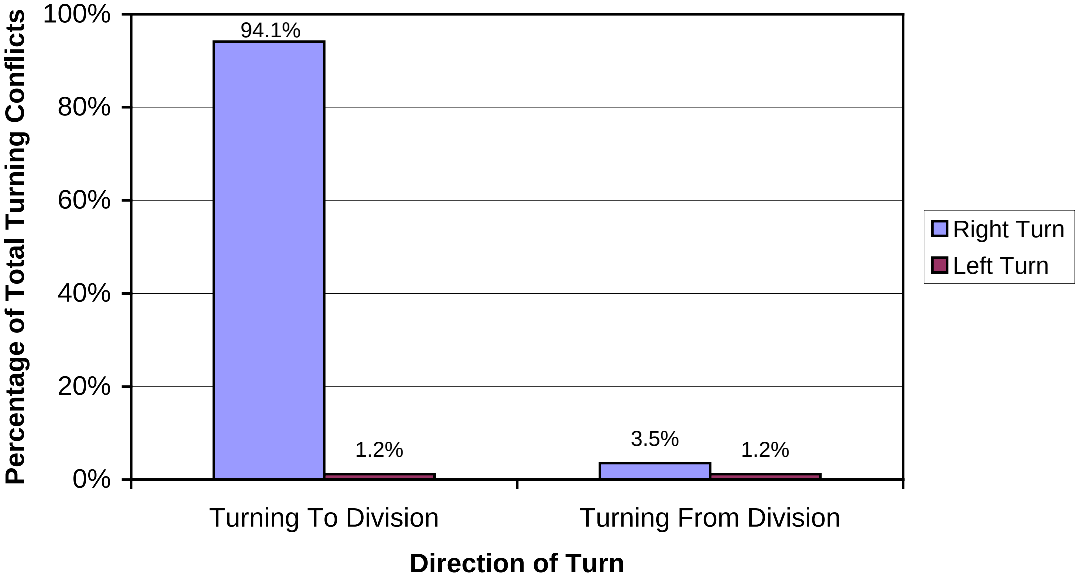


Figure B-75. Direction of turning conflicts at Wellesley Avenue—Spokane

Additional Factors Affecting Conflicts

At the Airway Heights site, each of the conflicts was examined further in an attempt to find the influences on and/or root causes of the conflict. The following factors were considered: direction of travel, day of the week, natural lighting, road surface condition, time of day, weather, crossing strategy, crossing location/flasher use, and stop bar compliance. Results for natural lighting, crossing location/flasher use, and stop bar compliance were particularly noteworthy or statistically significant. Those results are shown below.

Figure B-76 and Figure B-77 show the conflicts experienced by pedestrians during different lighting conditions. These conditions are a measure of the approximate level of natural lighting available at street level at the time of each pedestrian crossing.

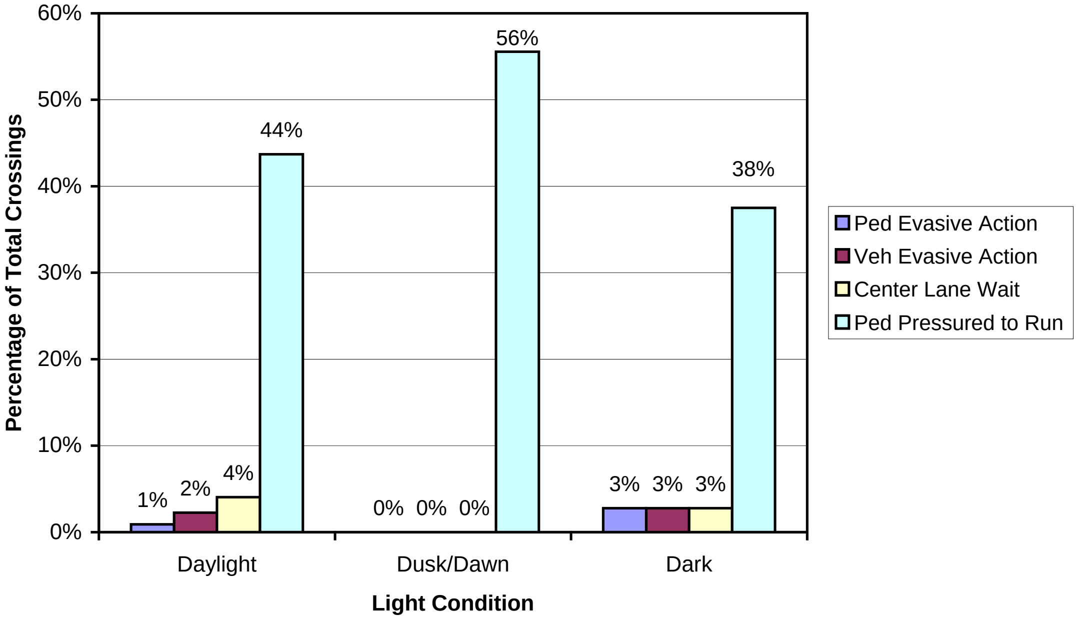


Figure B-76. Pedestrian and vehicle conflicts by light condition—*before* phase—Airway Heights

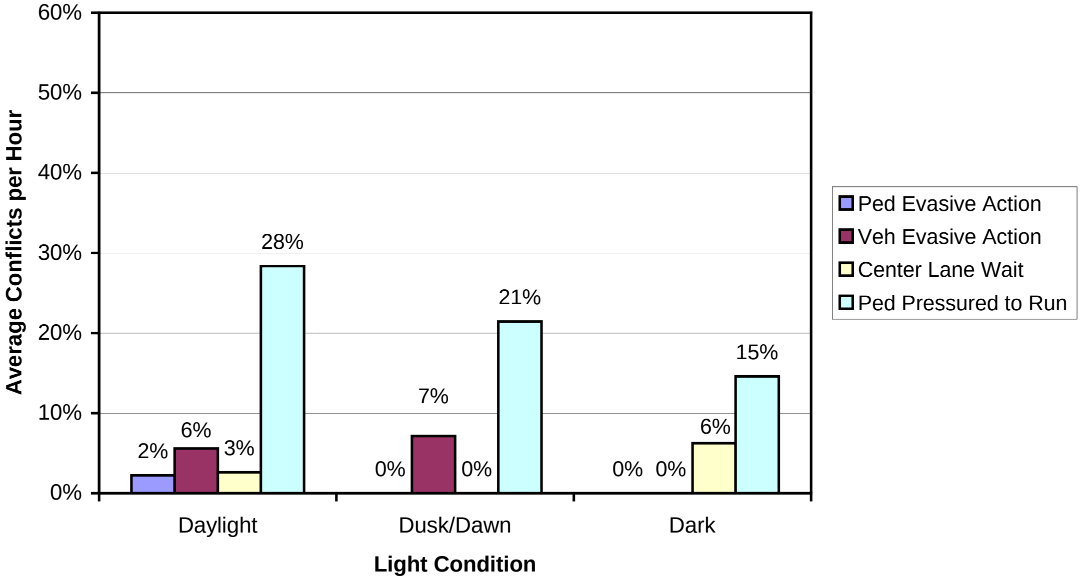


Figure B-77. Pedestrian and vehicle conflicts by light condition—*after* phase—Airway Heights

Conflicts in Airway Heights were somewhat more prevalent during daylight hours, perhaps because pedestrians and drivers were more comfortable in that condition and may have been less vigilant than at other times. The change in crossings that involved "pedestrian pressured to run" conflicts was statistically significant (at the 0.0001 level) between the *before* and *after* phases of the study. However, this appears to be part of an overall reduction in conflicts of this type and not related to the lighting condition of the crossings. In an attempt to further understand whether light condition was related to conflicts, conflict rates were calculated on the basis of their accompanying light condition. For these conflict rates, crossings made when no cars were present were excluded. In doing this, the dusk/dawn and dark conflicts were rendered insignificant, as the sample sizes were now too small to be evaluated. Also, because of the statistically significant change in "pedestrian pressured to run" conflicts recorded between the *before* and *after* studies, these conflicts and the center lane conflicts were excluded. This left daytime crossings with "serious conflicts" (pedestrian evasive action, vehicle evasive action, and near misses). <u>The rate of these conflicts for the *before* study was 0.047</u>

serious conflicts per crossing and 0.117 serious conflicts per crossing during the *after* study. This result was statistically significant at the 0.04 level.

Figure B-78 and Figure B-79 show the conflicts experienced, by crossing location and flasher use.

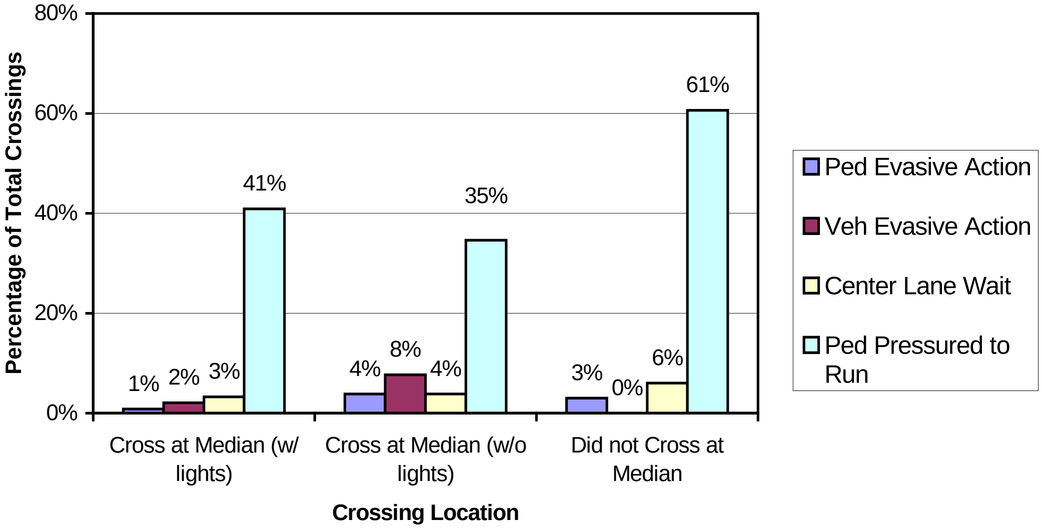


Figure B-78. Pedestrian and vehicle conflicts by crossing strategy/flasher use—*before* condition—Airway Heights

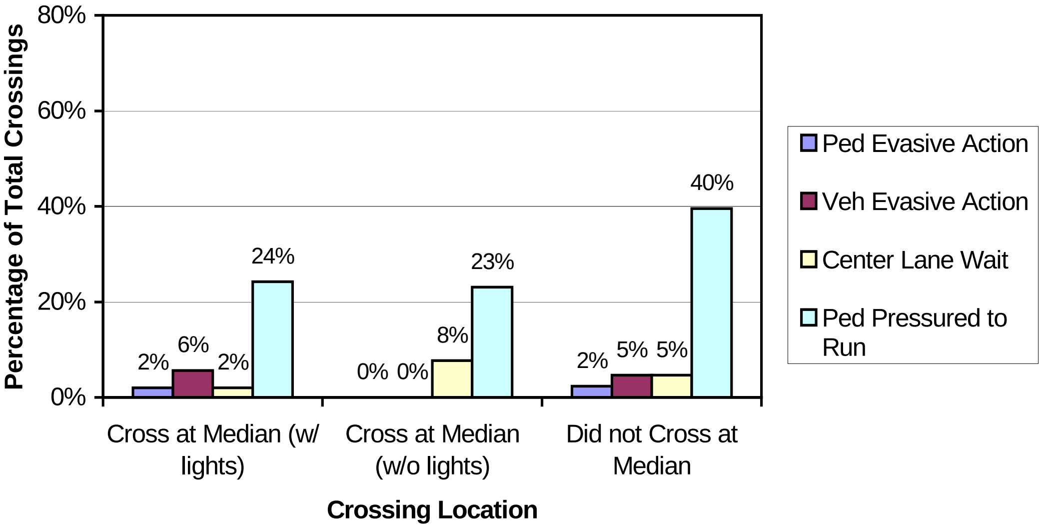


Figure B-79. Pedestrian and vehicle conflicts by crossing strategy/flasher use—*after* condition—Airway Heights

In the *before* study, those using the median and flashers in Airway Heights experienced fewer serious conflicts (pedestrian and vehicle evasive action) than those who used the median without the flashers (statistically significant at the 0.04 level). And those using the median were less likely to run than those crossing at other locations (statistically significant at the 0.05 level).

In the *after* study, there was a statistically significant difference in the running behavior of those using the median and lights versus those not using the median (at the 0.04 level). Also, the crossings made using the median and lights were less likely to have to wait in the center lane than those using the median and not the lights (statistically significant at the 0.05 level).

The change between the *before* and *after* phases of the Airway Heights study was statistically significant for vehicle evasive action (at the 0.05 level) and pedestrian pressured to run (at the 0.0001 level) for those pedestrians who used the median and lights. The increase in vehicle evasive action conflicts could have been due to the decrease in warning provided to drivers because of the failing in-pavement flashers. The decrease in pedestrian pressured to run conflicts may have been due to the addition of the stop bar and is discussed in more detail later in this report. Differences between those crossing with the median and no lights and those not using the median were not statistically significant.

Also, many of the pedestrians crossing and not using the median crossed in gaps in traffic, which may explain the lower conflict rate overall. As an illustration, in the *before* study, 24 out of the 33 crossings were made by using in a gap in traffic and in the *after* study, 34 out of the 43 crossings were made by using a gap. Of the nine crossings that were made without the median and not using a gap in traffic in the *before* study, two had to wait in the center lane, and six were pressured to run. In the after study, there were also nine crossings that did not use the median or a gap in traffic. Of these crossings, one experienced a pedestrian evasive action conflict, two experienced a vehicle evasive action conflict, one had to wait in the center lane, and three were pressured to run. In both cases, the small sample size precludes statistical significance calculations.

As with the natural lighting discussion above, further insight into conflicts and crossing location/flasher use was desired. Again, Airway Heights crossings were grouped by crossing location, and crossings that occurred without vehicles present were excluded, along with pedestrian pressured to run and center lane wait conflicts. In doing this, the crossings included in the "median without lights" and "did not cross in median" groups were reduced to a statistically insignificant sample size. The remaining group—those using both the median and the flashers—was examined. The conflict rate in this group was found to be 0.041 in the *before* study and 0.103 in the *after* study—a result that is statistically significant at the 0.04 level.

Figure B-80 shows the conflicts experienced by pedestrians when vehicles stopped behind or in front of the painted stop bars that were added as part of the *after* condition.

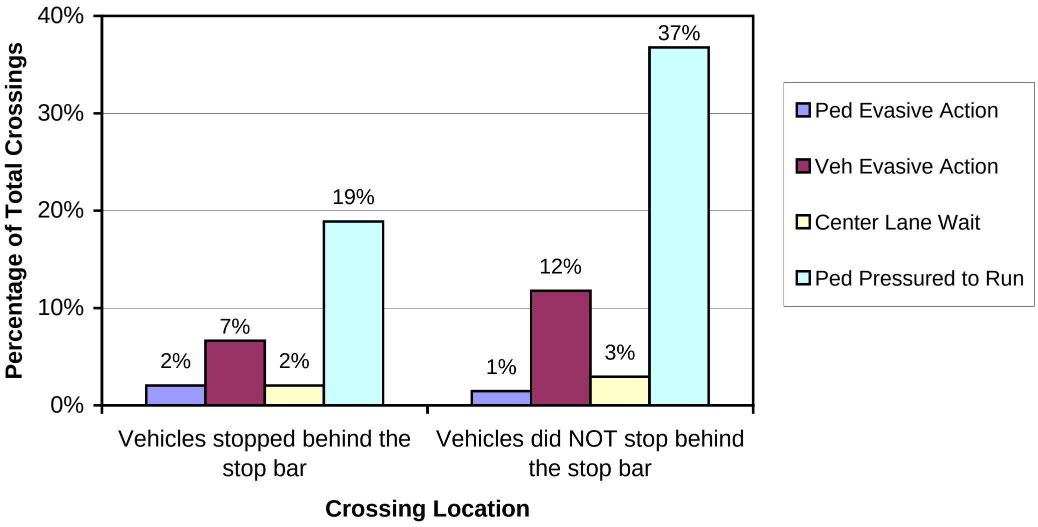


Figure B-80. Pedestrian conflicts experienced by vehicle stop bar compliance—Airway Heights

The difference between the running behavior of pedestrians when vehicles stopped or did not stop behind the line was significant at the 0.005 level. The stop bar may have given pedestrians a simple way to judge whether they felt safe while crossing and, consequently, whether they felt the need to run during the crossing to avoid the potential danger of the vehicles that were either stopped beyond the stop bar or proceeding at a rate of speed that suggested they would not be able to stop in time behind the stop bar.

There was no statistically significant difference in the rate of serious conflicts (pedestrian evasive action, vehicle evasive action, and near miss) in crossings where the vehicles stopped behind the stop bar and those that did not at Airway Heights.

TRANSIT RELATED ACTIVITY

The proportion of transit-related trips was also considered at each of the sites. These data are given below, followed by an examination of the frequency of conflicts that were experienced by those using transit and those not using transit. Both sets of data are given for each site, as applicable.

At the Spanaway site, approximately three-quarters of the pedestrian crossings were directly related to transit use, as shown in Figure B-81.

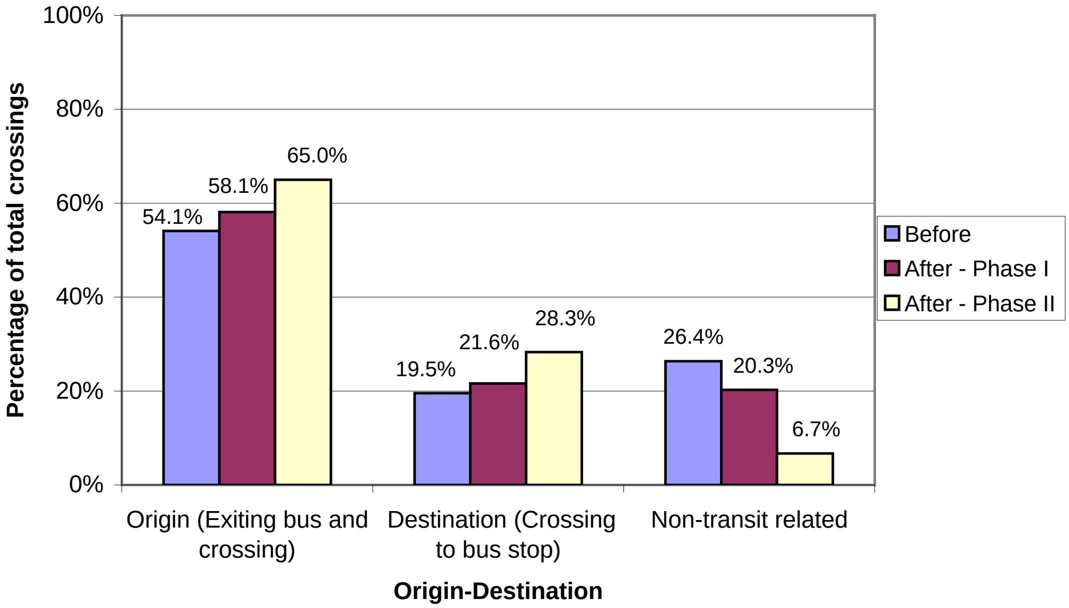


Figure B-81. Percentage of transit related crossings—Spanaway

Figure B-82 through Figure B-84 show the conflicts experienced by pedestrians in Spanaway, grouped by whether or not they were using transit.

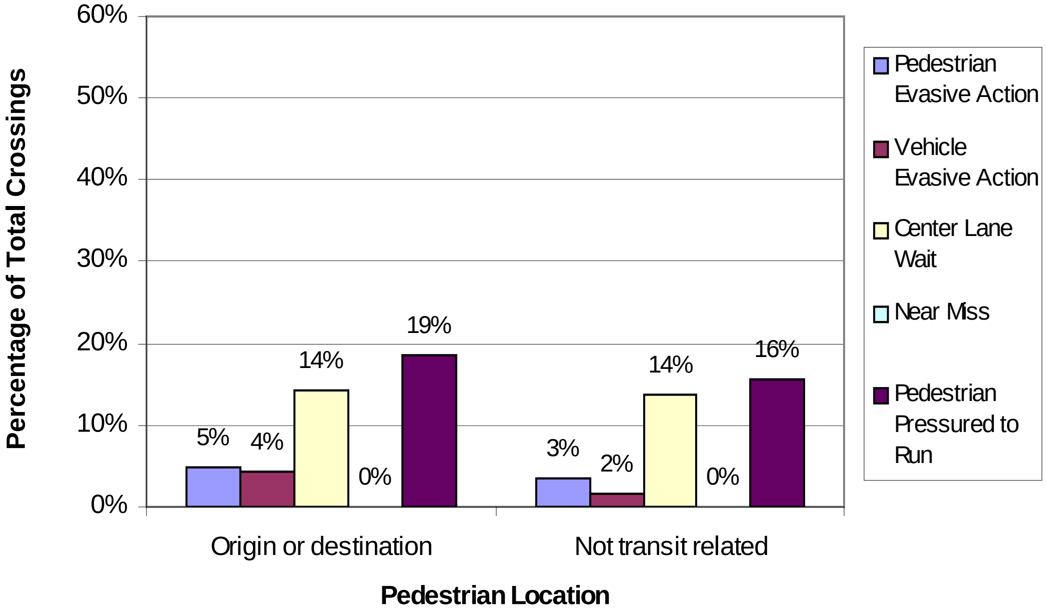


Figure B-82. Conflicts by transit use—*before* condition—Spanaway

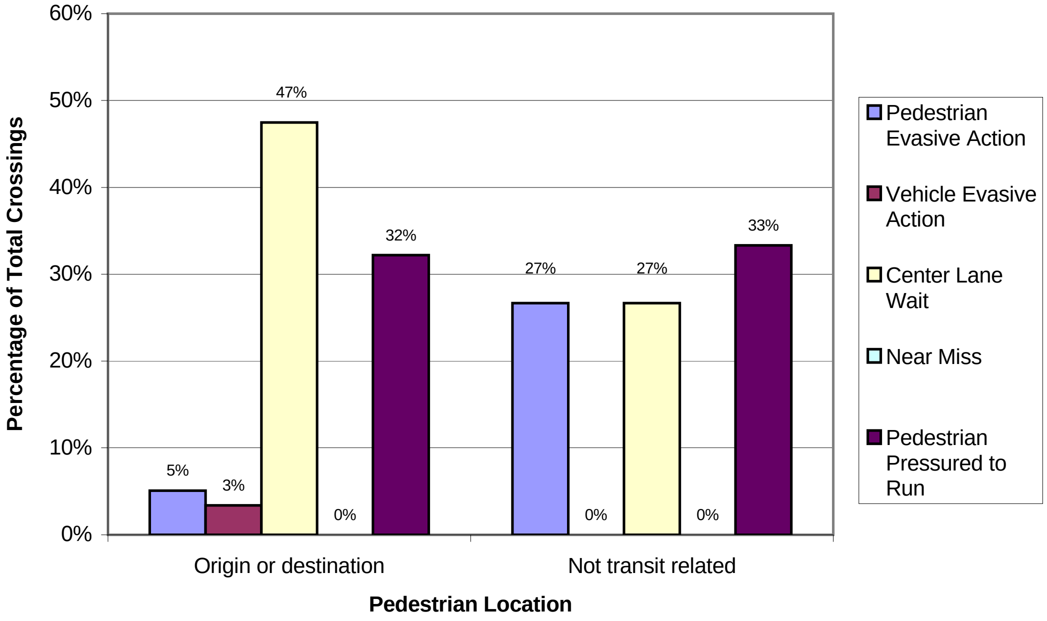


Figure B-83. Conflicts by transit use—*after*—*phase I* condition—Spanaway

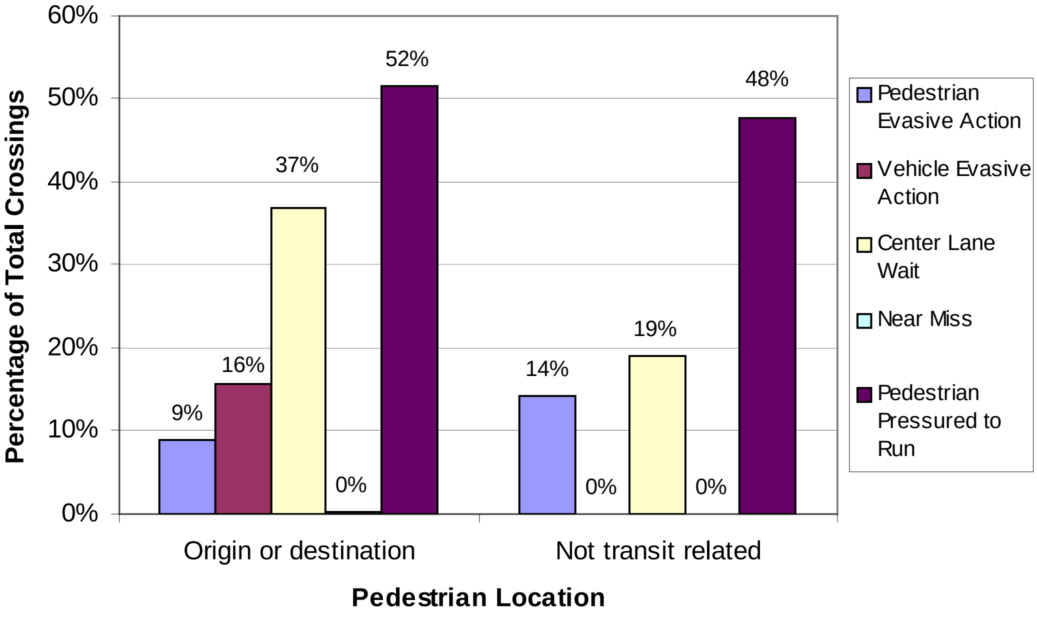


Figure B-84. Conflicts by transit use—*after*—*phase II* condition—Spanaway

In comparing those crossings that were transit related with those that were not, no statistically significant difference was found to exist between the two groups of pedestrians in Spanaway. However, only a small sample size was available for the non-transit related crossings in both of the *after* phases of the study.

At the Shoreline site, about half of the pedestrian crossings (45.7 percent) were directly related to transit use, as shown in Figure B-85.

Figure B-86 shows the relationship between transit users and vehicle-pedestrian conflicts at the Shoreline site.

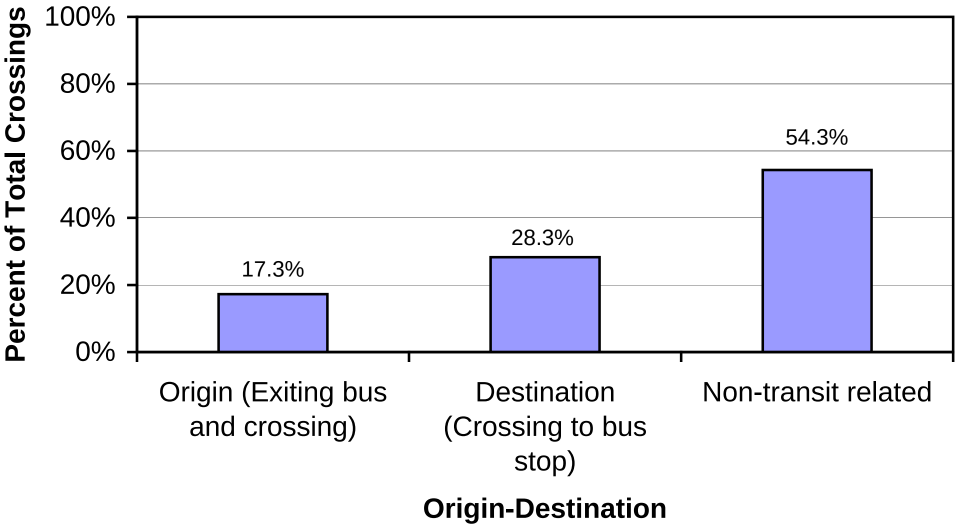


Figure B-85. Percentage of transit related crossings—Shoreline

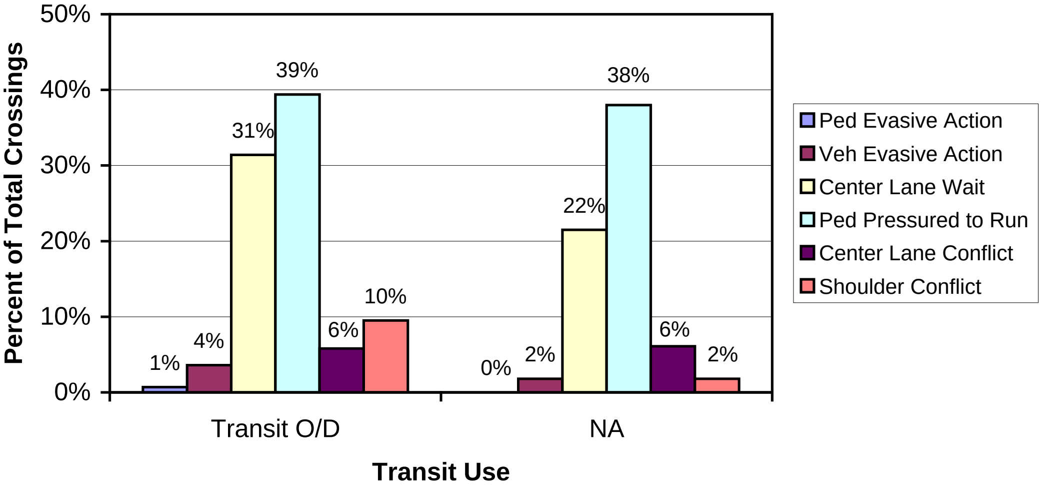


Figure B-86. Pedestrian conflicts related to transit use—Shoreline

Transit users at the Shoreline site experience a significantly (at a 0.0001 level) higher number of conflicts per crossing than non-transit users. Although the transit users only accounted for 45.7 percent of the pedestrian crossings in the area, they had 52.3 percent of the conflicts.

The occurrences of shoulder conflicts were especially high in this group. While transit users stood on the shoulder while waiting to cross 27.7 percent of the time and non-transit users did this 28.2 percent of the time, transit users had conflicts while waiting on the shoulder 9.5 percent of time, whereas non-transit users had conflicts of this type only 1.8 percent of the time, a statistically significant difference (at the 0.005 level). This appears to be due to the location of the transit stops. The majority of conflicts with transit users occurred on the east side of the street, between the transit stop near Goldie's and the corner of North 152nd Street, by drivers turning right into the businesses located there or turning right onto North 152nd Street.

At the Kent study site, almost two-thirds of the pedestrian crossings (64.6 percent) during the *before* portion of the study and more than three-quarters (79.5 percent) of the crossings made during the *after* portion of the study were directly related to transit use as, shown in Figure B-87. The significant increase (at the 0.0001 level) in the proportion of transit related trips is thought to be the direct result of the road widening: fewer pedestrians were willing to attempt to cross a seven-lane street versus the five-lane roadway that was observed in the *before* study and, therefore, they were more likely to cross at the traffic signal. This behavior may have been more prevalent among residents of the area, who had control over when they traveled, than transit riders, who typically boarded and exited at a time that was near that of their classes at Highline Community College.

Figure B-88 and Figure B-89 show the relationship between transit users and vehicle-pedestrian conflicts at the Kent site.

At the Kent site, pedestrians experience rates of conflicts that were not statistically different, whether or not they were making transit-related crossings.

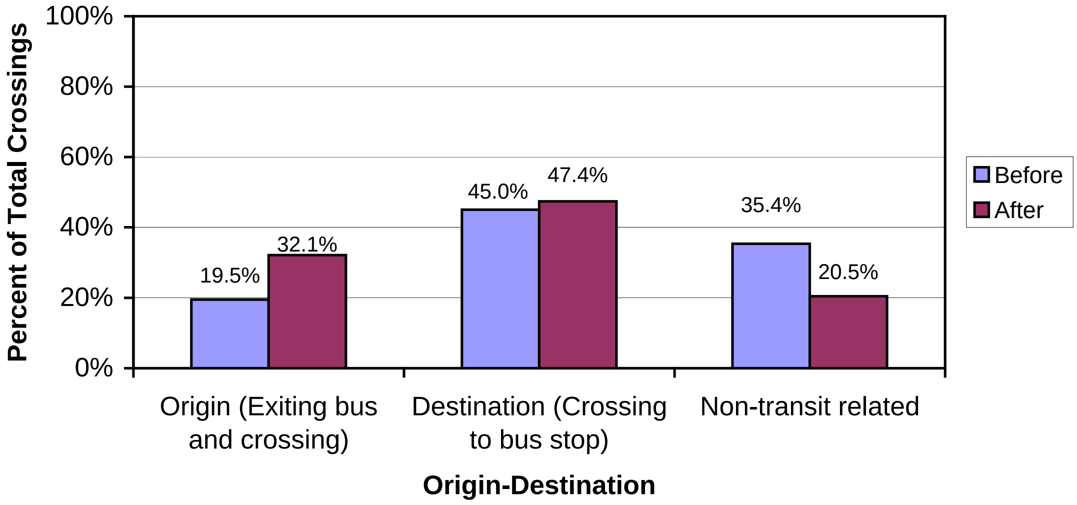


Figure B-87. Percentage of transit related crossings—Kent

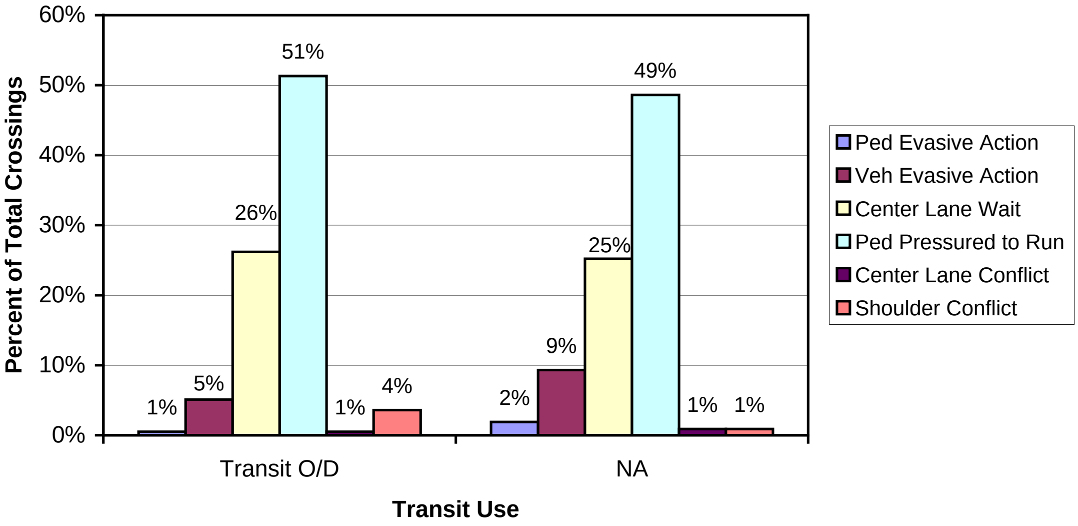


Figure B-88. Pedestrian conflicts related to transit use—*before* condition—Kent

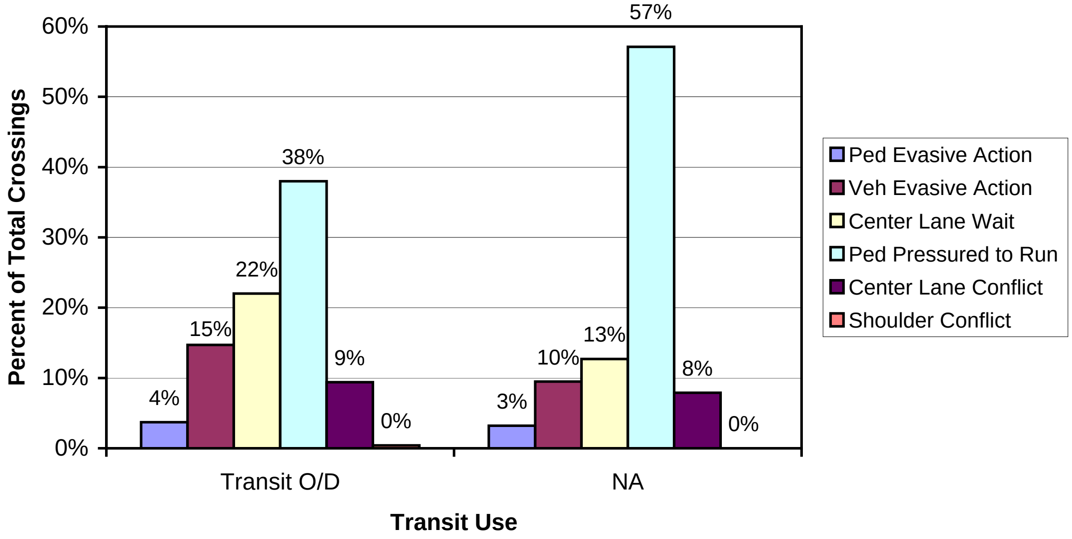


Figure B-89. Pedestrian conflicts related to transit use—*after* condition—Kent

There were no transit stops within the observation boundaries at the Airway Heights site, so no data pertaining to transit users were taken.

At the Spokane study sites, only a small percentage of the pedestrian crossings directly related to transit use (5.3 percent to 13.4 percent, depending on the site), as shown in Figure B-90 through Figure B-92. (Note that because of visibility restrictions (obstructions, camera angle, and available camera placement locations) some pedestrians arriving in or departing from the study areas by bus may not have been identified.)

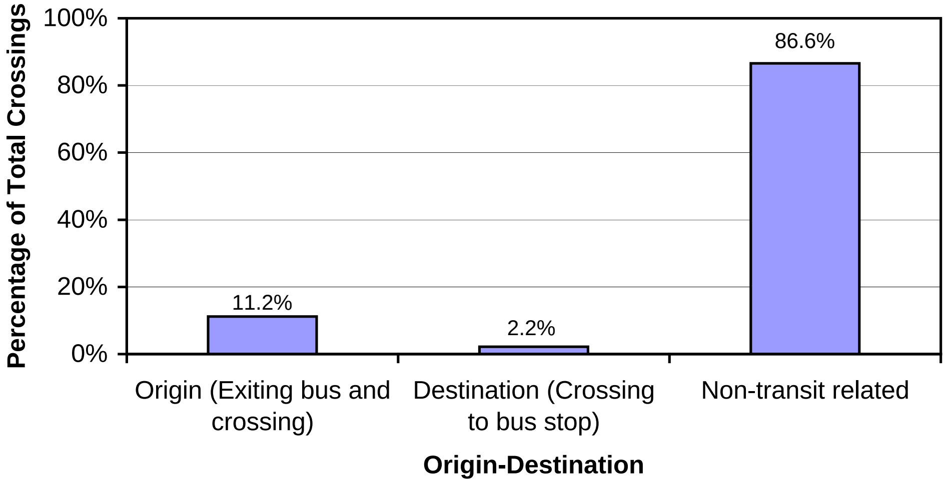


Figure B-90. Percentage of transit related crossings at Lacrosse Avenue—Spokane

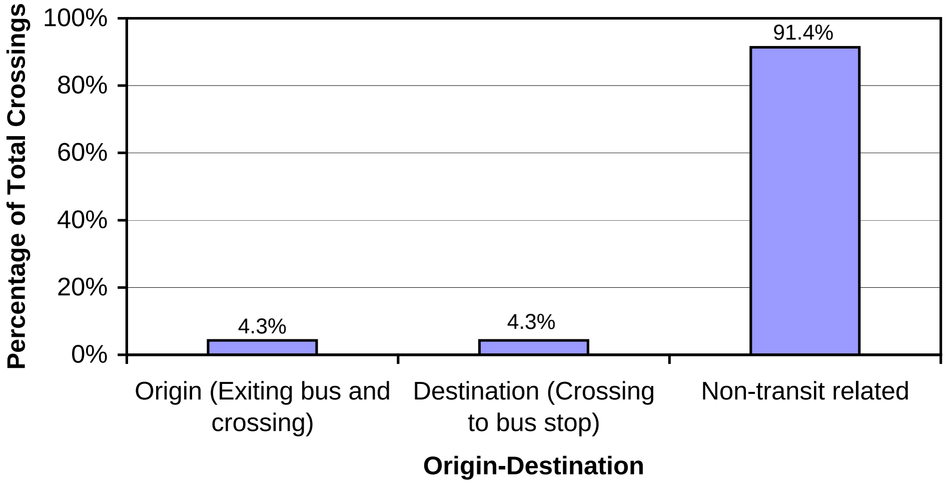


Figure B-91. Percentage of transit related crossings at Rowan Avenue—Spokane

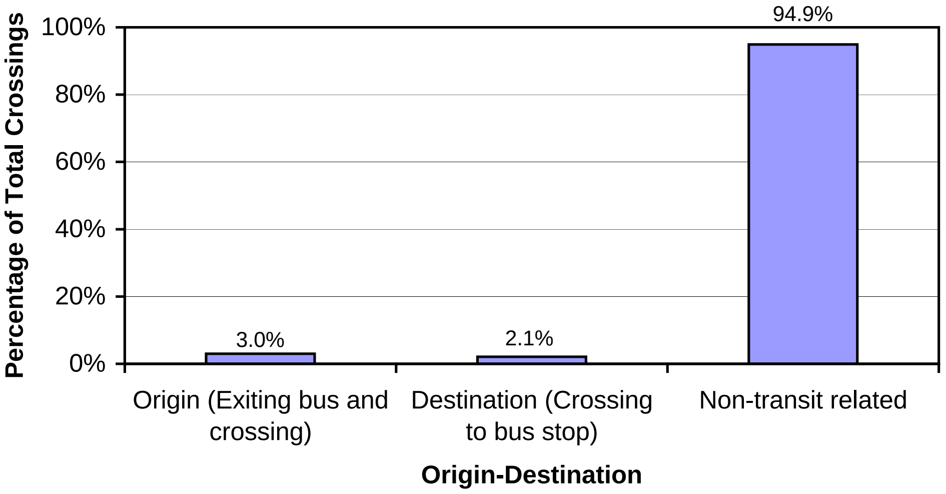


Figure B-92. Percentage of transit related crossings at Wellesley Avenue—Spokane

Figure B-93 through Figure B-95 show the relationship between transit users and vehicle-pedestrian conflicts at the Spokane sites.

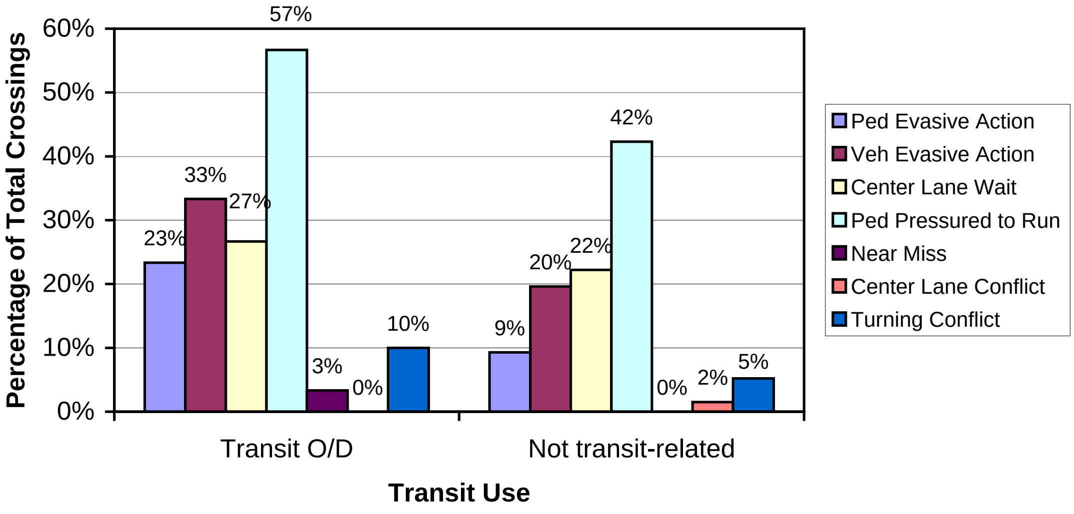


Figure B-93. Pedestrian conflicts related to transit use—Lacrosse Avenue—Spokane

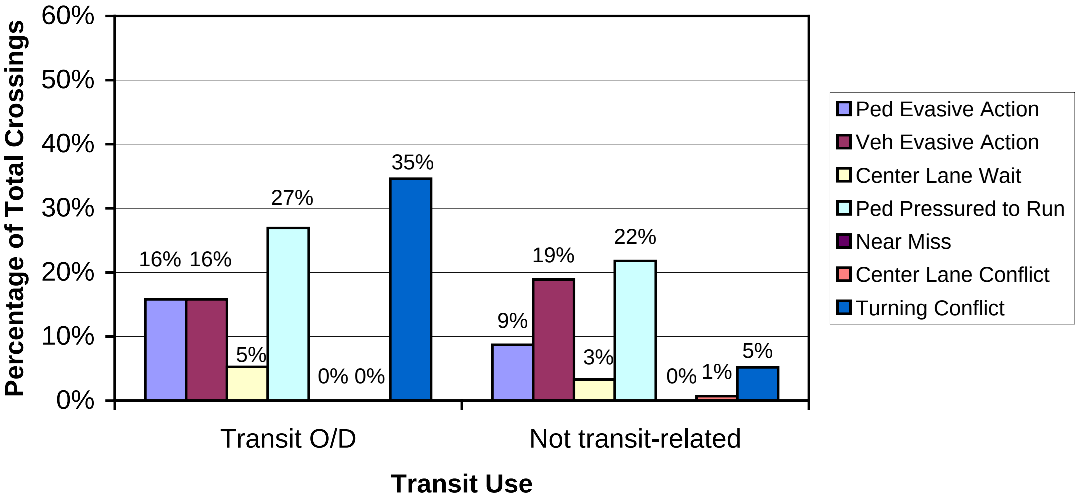


Figure B-94. Pedestrian conflicts related to transit use—Rowan Avenue—Spokane

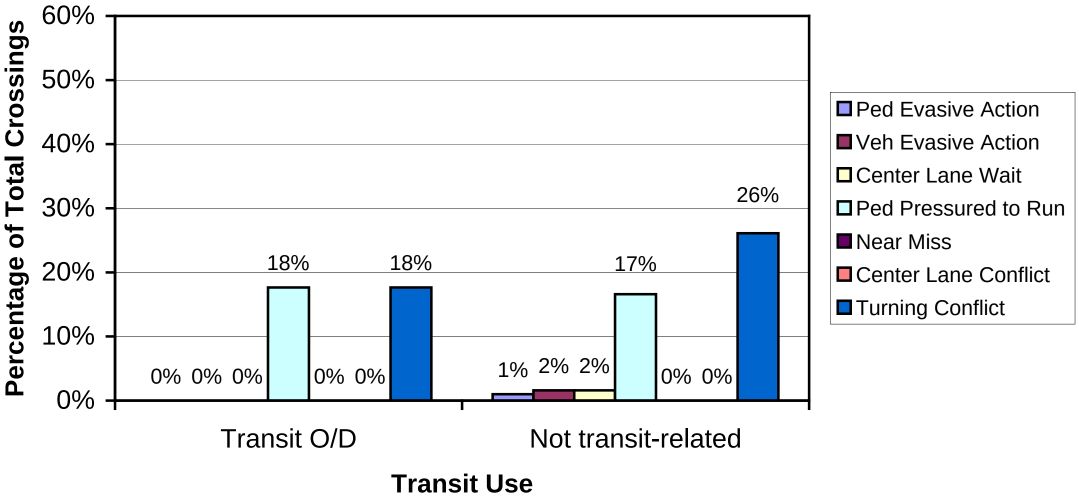


Figure B-95. Pedestrian conflicts related to transit use—Wellesley Avenue—Spokane

In most cases in Spokane, it appears that the transit users were involved in more serious conflicts (pedestrian and vehicle evasive action) and also ran across the road more often than non-transit users. It is possible that these pedestrians were more likely to engage in risky behavior to cross the street because of the time penalty that was associated with missing the bus (in this case, 20 to 30 minutes until the next bus would arrive, depending on the time of day and day of the week). In all cases, the sample size for transit related crossings was very small (31 at Lacrosse Avenue, 26 at Rowan Avenue, and 17 at Wellesley Avenue), and so these results may not be statistically significant.

Transit: Other Factors Affecting Conflicts

The Kent study site was examined in additional detail. Conflict frequency among transit users can vary significantly when different scenarios are considered. Figure B-96 and Figure B-97 show the conflicts experienced by transit users who were traveling from the bus stop (Origin) or to the bus stop (Destination), and whether or not the transit vehicle was present at the stop, in view of the pedestrian, or neither (N/A). Non-transit related conflicts are also shown as a baseline for comparison.

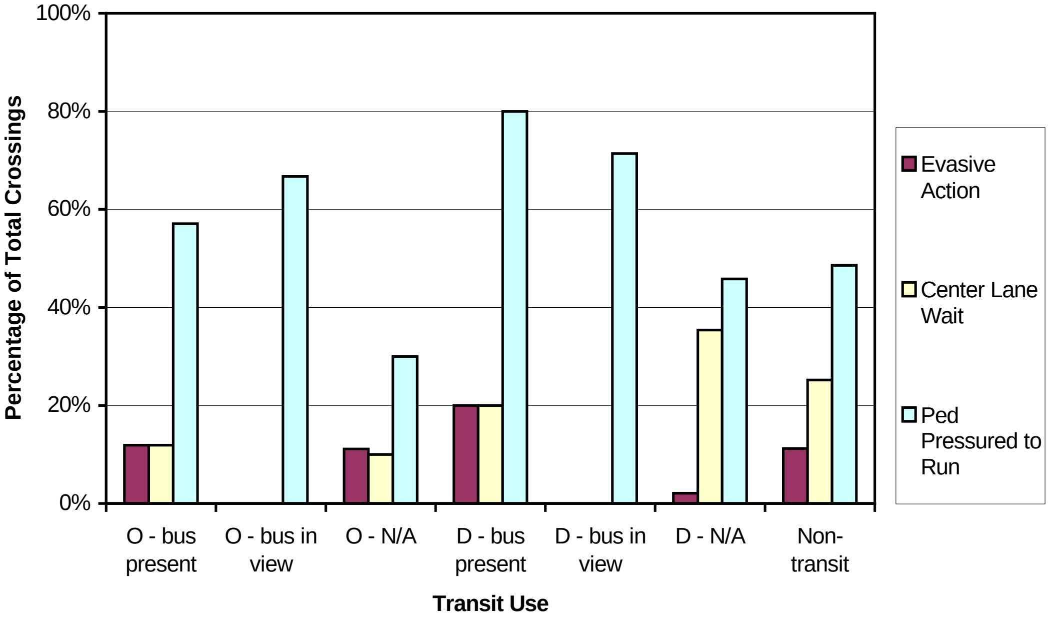


Figure B-96. Pedestrian conflicts related to transit use, by transit vehicle location—*before* condition—Kent

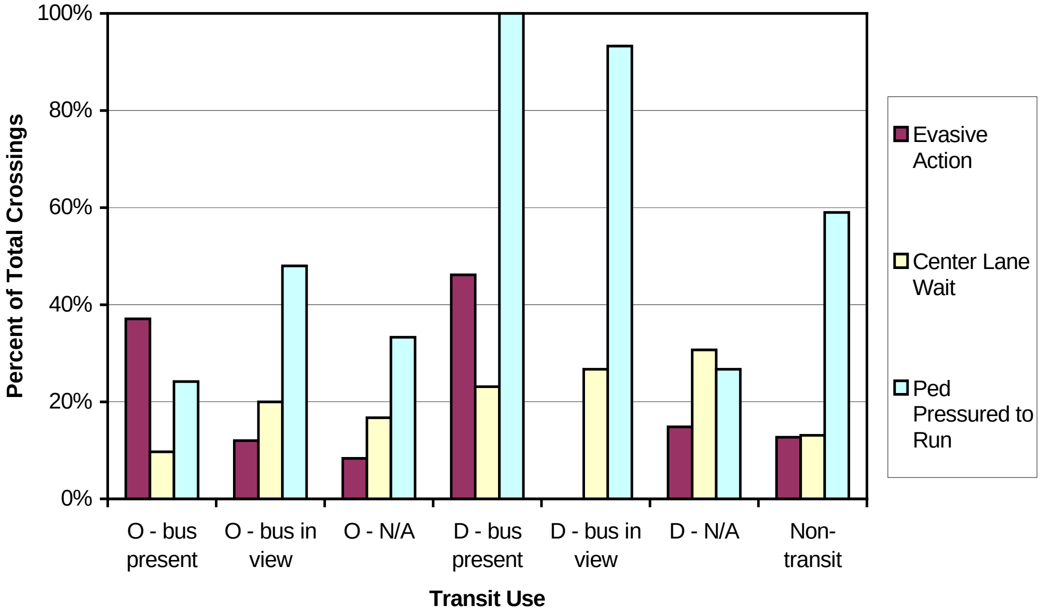


Figure B-97. Pedestrian conflicts related to transit use, by transit vehicle location—*after* condition—Kent

Understandably, more evasive action conflicts (this category includes pedestrian evasive action, vehicle evasive action, and near miss conflicts) occurred when the transit vehicle was present and riders were attempting to cross to board the vehicle (Destination) than at other times. This may indicate that riders are more likely to take risks in order to catch their bus. Riders who were going to board a transit vehicle when one was not present at the stop were much more likely to wait—on the shoulder/sidewalk or in the center lane—on their way to the transit stop. Riders leaving the stop (Origin) and crossing had higher instances of evasive action conflicts during the after study. This may have been due to the time of their arrival versus the time of their next commitment (i.e., college class, work, etc.).

Because the Kent study location was adjacent to a community college, there were also different behaviors based on time: i.e., those crossing close to the time when classes started or ended or when the next bus was due may have acted differently than those who arrived or left at times that were not close to these events. Highline Community College classes begin on the hour and end at 10 minutes before the next hour. Buses stop near SR 99 and South 240th Street between 17 and 24 minutes past the hour and between 45 and 52 minutes past the hour, making transit headways for the routes approximately 30 minutes. The conflicts shown in Figure B-98 and Figure B-99 are sorted by pedestrian origin and destination and also by when the crossing was completed.

Transit users who exited near the start time of classes (minutes 45-15) had a higher incidence of evasive action behavior (pedestrian/vehicle evasive action or near misses). This is likely due to the anxiety caused by arriving at the stop shortly before or after community college classes began (and the necessity of the walk that followed to get to the proper building on campus). Those traveling to the bus stop near a transit boarding time (minutes 01-15 and 31-45) also experienced evasive action conflicts, likely due to their desire to catch the next bus, as opposed to waiting an additional 30 minutes for the following bus boarding time. Unfortunately, because of the small sample size for many of these categories, the results are not statistically significant. More research in this area could be beneficial.

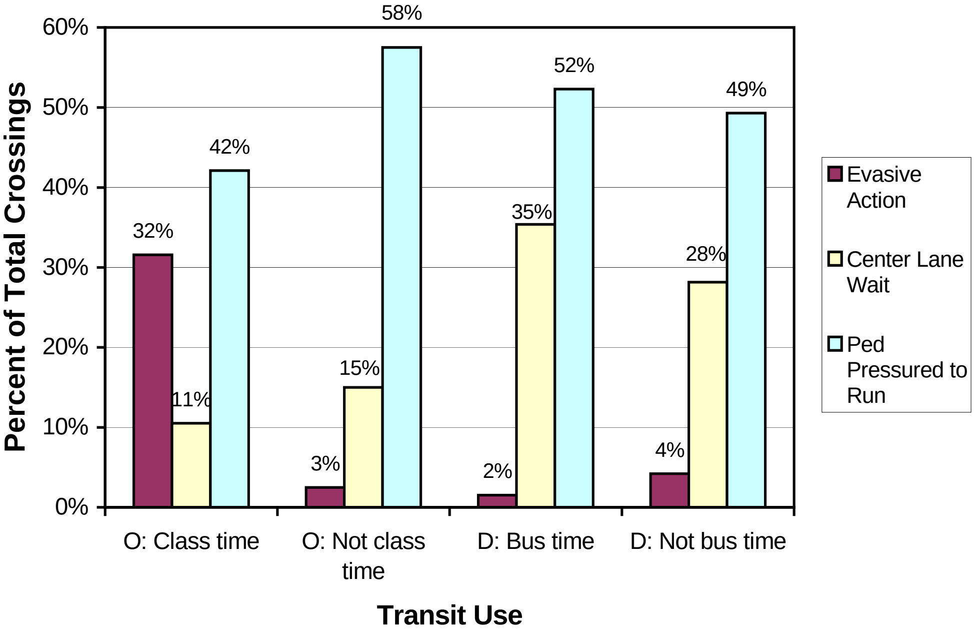


Figure B-98. Pedestrian conflicts related to transit use, by time—*before* condition—Kent

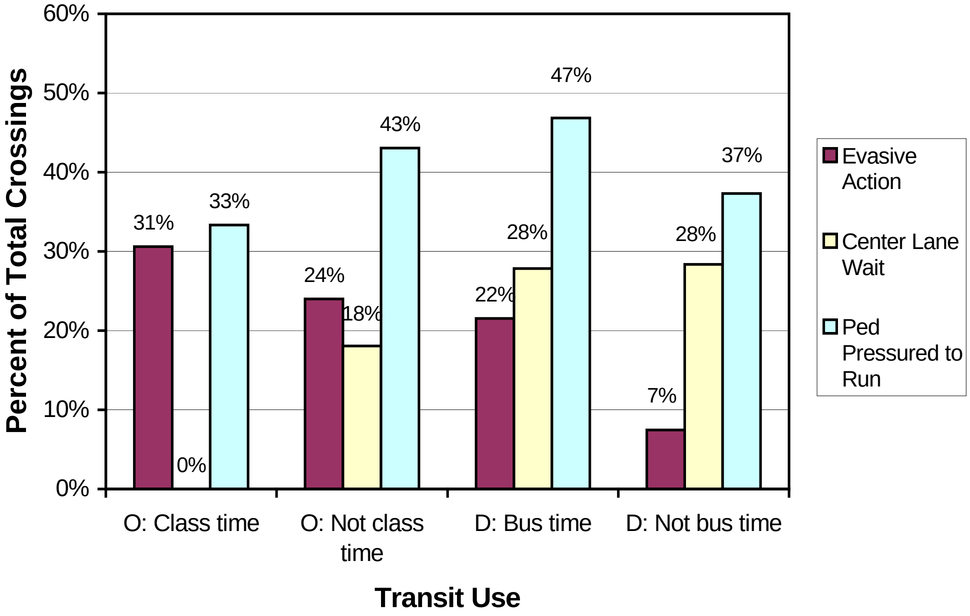


Figure B-99. Pedestrian conflicts related to transit use, by time—*after* condition—Kent

Transit: Crossing Behavior

At the Shoreline study site, there were transit stops on both sides of the street: one adjacent to an unmarked crosswalk and one that was not. The majority of transit users were observed crossing directly across the street from the bus stop, regardless of whether or not a crosswalk or intersection existed. The occurrences of this behavior are displayed in Table B-32.

Table B-32. Transit related pedestrian crossing behavior—Shoreline

	Transit patrons making a direct crossing
Transit stop is adjacent to crosswalk	89.4%
Stop is not adjacent to crosswalk	79.2%

This behavior should be taken into account when transit stops are placed or those that already in use are evaluated.

At the Kent site, data were taken to be able to examine how the pedestrians interacted with the transit vehicle itself. Most transit users at this location crossed behind the transit vehicle when it was present. This is shown in Figure B-100 and Figure B-101.

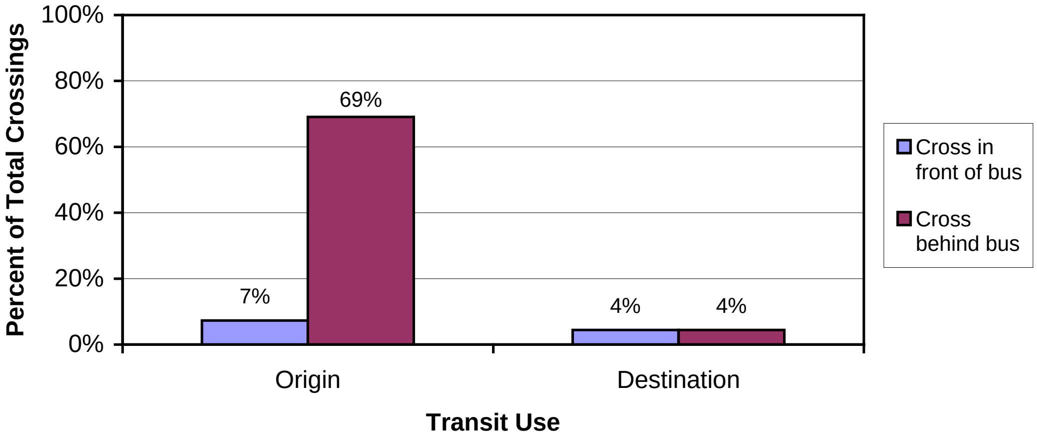


Figure B-100. Transit related pedestrian crossing behavior, with transit vehicle present—*before* condition—Kent

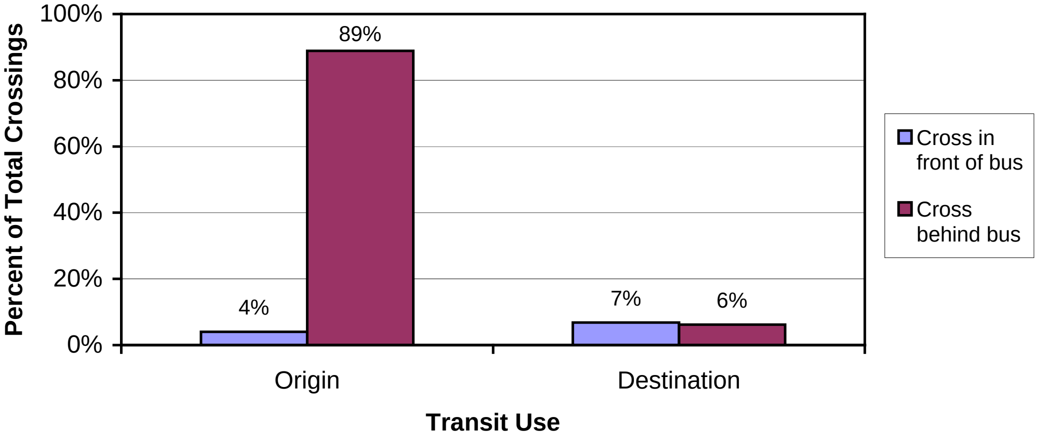


Figure B-101. Transit related pedestrian crossing behavior, with transit vehicle present—*after* condition—Kent

Because of the urgency with which crossings to the bus stop were made, when the transit vehicle was present (Destination crossings), the pedestrians’ decisions about where to cross appeared to be made on the basis of where the pedestrian was located when he saw the bus at the stop and not necessarily on crossing location preference. Crossings classified as “Origin” were much more likely to be made at the rear of the transit vehicle. The frequency of conflicts versus where a pedestrian crossed in relationship to the bus was also explored. The conflicts appeared to be tied much more closely to whether or not the transit vehicle was present at the time of crossing than with the location of the crossing in relationship to the vehicle.

Transit Stop Placement

At the Kent site, most observed transit users had little incentive to cross at the signalized intersection. Directly across from the transit stop was a restaurant driveway, which also happened to connect, through the parking lot of the restaurant, to a pathway from the college, from which the majority of the transit users originated. This was coupled with 30-minute transit route headways, buses that boarded/exited at times that were very close to community college class starting and ending times, and the fact that there was a heavily traveled urban arterial located between the school and the northbound transit stop. These factors may have created enough stress for the riders to cause them to discount their own safety and that of others in favor of catching the next bus. The convenience of the path through the restaurant parking lot (in the *before* study) or through the new Highline Community College building parking lot (in the *after* study) made it even easier for the riders to justify their actions and complete this task.

Possible options for improving the safety of transit users at this study site are as follows:

- Provide mid-block crosswalks coupled with actuated pedestrian crosswalk lights near the northbound transit stop to increase driver and pedestrian awareness.
- Work with King County Metro to review the site of the northbound transit stop in the study area to ensure that it is located in an atmosphere that would allow safe pedestrian crossings (i.e., slightly farther north to avoid the complexities of the intersection or to the south of the intersection at South

240th Street to allow boarding and alighting passengers immediate access to a marked, signalized crosswalk).

Moving or redesigning a transit stop is not always best for pedestrian safety or other stakeholders. Careful coordination among all agencies involved is imperative to balance the needs of the transit agency, neighborhood, accessibility concerns, vehicular traffic, and the needs of other roadway users.

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Kopf, Jaime M. and Mark E. Hallenbeck. A Motorist and Pedestrian Behavioral Analysis on SR 7. Seattle: Washington State Transportation Center. 2005.