Research Report
Agreement T2695, Task 10
Pedestrian Safety

PEDESTRIAN SAFETY AND TRANSIT CORRIDORS

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16. ABSTRACT

This research examines the relationship between pedestrian accident locations on state-owned facilities (highways and urban arterials) and the presence of rider boardings and alightings from bus transit. Many state facilities are important metropolitan transit corridors with large numbers of bus stops users, so that these facilities expose higher numbers of pedestrian to traffic and an increased number of collisions. The research also examines the association between pedestrian collisions and other pedestrian travel generators, such as concentrations of retail activity and housing, as well as environmental conditions such as wide roadways, high traffic volumes, and high speed limits.

On the basis of a retrospective sampling approach and logistic regression models, the study shows that bus stop usage is strongly associated with pedestrian collisions along state facilities. Less strong but significant associations are shown to exist between retail location and size, traffic volume and number of traffic lanes, and locations with high levels of pedestrian-vehicle collisions. The findings suggest that facilities with high numbers of bus riders need to accommodate people walking safely along and across the roadway. They support the development of state DOT programs for multi-modal facilities that integrate travel modes in major regional facilities within local suburban communities and pay specific attention to the role of transit in shaping the demand for non-motorized travel on the facilities. Also, state DOT, local jurisdiction, and transit staff must work together to identify facilities and locations where bus riders are at risk and take appropriate steps to ensure pedestrian safety.

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EXECUTIVE SUMMARY

Each year in Washington State, pedestrian *fatalities* constitute 12 to 14 percent of all fatalities related to motor-vehicle collisions. More than 30 percent of these fatal collisions between pedestrians and motor-vehicles are on state roads. Many state facilities are important metropolitan transit corridors with large numbers of bus stops users, increasing the exposure of pedestrians to traffic and the number of collisions.

This research examines the relationship between pedestrian accident locations on state-owned facilities (highways and urban arterials) and the presence of riders loading into and alighting from bus transit. It also studies the association between pedestrian collisions and other pedestrian travel generators, such as concentrations of retail activity and housing, as well as traffic conditions such as wide roadways, high traffic volumes, and high speed limits. The research questions the current practice of dedicating regional or trans-regional state facilities principally to vehicular traffic, and investigates the need to integrate non-motorized travel, and specifically bus riders, in the design of these facilities.

On the basis of a retrospective sampling approach and logistic regression models, the study shows that bus stop usage is strongly associated with pedestrian collisions along state facilities. Less strong but significant associations are shown to exist between retail location and size, traffic volume and number of traffic lanes, and locations with high levels of pedestrian-vehicle collisions.

The findings suggest that state facilities with high numbers of bus riders need to accommodate people walking safely along and across the roadway. They support the development of state DOT programs for multi-modal facilities that integrate motorized and non-motorized travel modes in major regional facilities within local suburban communities, and pay specific attention to the role of transit in shaping the demand for non-motorized travel on the facilities. The findings also suggest that state DOT, local jurisdiction, and transit staff must work together to identify facilities and locations where bus riders are at risk of collision with motor vehicles and take appropriate steps to insure pedestrian safety.

PROBLEM STATEMENT

Collisions between motor vehicles and pedestrians along transit routes are associated with high rates of injury and death of pedestrians, which constitute a significant societal problem. Each year in Washington State, pedestrian *fatalities* constitute 12 to 14 percent of all fatalities related to motor-vehicle collisions. The national average is higher at 16 percent. Further, collisions between pedestrians and motor vehicles have a severity rate that is three times higher than collisions involving only motor vehicles, and therefore have disproportionately high associated societal costs. In Washington State, 60 percent of collisions are located on city streets, where people are expected to travel on foot. But more than 30 percent of fatal collisions are on state roads that are typically considered regional or trans-regional facilities dedicated principally to vehicular traffic and designed accordingly (Washington State DOT 1997).

Table 1 shows the geographic distribution of pedestrian-vehicle collisions on state facilities in Washington State for the six-year period between January 1995 and December 2000. There were 1795 collisions involving more than 1895 pedestrians. Of these, 175 pedestrians were killed and 376 were disabled. Average yearly societal costs were over $ 100,000,000.

In King County, the state's most populated county with the densest development patterns, the 675 collisions with 714 pedestrians that occurred over the six-year period constitute more than 37 percent of state totals. The 56 pedestrian fatalities and 144 disabling injuries in the county account for 32 percent and 38 percent of state fatalities and injuries, respectively. Likewise, King County yearly societal costs of more than $ 37,002,500 account for 36 percent of state totals.

Within King County, collisions are concentrated on State Route 99 (SR 99). Originally part of the US 99, first commissioned in 1926 and stretching from Canada to Mexico, SR 99 became the region's second most important north-south through-way after the construction of Interstate 5 in the 1960s. Much of the development along it can be characterized as strip commercial. The facility has four to six travel lanes, typically with a center turn lane, traffic volumes are high (ranging from 20,000 ADT to 60,000), and it is an important transit corridor. For the 1995-2000 data, SR 99 had 43 percent of collisions in the county and 16 percent for the state as a whole, amounting to 16 percent of state total societal costs.

Table 1. Reported Pedestrian Collisions on State Routes, 1995-2000

	Washington State		**King County**		**SR99 in King Co.**	
	1995-2000	Avg. Yearly	1995-2000	Avg. Yearly	Total 1995-200	Avg. Yearly
Collisions	1795	299	670	112	289	48
Pedestrians	1895	316	714	119	303	51
Fatal Injuries	175	29	56	9	23	4
Disabling Injuries	376	63	144	24	65	11
Societal Costs	$ 610,208,000	$ 101,701,333	$ 222,015,000	$ 37,002,500	$ 97,414,000	$ 16,235,667

These figures show that pedestrian-vehicle collisions on state facilities are disproportionate to the distribution of the population—King County holds slightly more than 20 percent of the state's population, and the population along SR 99 is 25 percent of King County's. They indicate that King County's state roads, and SR 99 specifically, are very high-risk locations for pedestrians. These dire conditions likely come from the mismatch of roadway design and use, where the original design catered to automobile traffic whereas the current use of the facilities includes transit and associated non-motorized travel both along and across the facilities. Such changes in the use of state facilities are replicated in many metropolitan areas of the country, specifically in areas that have become densely populated, and along transportation corridors that have evolved from trans-regional parkways or limited access roads to local through-streets or even "main streets" for recently developed suburban communities. There are typically no other options for local travel along these corridors, as few through-streets have been built in suburban communities since the 1960s (Untermann 1984, Southworth and Owens 1993).

National, state, and local road design programs are being developed and implemented to address the growing demand for multi-modal transportation on state and other facilities of regional significance within metropolitan areas (U.S.DOT and FHWA, FHWA, Huang et al 2001, Florida DOT 2001). Central to these programs are issues related to pedestrian safety and to the safe integration of transit users with the driving public. This research focuses on regional traffic facilities as *de facto* transit and pedestrian zones where safety investments must be carried out to further these programs and policies.

RESEARCH OBJECTIVE

The main purpose of this research was to examine the relationship between pedestrian accident locations on state facilities and the presence of riders loading into and alighting from bus transit, controlling for other factors. Many state facilities are important transit corridors with many people accessing transit along them. Before getting on and after getting off the bus, these transit riders are pedestrians and are potentially exposed to vehicle collisions. Riders who, for example, use transit for their commute trip will be getting on the bus on one side of a highway in the morning, and off on the other side in the evening, necessitating at least one daily crossing of a wide roadway. Large numbers of bus stops users should, therefore, be associated with increased exposure of pedestrians to traffic and to increased collisions. The research also examined other pedestrian travel generators, such as concentrations of retail activity and housing, as well as environmental conditions that are associated with pedestrian-vehicle collisions, such as wide roadways, high traffic volumes, and high speed limits (Zegeer et al 2002a).

This approach differed from most previous research efforts that have focused on identifying unsafe roadway conditions and developing engineering solutions independent from *where,* along state facilities roadway, pedestrian activity tends to be concentrated (Zegeer 2002b, Koepsell et al. 2002). Instead, this research attempted to examine if and how pedestrian collisions are associated with pedestrian generators, especially bus stop use, along large state roadways.

WASHINGTON STATE AND KING COUNTY COLLISIONS DATA

Two levels of data were examined: one, data on individual collisions involving pedestrians on state owned facilities; and two, data on locations with high concentrations of pedestrian collisions of state facilities call Pedestrian Accident Locations (PALs).

COLLISION DATA

Data were examined for collisions occurring on state facilities for the six-year period between January 1995 and December 2000. Collision data were obtained from the Washington State Department of Transportation (WSDOT) and were compiled from police reports collected by the Washington State Patrol. Collisions constituted a vehicle striking one or more pedestrians. Injuries were classified into deaths, disabling injuries, evident injuries, possible injuries, and non-injuries. Each was assigned a societal cost by WSDOT using federal figures as shown in Table 2.

Table 2. Injury Type and Assigned Societal Costs

Injury Type	Assigned Cost
Death	$ 1,000,000
Disabling Injury	$ 1,000,000
Evident Injury	$ 65,000
Possible Injury	$ 35,000
No Injury (Property damage only)	$ 6,000

Note that the number of pedestrians may have been slightly underestimated because records for the years 1997 and 1998 were not complete and did not give full accounting for the number of pedestrians involved in each collision. For these data years, only two pedestrians were counted for any collision in which two *or more* pedestrians were involved. This constituted only a very small number of collisions (less than 1 percent in the years for which there were complete data).

PEDESTRIAN ACCIDENT LOCATIONS

Pedestrian collisions are not distributed randomly along state facilities. Instead, some roadway segments have high concentrations of collisions (Figure 1). To understand this, the Washington State Department of Transportation (WSDOT) developed the concept of Pedestrian Accident Locations (PALs). A PAL is defined as four or more collisions over a six-year period along a 0.1-mile section of roadway. Thus, PALs are at least 0.1 mile (528 feet) long, but they may be longer. PALs are determined by analyzing the first 0.1-mile of a state route to see if it meets the definition. Then the segment being analyzed is shifted by 0.01 of a mile to see if it meets the definition (Figure 2). If a segment meets the definition of four accidents in six years, and the next 1/100 of a mile shift also meets the definition, then both segments are combined, creating a PAL that is 0.11 miles long. If not, the segment is shifted again to see if it meets the definition. This process is repeated along the entire length of the route. Societal costs associated with PALs are an aggregation of assigned costs for the collisions within them. Thus, a PAL with two fatalities, one disabling injury, and one evident injury would be assigned a societal cost of $3,065,000.

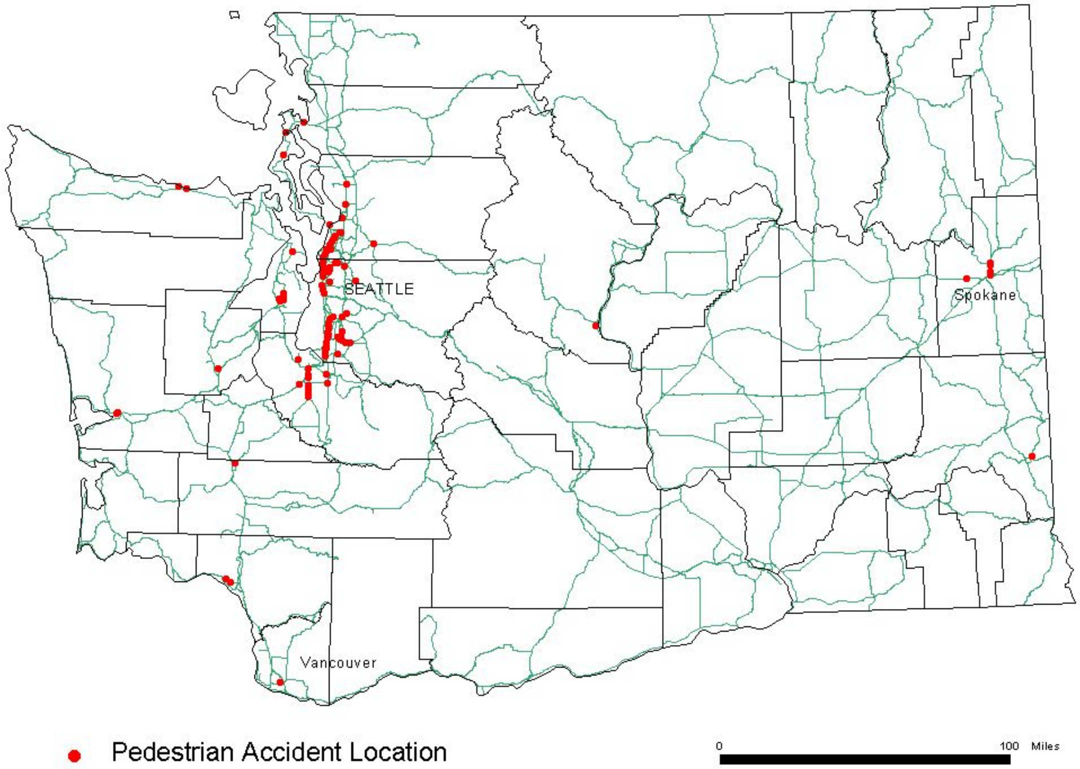
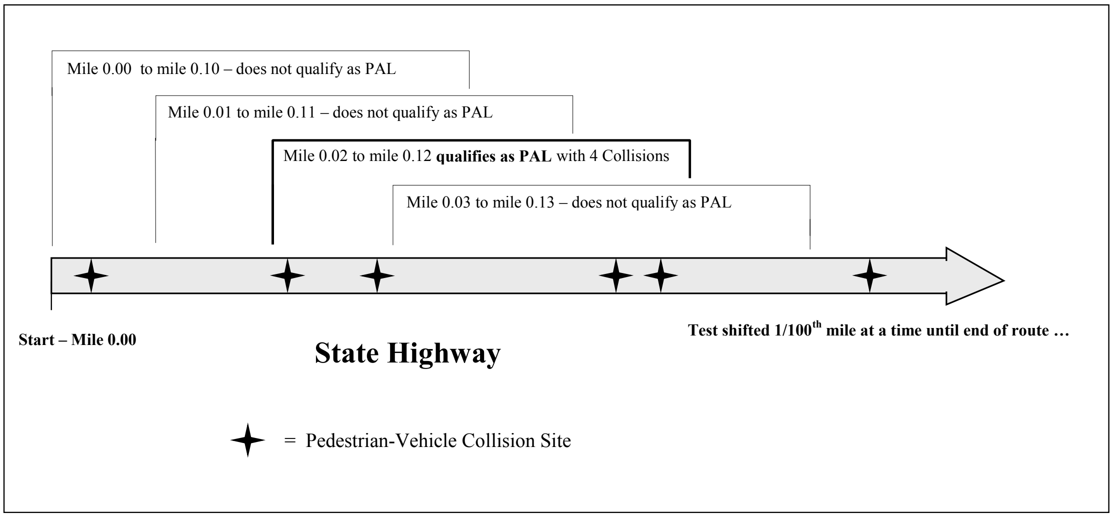


Figure 1: Pedestrian Accident Locations (PALs), on Washington State Routes (Washington State 1995-2000 Data)

Figure 2: Testing State Route Segments for Meeting Pedestrian Accident Location Criteria*



* Method used to test 1/10-mile long route segments to determine if they meet the definition of a Pedestrian Accident Locations (at least four pedestrian collisions over a six year period). Test begins at mile 0.00 (start of route), and test segmented is shifted 1/100th mile at a time until end of route is reached.

For the 1995-2000 data period, WSDOT identified 120 PALs (Table 3). Of these, 57 (47 percent) were located in King County (Figure 3). King County also accounts for 55 percent of collisions located within PALS, 60 percent of fatalities, and 56 percent of disabling injuries found within PALS.

As individual collisions, most PALS and accidents within PALS in King County were along SR 99, both north and south of Seattle. SR 99 had 33 PALS or 57 percent of the PALS in King County and 27 percent or the PALS in the state! SR 99 PALS contained 186 collisions (61 percent of those in King County PALs and 33 percent of the state), 13 fatalities (72 percent of those in King County PALs and 43 percent of those in PALs statewide), and 45 disabling injuries (65 percent of those in King County PALs and 36 percent of PALs in the state). Calculated societal costs for the data years in question were almost $65,000,000; that is, an average of more than $10,000,000 a year. These costs made up 66 percent of those for PALs in the county and 37 percent for those in the state (Figure 4).

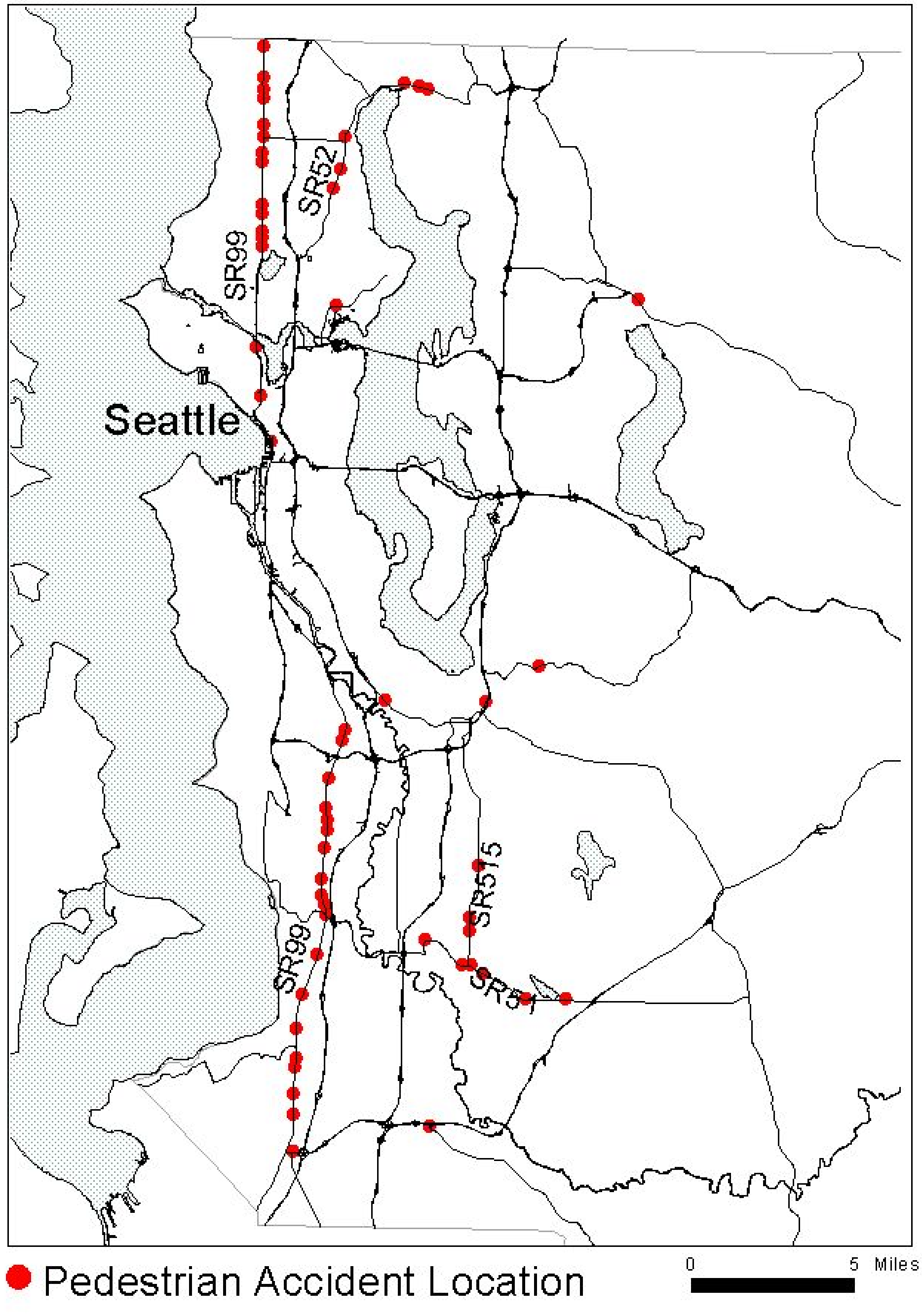


Figure 3: Pedestrian Accident Locations (PALs) on King County State Routes (Washington State 1995-2000 Data)

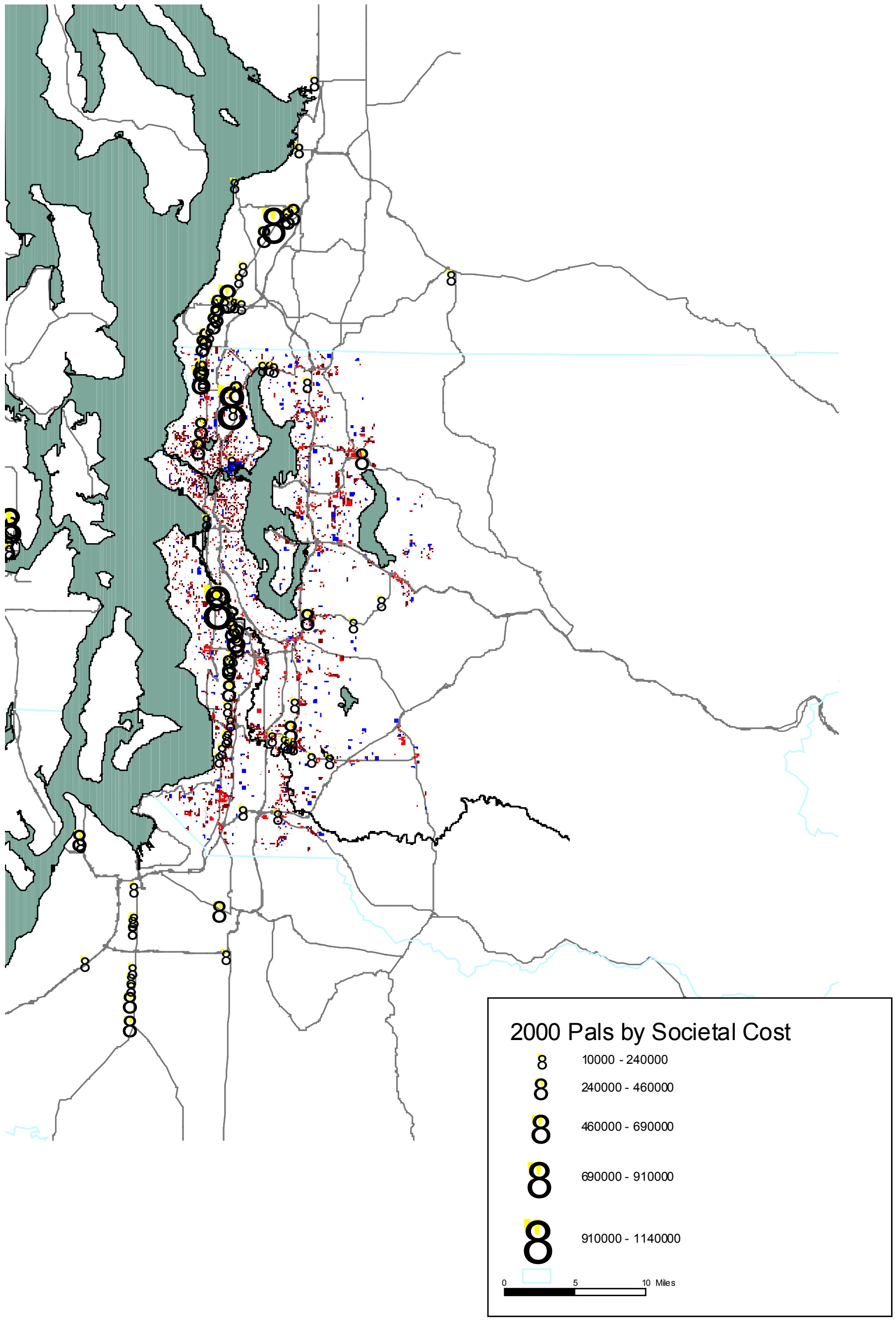


Figure 4: Pedestrian Accident Locations (PALs), by Societal Costs, on King County State Routes (Washington State 1995-2000 Data)

Table 3. PALs, Constituent Injuries, and Related Costs in Washington State, King County and SR 99 in King County

	State		**King County**		**SR99 in KC**	
	1995-2000	**Yearly avg.**	**1995-2000**	**Yearly avg.**	**1995-2000**	**Yearly avg.**
PALs	120	NA*	57	Not app.	33	NA.
Collisions	554	92	305	51	186	31
Fatal Injuries	30	5	18	3	13	2
Disabling Injuries	123	21	69	12	45	8
Societal Cost	$173,919,000	$28,986,500	$98,327,000	$16,387,833	$64,795,000	$10,799,167

* Not applicable because PALS are defined as four or more collisions over a six-year period along a 0.1-mile section of roadway

Clearly, areas of concentrated pedestrian collisions along SR 99 in King County are a very serious safety problem for the state. Other significant PAL locations in King County are near concentrations of multifamily housing and retail services along SR 522 in Lake City in Seattle and the city of Kenmore, and SR 515 and 516 in the East Hill area of the city of Kent. All these locations have multiple PALs.

PALs in King County are the basic level of analysis in this study.

RESEARCH DESIGN

The study area for the project was the urbanized area of King County, Washington, because it accounts for the largest share of pedestrian-vehicle accidents in Washington State. PALs located in King County were the basic unit of analysis for the study. Because of the concentration of PALs along SR 99, separate analyses were carried for this facility and for state facilities in King County excluding SR 99.

The basic analytical approach tested variables for their power to distinguish between PALs and non-PAL sample points. Variables, non-PAL points sampling procedure, and analytical methods are described in later sections.

DATABASES AND DATA DEVELOPMENT

Table 4 shows the principal data sources used for the study analysis.

Table 4. Data Names, Types, and Sources

Name	Data Type	Description	Dates	Source	Notes
Accident Data					
Pedestrian Accident Locations	Tabular	Concentrations of pedestrian accidents on state facilities	1995-2000	WSDOT	Data partial for 97-98; Geocoded after conversion using SRMPARM converter
Pedestrian Collisions	Tabular	Individual pedestrian collisions on state facilities	1995-2000	WSDOT	Data partial for 97-98; Geocoded after conversion using SRMPARM converter
Roadway Data					
State Roadways	Geo-Spatial	State Routes capable of geocoding using linear reference system	2001	WSDOT	Used to geo-code PALs and accident locations
EMME2 Model Data	Geo-Spatial	Model data for Puget Sound Region roadways containing traffic volumes and speeds	2001	PSRC	Used for 24 hour volume, and off-peak congestion speed
GPS Highway Data	Geo-Spatial data	Data on lanes and other roadway attributes for Puget Sound roadways	2001	PSRC	Used number of lanes
Intersections for King County Street network	Geo-Spatial	Location of all non-freeway intersections	2001	King Co	Developed from King County Street network data
Bus Data					
APC	Tabular	Automatic Passenger Counts -Boardings and Alightings by bus stop in KC	Fall 2000 and 2001	METRO	Used to calculate average total bus stop usage for area of 250 feet around the center of PALs
Bus Zones	Geo-Spatial	Bus stops in KC	2001	King Co WAGDA	Used to Geo-code APC data
Land Use Data					
KC Parcel Layer	Geo-Spatial	GIS layer of 600,000 KC parcels	2001	King Co WAGDA	
KC Assessors Data		Land use by parcel type, number of housing units, square footage of commercial buildings	2001	King Co WAGDA	Used to calculate housing unit densities and presence of commercial activity around accident locations
School Sites	Geo-Spatial	Location of schools	2001	King Co WAGDA	Use to determine the presence of schools near accident locations.

PSRC is the Puget Sound Regional Council; METRO, King County Transit: WAGDA, the Washington Geo-Spatial Data Archive, maintained by the University of Washington Libraries.

ACCIDENT DATA

PAL Data

Pedestrian Accident Location data obtained from WSDOT were the basic data source for this study. As described above, these tabular data consisted of aggregated collision data for the six years between 1995 to 2000. PALs consist of at least four reported accidents over a six-year period on a 0.10-mile state route segment.

For each PAL, attribute data included the state route on which the PAL was located, the beginning and ending mileage post for the PAL, the type and number of pedestrian accidents located in the PAL, and the associated societal cost.

Mileage post numbers on state routes were converted by a software program developed by WSDOT, SRMPARM, to properly geo-code PAL locations using Geographic Information System (GIS) software. This is necessary because the geo-coding process locates the PAL location by measuring the actual distance from the beginning of the line representing the state route in the GIS. In many cases the state mileage post does not correspond to the actual distance along routes because of changes in the highway over time. For example, the first six or so miles of SR 99 no longer exist in King County, having been replaced by part of I-5. If state mileage post numbers were not corrected for this missing segment, PAL locations would be off by about six miles. The conversion process accounts for these differences. PALs were geo-coded as the midpoint between the beginning and ending state mileage post for the PAL. The length of the PAL was also recorded.

Pedestrian Collision Data

Pedestrian collision data for the years 1995-2000 were used as a secondary data source. These tabular data include individual crashes on state facilities. In addition to the mileage marker, the data include roadway conditions, lighting conditions, and what action the pedestrian made as the accident occurred (e.g., the pedestrian was crossing a roadway at a signalized intersection). These data were geo-coded using the same process described for the PAL data above.

ROADWAY DATA

State Roadways

Geo-spatial data of state roadways were used for geo-coding and mapping PALs and pedestrian collision data.

State Highway Log

The state highway log lists roadway attributes for state facilities. Number of lanes, roadway width, and posted speed limits are among available information. These data were not available as digital tables and could not be geo-coded using GIS. Therefore, alternative data sources were used when possible. Roadway widths for PAL locations and for sampled locations that were not PALs were obtained from this data source. This information was attached to locations manually.

Emme2 Model Data

Data from the Puget Sound Regional Council (PSRC) traffic model were used for traffic characteristics. Model data provide estimates for traffic volumes and speeds. The data are geo-spatial with links in the traffic network mapped in GIS. Separate links exist for both traffic directions for a particular roadway segment, and directional volumes for a particular roadway segment must be aggregated. GIS was used to attach 24-hour traffic volumes and off-peak congestion speeds to PAL and sample points. The procedure for attaching data was iterative as follows:

1. PAL and non-PAL sample points were given a unique identifier.

2. A spatial join was used in the GIS to assign the identifier of the nearest PAL or non-PAL sample point to each segment in the traffic network. Along with the identifier of the nearest PAL or non-PAL sample point, the GIS also calculated the distance that the point was from the network segment.

3. These data were exported and arranged by PAL and non-PAL sample point identifier. In many cases, more than one network segment with its attached traffic data was assigned a particular identifier. In these cases, the two links (one for each traffic direction) located closest to the PAL or sample point were selected. Volumes for these two segments were added, and the mean of traffic speed was calculated. This created a single volume and speed attribute for each identifier in the exported data.

4. Note that if more than one PAL or non-PAL sample point was along a particular network segment, only the one identifier would be assigned to the segment. Therefore, data created in step three were imported into the GIS and attached to PAL and non-PAL sample points. PAL

and non-PAL sample points without volume and traffic speed were then selected. These points then had data speed and volume data attached as in steps two and three above.

5. This process was repeated until all PAL and non-PAL sample points had attached data.

GPS Highway Data

The PSRC built this data set by using Global Positioning System technology and surveying highways and major roadways in the Puget Sound region. The data are geo-spatial and can be mapped in a GIS system. They contain various roadway attributes, including posted speed limits and number of traffic lanes attached to network segments. Different roadway directions are recorded as different segments. The data were attached to PAL and non-PAL sample points using a similar iterative approach as described above for traffic data.

Intersection Data for King County Street Network

These data were developed from King County Street Network GIS data. Intersections were extracted from the street network and were used to calculate the number of street intersections per quarter mile along highway segments on which PAL and sample points were located. The quarter mile measure of intersections was used to provide an average for the number of intersections in the neighborhood of the PAL site or sample point. It was intended as a measure of the number of the connections of the state roadway to other roadways. One-quarter mile was used to accord with the buffer distance for other uses.

The following method was used:

1. All intersections within 50 feet of a state route were selected and mapped.

2. Observation was used to eliminate any intersections within 50 feet but not on the state routes.

3. The remaining intersections were converted to grid data, with grid cells set to 10 feet. The fine-scaled 10-foot raster was used to make sure intersections were not lost in the raster conversion Note that only intersections along the state facility were modeled–that is, other intersections were eliminated from the data before they underwent the raster conversion process.

4. Neighborhood analysis was used to sum the number of intersections within one-quarter mile of each grid point. The result was a new grid with each cell representing the number of intersections within one-quarter mile of its location.

5. This grid was converted to point data with each cell represented by a point in a 10-foot by 10-foot array. A spatial join was used between these points and PAL and sample points. Values for points nearest to PAL and sample points were joined to the latter. Thus, PALs and sample points were given a value for the number of intersections within one-quarter mile on state facilities.

BUS DATA

Bus Zones

Geo-spatial data of all bus stops (also known as bus zones) were obtained from King County. Bus stops were represented as points. Each stop had a unique identifier.

Automatic Passenger Counts (APC)

Automatic passenger count data were obtained from Metro, the King County transit agency. Automatic passenger count data are obtained from recorders that are placed on buses several times a year. The agency aims for at least six runs on each route to obtain data. Data were averaged for two counting periods (Fall 2000 and Fall 2001) to increase data reliability. These tabular data included bus passenger boardings and alightings for each bus stop, broken down by time of day, as well as other data. Total daily boardings and alightings for each stop were aggregated as a single measure of bus stop activity.

Before attaching passenger boarding and alightings to PALs and non-PAL sample points, bus stop activity was aggregated for all stops within 250 feet of the points. The 250-foot buffer was designed to correspond to the 0.1 mile (528 ft) PAL spatial definition. It was a measure of how much total bus stop usage there was around the PAL.

The procedure used was similar to that of attaching intersection counts described above:

1. APC data were attached to bus zone points and converted to grid data using 50- by 50-foot cells. Each cell then represented the total daily boardings and alightings in that location. Raster size was examined to make sure individual bus stops would fall into different cells (i.e., so that information would not be lost). Fifty-foot cells were found to be adequate for this purpose without crashing the computer.

2. Neighborhood analysis was used to sum the number of bus stop users within 250 feet of each grid point. The result was a new grid with each cell representing the number of bus stop users within 250 feet of each location.

3. This was converted back into an array of points, and a spatial join was used to attach the number of total bus stop users within 250 feet of each PAL or non-PAL sample point.

LAND USE DATA

King County Parcel Layer

The King County Parcel Layer contains geo-spatial data that allow mapping of approximately 600,000 parcels in King County. Each polygon in the data layer, representing a tax parcel, has a unique parcel identification number (PIN).

King County Assessor's Data

King County Assessor's data provide information on each tax parcel and may be attached to the King County Parcel Layer using the PIN. Information used included a parcel's land use designation, number of residential housing units, and square feet of building space by use.

Parcel data were used to calculate the number of housing units within one-half mile of each PAL or sample point and total square footage of retail space within one-quarter mile of each PAL or sample point. One-half mile buffers were used for housing units because the one-quarter mile buffer did not capture many units or much variation. This is probably because intensive commercial development, especially along SR 99, "pushes" most residential development back beyond the quarter-mile distance.

Data were aggregated and attached using the same basic method as for intersections or bus stop usage. Housing units or retail square footage, respectively, were mapped, converted to grid data, aggregated, turned into points, and attached to the PAL and non-PAL sample points.

Parcel data were also used to indicate the presence of supermarkets or fast food restaurants along the state roadway within one-quarter mile of the center of a PAL or sample point. In the GIS, points representing PALs and sample points were buffered one-quarter mile. Buffers were selected that intersected parcels containing supermarkets. These buffers were visually inspected to make sure the supermarkets were along the roadway and not on an adjoining roadway. If the buffer met this test, the point corresponding to the buffer was designated as containing a supermarket. The same method was used for fast food restaurants. However, the tax assessor's data were not adequate for testing the presence of other land uses of interest such as taverns and bars.

School Sites

School sites were mapped in the GIS using King County data. PAL and non-PAL sample points were buffered by one-quarter mile. Points with buffers containing school sites were designated as having a school. Unlike supermarkets or fast food restaurants, schools could be anywhere within the buffer, not just along the state route.

VARIABLES

Table 5 shows the principal variables used in the study and derived from the data as described above. There were three basic classes of variables. One, the designation of whether a point was a PAL site or sample point, was considered the dependent variable in the study.

The second class of variables consisted of indicators of pedestrian activity. These included bus stop usage, the presence of retail uses, concentrations of dwellings, and the presence of a supermarket, fast food restaurants, or school site. It was hypothesized that pedestrian activity should be positively associated with PAL sites. The variable measuring retail activity based on land-use codes is shown in Table 6. Some services such as post offices were included. Automobile showrooms, car washes, and other auto-oriented retail and services were not included.

The third class included indicators of roadway conditions. These included traffic volumes, roadway width and number of lanes, traffic speed, and speed limits. As volume, speed, and roadway size increase, it was hypothesized that pedestrian risk, especially for street crossings, also increases. Thus, these variables were also hypothesized to be positively associated with PAL sites.

A final roadway characteristic was the density of intersections along the state facility. There was no hypothesized direction of association for this variable. Increased intersection density possibly creates more traffic turning movements and increased pedestrian risk. However, places with few intersections may still have many driveways servicing retail uses, and may, therefore, still have many turning movements (implying an interaction effect). Additionally, places with few intersections may have few signalized and protected opportunities for pedestrians to cross the state facility. This may encourage dangerous mid-block crossing behavior by pedestrians, thereby increasing pedestrian risk.

A final variable was whether a PAL site or non-PAL sample point was located on SR 99. This dummy variable was used in the analysis for two reasons. First, the large numbers of PALs along SR 99 suggest that conditions along the roadway are particularly dangerous. Second, the

Table 5. Principal Variables

Variable	Description	Source Data	Notes	Data Type
PAL	Designation of whether a point is a PAL or a sample point	WSDOT for PAL data	Dependent Variable	Dummy
SR99	Designation of whether PAL or sample point is located on SR99	WSDOT for PAL data	Different relationship between variables may exist on SR99 and other locations	Dummy
BUS250	Mean daily people getting on and off bus within 250 feet of center of PAL or sample point. Expressed in 10's of users.	Metro Automatic Passenger Counts (APC)	APC data is for bus stops. Data for stops within 250 ft. of PAL or sample aggregated	Continuous
RETQRTMI	Square feet of retail space within one-quarter mile of center of PAL or sample point. Expressed in 100,000's of sq. ft.	King County Parcel Data (Assessor's files)	Square footage aggregated and attached to PAL or sample point	Continuous
DUHLFMI	Number of dwelling units within one-half mile of PAL or sample point	King County Parcel Data (Assessor's files)	Units aggregated and attached to PAL or sample point	Continuous
HWYGRCRY	Grocery store on state route within one-quarter mile of center of PAL or sample point	King County Parcel Data		Dummy
HWYFSTFD	Fast food restaurant on state route within one-quarter mile of center of PAL or sample point	King County Parcel Data		Dummy
SCHOOL	School located within one-quarter mile of center of PAL or sample	King County School Theme		Dummy
24HR_VOL	Average daily traffic volume. Expressed in 1000's of vehicles	PSRC Emme2 model data	Volume for closest link to center of PAL or sample point	Continuous
LAN_OP	Number of lanes	PSRC GPS roadway data	Lanes for closest link to center of PAL or sample point	Ordinal (varies from 2 to 8)
CSPD_OP	Congestion traffic speed for off peak period	PSRC Emme2 model data	Speed for closest link to center of PAL or sample point	Continuous, but relatively little variation
INTSECT	Number of intersections within one-quarter mile of PAL or sample on Roadway that PAL or sample is located	King County intersection theme derived form street theme	Aggregated and attached to PAL or sample point	Continuous

Table 6. Assessor's Codes and Descriptions for Retail Land Uses

Use Code	Description
60	Shopping Ctr (Neighbrhood)
61	Shopping Ctr (Community)
62	Shopping Ctr (Regional)
63	Shopping Ctr (Major Retail)
96	Retail (Line/Strip)
101	Retail Store
104	Retail (Big Box)
105	Retail (Discount)
140	Bowling Alley
147	Movie Theater
162	Bank
167	Convenience Store without Gas Station
168	Convenience Store with Gas Station
171	Restaurant (Fast Food)
183	Restaurant/Lounge
188	Tavern/Lounge
189	Post Office/Post Service
191	Grocery Store
274	Historic Property (Retail)

environment on and along SR 99 is relatively homogeneous in comparison to other locations. Traffic volumes and bus ridership are relatively high in comparison to other facilities without controlled access, the roadway is continuously wide, and strip commercial and concentrations of housing are found along much of its length.

Other variables of interest describing the pedestrian environment were not available. These would have included the presence of sidewalks, the presence of signalization at intersections, and whether or not a roadway had a median. These types of variables may have been significant in explaining the location of PALs but could not be tested.

SAMPLING PROCEDURE

This research used a retrospective sampling approach common in many fields. In the approach, one set of samples is determined by the phenomenon of interest. For example, Ramsey et al. (1994) were interested in understanding the landscape conditions used by spotted owls to select nesting sites. The owls determined the location of nesting sites. These were retrospectively compared to a random sample of sites without nests to model differences in conditions. In this research, the location of PAL sites was predetermined. These sites were compared to a random sample of sites along state roadways that were not PAL sites (referred to as sample points above).

Because of the high proportion of PAL sites along SR 99, the sample was stratified. First a sample was drawn from SR 99, with a second sample drawn for non-SR 99 state routes. This allowed for a proportionately higher sample to be drawn on SR99 than would be the case with a single, unstratified sample drawn for all routes. This was important for conducting a separate analysis on SR 99 and allowed better capturing of variations in the conditions along SR 99.

All King County PAL sites were found inside the urban growth boundary, and samples were restricted to this area also. This avoided comparing PAL sites to rural areas with little potential for the presence of pedestrians.

Sampling followed the following procedure:

1. Points were geo-coded every 0.10 miles along state routes.
2. Points along limited access portions of routes were excluded (for example Interstate-90 and the portion of SR 99 that goes through the center of Seattle in a tunnel and on a viaduct).
3. Points falling within 125 feet of the border of a PAL were excluded. This ensured that PALs and route segments associated with a sample point would not overlap, assuming a 0.01-mile route segment assigned to a sample point.
4. The remaining points were randomly sampled, first for SR 99 and then for other state routes. Fifty and 75 sample points were drawn for SR 99 and other routes respectively.

The numbers of PAL and sample points on SR 99 and other routes are shown in Table 7.

Table 7. PAL and Sample Points on All State Facilities in King County

Points	SR99	Other Routes	Total
PALs	33	23	56
Non-PAL Sample Points	49	76	125
Total	82	99	181

ANALYSES AND FINDINGS

Variables were explored in terms of their mean and standard deviations. Correlation analysis was used to explore basic relationships between variables and to test for multi-colinearity. The principal modeling technique used was binary logistic regression. As stated, analyses were performed on three sets of data:

1. <u>All State Facilities in King County</u>: PAL and non-PAL sample points on all state routes.
2. <u>SR 99 Only</u>: PAL and non-PAL sample points on SR 99.
3. <u>Non-SR 99 Facilities in King County</u>: PAL and non-PAL sample points on all state routes other than SR 99

DESCRIPTIVE STATISTICS: MEANS AND STANDARD DEVIATIONS

Basic descriptive statistics were examined for the three sets of data. Differences in statistics were also compared between PAL and non-PAL sample points.

PAL and Sample Points on All State Facilities in King County

Basic statistics for the data set containing all PAL and sample points located both on and off of SR 99 is shown in Table 8. Comparative statistics for PAL and sample points are shown in Table 9.

Mean daily bus stop usage for areas within 250 feet of the center of PALs and non-PAL sample areas was 54 persons, a fairly low figure. Variation in bus stop use, as expressed by the standard deviation, was fairly high. Retail space in an area of one-quarter mile around points was just shy of 100,000 square feet, with substantial variation. On average, over 1500 housing units were located within one-half mile of points, again with substantial variation (Figure 5). Thirteen percent of points were near a grocery store, 38 percent were near a fast food restaurant, and 29 percent were near a school. On average the segments on which points were located carried 40,000 vehicles a day on an average of about four travel lanes. Variation for both these variables was comparatively low. Average off-peak congestion traffic speeds were modeled to be about 31 miles and hour, again with not much variation. Finally, highway segments on which points were located had an average of 4.6 intersections per one-quarter mile, or about one intersection about every 300 feet. There was a fair degree of variation in this figure.

Table 8. Descriptive Statistics for PAL and Non-PAL Sample Points on All State Facilities in King County

VARIABLE	N	Minimum	Maximum	Mean	Std. Deviation
BUS250	181	.00	93.00	5.42	12.88
RETQRTMI	181	.00	8.95	.94	1.29
DUHLFMI	181	.000	5578.10	1536.06	1031.42
HWYGRCRY	181	0	1	.13	.334
HWYFSTFD	181	0	1	.38	.486
SCHOOL	181	0	1	.29	.456
24HR_VOL	176	.40	109.61	40.29	26.13
LAN_OP	176	2.0	8.0	3.9	1.16
CSPD_OP	176	12.1	44.70	31.5	5.9
INTSECT	181	1	13	4.57	3.00

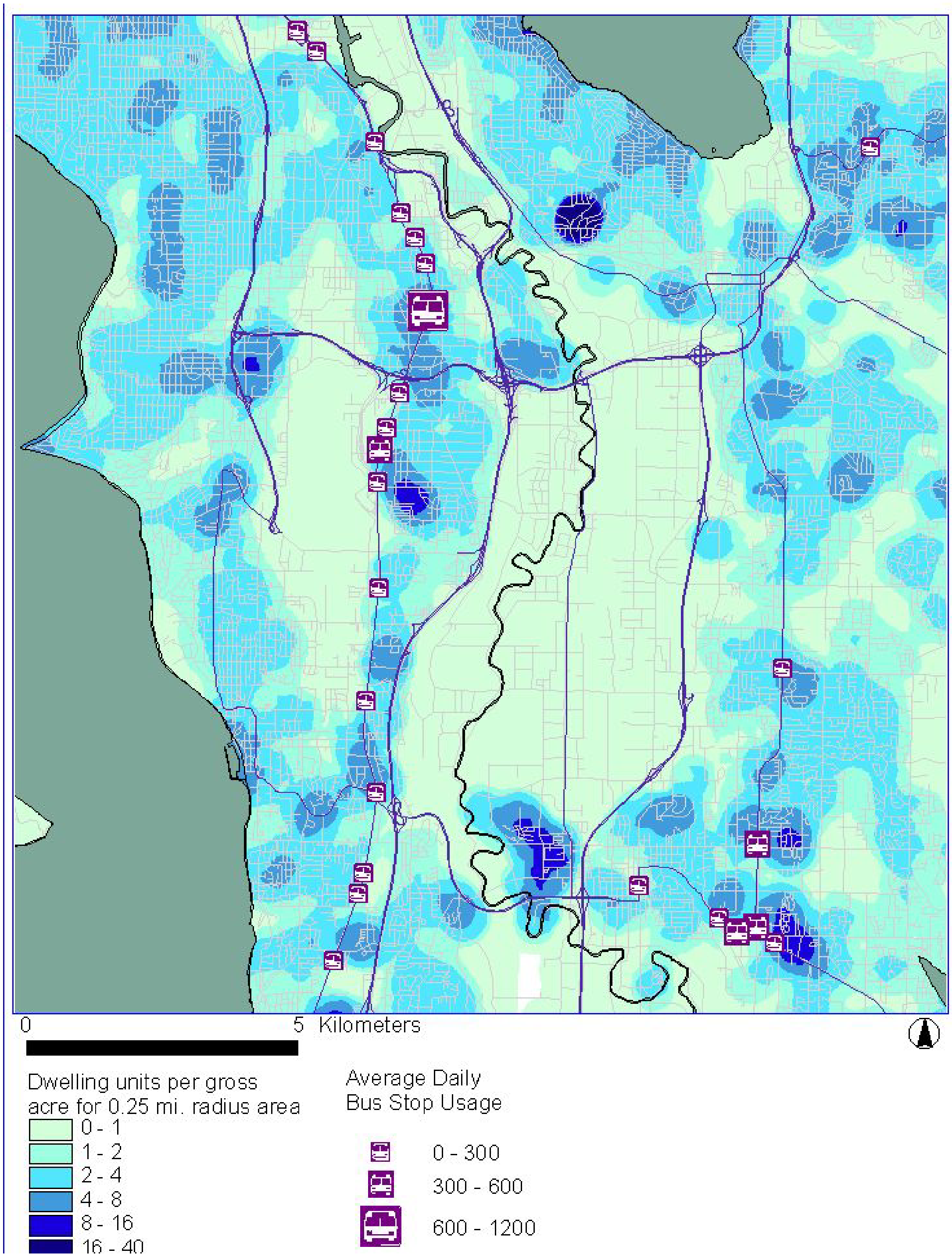


Figure 5: Bus Stop Usage and Gross Residential Density at Pedestrian Accident Locations (PALS), on South King County State Routes

Table 9. Comparative Descriptive Statistics for PAL and Non-PAL Sample Points on All State Facilities in King County

Points	VARIABLE	N	Minimum	Maximum	Mean	Std. Deviation
Sample Points	BUS250	125	.00	29.20	1.50	4.50
	RETQRTMI	125	.00	5.51	.70	1.05
	DUHLFMI	125	.000	5578.10	1387.24	1071.15
	HWYGRCRY	125	0	1	.14	.344
	HWYFSTFD	125	0	1	.30	.458
	SCHOOL	125	0	1	.30	.458
	24HR_VOL	120	.40	109.61	37.14	27.29
	LAN_OP	120	2.00000	6.00	3.67	1.17
	CSPD_OP	120	12.10000	44.70	31.47	5.98
	INTSECT	125	1	13	4.40	2.98
PALS	BUS250	56	.00	93.00	14.17	19.61
	RETQRTMI	56	.04	8.95	1.55	1.57
	DUHLFMI	56	25.518	4008.02	1868.25	855.65
	HWYGRCRY	56	0	1	.11	.31
	HWYFSTFD	56	0	1	.55	.50
	SCHOOL	56	0	1	.29	.46
	24HR_VOL	56	8.77	103.60	47.03	22.23
	LAN_OP	56	2.00000	8.00	4.34	.99
	CSPD_OP	56	18.95000	43.15	31.70	5.73
	INTSECT	56	1	13	4.96	3.02

Briefly comparing PAL and sample points, notable differences were found in bus stop usage, retail area, and housing units. Mean daily bus stop usage around PALs was almost ten times higher, at 142 people a day, than at sample points. In comparing means to standard deviations, there was also less variation for the PALs. The average amount of retail space was about 2.5 times higher for PALs than for sample points, and there were also more housing units. More surprisingly, a smaller percentage of PALs than sample points were located near grocery stores, but more PALs were located near fast food restaurants. There was little difference between the percentage of PALs and sample points located near schools. Roadway characteristics were more similar for the two types of locations, although PALs had somewhat higher traffic volumes and more lanes of traffic. Modeled traffic speeds were nearly identical, although PALs had a slightly higher density of intersections. The logistic regression modeling presented below was used to test for which of these differences were statistically significant in predicting whether or not a location was a PAL.

PAL and Sample Points on SR 99

Basic statistics for the data set containing all PAL and sample points on SR 99 are shown in Table 10. Comparative statistics for PAL and sample points are shown in Table 11. In comparison to the complete data set just discussed, SR 99 was a more intensively developed and used. For example, bus stop usage around points was almost twice as high as around points along other state highways in the county, with an average of 101 people. The amount of retail development was slightly higher, with an average of over 100,000 square feet around points; there were on average more housing units located around points on Aurora than along other state highways in the county; and there were more points located near groceries, fast food restaurants, and schools. Mean traffic volumes were somewhat higher, with 57,000 vehicles a day, and there were, on average, more travel lanes. On the other hand, speeds and intersections densities were similar. The degree of variation in the variables for SR 99 mirrored that for the data set as a whole.

Table 10. Descriptive Statistics for PAL and Non-PAL Sample Points on SR 99

VARIABLE	N	Minimum	Maximum	Mean	Std. Deviation
BUS250	82	.00	93.00	10.12	17.63
RETQRTMI	82	.00	8.95	1.17	1.47
DUHLFMI	82	18.64	5578.11	1984.49	1181.44
HWYGRCRY	82	0	1	.16	.37
HWYFSTFD	82	0	1	.46	.50
SCHOOL	82	0	1	.38	.49
24HR_VOL	82	12.86	109.61	56.97	24.62
LAN_OP	82	2.00	8.00	4.49	1.02
CSPD_OP	82	24.05	43.80	33.44	5.10
INTSECT	82	1	13	4.88	3.34

A comparison of descriptive statistics for SR 99 PAL and sample points (Table 11) shows substantial variations between bus stop usage, which was six times higher for PAL sites, and retail uses, where PAL sites had about 50 percent more square footage than sample points, on average. For all other variables, there was little difference between the PAL and sample points. These other variables were not, then, expected to be significant variables in the logistic regression models. This did not mean, however, that they were not related to pedestrian collisions, but rather that there was not enough variation in the variables along SR 99 to test effect.

Table 11. Comparative Descriptive Statistics for PAL and Non-PAL Sample Points on SR99

Points	VARIABLE	N	Minimum	Maximum	Mean	Std. Deviation
Sample Points	BUS250	49	.00	29.20	3.28	6.71
	RETQRTMI	49	.00	5.51	.93	1.22
	DUHLFMI	49	18.64	5578.11	1952.58	1356.72
	HWYGRCRY	49	0	1	.16	.37
	HWYFSTFD	49	0	1	.45	.50
	SCHOOL	49	0	1	.43	.50
	24HR_VOL	49	17.14	109.61	57.58	26.82
	LAN_OP	49	2.00	6.00	4.45	.94
	CSPD_OP	49	24.05	43.80	33.39	5.05
	INTSECT	49	1	13	4.80	3.30
PALS	BUS250	33	.00	93.00	20.26	23.28
	RETQRTMI	33	.05	8.95	1.52	1.74
	DUHLFMI	33	664.99	4008.02	2031.88	876.46
	HWYGRCRY	33	0	1	.15	.36
	HWYFSTFD	33	0	1	.48	.51
	SCHOOL	33	0	1	.30	.47
	24HR_VOL	33	12.86	103.60	56.06	21.30
	LAN_OP	33	4.00	8.00	4.55	1.15
	CSPD_OP	33	24.05	43.15	33.51	5.26
	INTSECT	33	1	13	5.00	3.45

PAL and Non-PAL Sample Points Not Located on SR99

Basic statistics for the data set containing all PAL and sample points located on state facilities other than SR 99 are shown in Table 12. Comparative statistics for PAL and sample points are shown in Table 13. Bus stop usage around points was low, with about 15 people daily. Retail space was also low in comparison to Aurora, with about 78,000 square feet within one-quarter mile of points. The mean number of housing units around non-SR 99 points was about only half of that found on SR 99. Likewise, fewer groceries, fast food restaurants, and schools were associated with non-SR 99 points. Traffic volumes and speeds were lower, and roadways had, on average, fewer lanes with slightly lower intersection densities. The general pattern of variation as expressed by standard deviations was similar between SR 99 and non-SR 99 points, with the clear exception of traffic volumes, which varied more for the non-SR 99 points.

Unlike SR 99, most variables showed substantial differences in their means when PALs and sample points were compared. Bus stop usage, for example, was about 15 times higher for the PALs; retail area was about three times higher; and numbers of housing units were about 1.5 times as high when compared to means for sample points. There are fewer groceries near PALs, but more fast food restaurants and schools. PALs also had higher traffic volumes, more travel lanes, and higher intersection densities. Off-peak congestion travel speeds were similar between the two groups. The statistical significance of these differences was modeled using logistic regression.

Table 12. Descriptive Statistics for PAL and Non-PAL Sample Points Not Located On SR99

VARIABLE	N	Minimum	Maximum	Mean	Std. Deviation
BUS250	99	.00	17.10	1.53	3.75
RETQRTMI	99	.00	4.20	.79	1.09
DUHLFMI	99	.00	2781.53	1164.63	701.89
HWYGRCRY	99	0	1	.10	.30
HWYFSTFD	99	0	1	.30	.46
SCHOOL	99	0	1	.22	.42
24HR_VOL	94	.40	65.69	25.73	17.25
LAN_OP	94	2.00	6.00	3.35	1.00
CSPD_OP	94	12.10	44.70	29.89	6.05
INTSECT	99	1	12	4.32	2.67

Table 13. Comparative Descriptive Statistics for PAL and Non-PAL Sample Points Not Located on SR 99

Points	VARIABLES	N	Minimum	Maximum	Mean	Std. Deviation
Sample Points	BUS250	76	.00	5.20	.35	1.09
	RETQRTMI	76	.00	3.41	.54	.89
	DUHLFMI	76	.00	2777.53	1022.74	612.75
	HWYGRCRY	76	0	1	.12	.32
	HWYFSTFD	76	0	1	.20	.40
	SCHOOL	76	0	1	.21	.41
	24HR_VOL	71	.40	61.37	23.03	16.67
	LAN_OP	71	2.00	4.00	3.13	.99
	CSPD_OP	71	12.10	44.70	30.15	6.24
	INTSECT	76	1	11	4.14	2.75
PALS	BUS250	23	.00	17.10	5.43	6.15
	RETQRTMI	23	.04	4.20	1.59	1.32
	DUHLFMI	23	25.52	2781.53	1633.47	784.35
	HWYGRCRY	23	0	1	.04	.21
	HWYFSTFD	23	0	1	.65	.49
	SCHOOL	23	0	1	.26	.45
	24HR_VOL	23	8.77	65.69	34.07	16.64
	LAN_OP	23	2.00	6.00	4.04	.64
	CSPD_OP	23	18.95	41.30	29.09	5.45
	INTSECT	23	2	12	4.91	2.33

CORRELATIONS

Pearson correlation coefficients are only presented for the complete data set (Table 13). Correlation coefficients showed similar patterns for SR 99 points and samples and for non-SR 99 points and samples. Pearson correlation coefficients ranged from –1.0, indicating a perfect negative relationship, to 1.0, indicating a perfect positive relationship. A coefficient of 0 indicates no relationship. Most variables had only weak to moderate relationships with each other, with only two variables having Pearson coefficients above 0.5. These were (24HRVOL) with the number of dwelling units located within one-half mile of points (DUHLFMI), where the correlation was 0.509, and 24-hour traffic volumes with the number of travel lanes (LAN_OP), where the correlation was 0.695. These correlations made basic sense and did not present statistical problems. Other correlations also made general sense. An exception was grocery stores located near points (HWYGRCRY), and retail space around points (RETQRTMI), where almost no relationship was shown.

Some interaction variables were also created and tested through correlation analysis. For example, traffic speed was multiplied with traffic volume to try to better model traffic hazard; retail area was multiplied with housing units numbers to better model combined pedestrian generators; and bus stop use was multiplied with traffic volume to better model pedestrian exposure. In all cases the interaction variables were highly correlated with one of their base variables, with Pearson coefficients well above 0.9, and only base variables were included in the regressions.

Table 14. Pearson Correlations for Pal and Non-PAL Sample Points on All State Facilities in King County

		PAL	BUS250	RETQRTMI	DUHLFMI	HWY GRCRY	HWY FSTFD	SCHOOL	24HR_VOL	LAN_OP	CSPD_OP	INTSECT
PAL	Pearson Correlation	1	.456	.306	.216	-.040	.246	-.010	.177	.271	.018	.087
	Sig. (2-tailed)	.	.000	.000	.003	.592	.001	.889	.019	.000	.814	.243
	N	181	181	181	181	181	181	181	176	176	176	181
BUS250	Pearson Correlation	.456	1	.180	.234	.043	.184	-.013	.228	.194	.132	.098
	Sig. (2-tailed)	.000	.	.015	.002	.565	.013	.859	.002	.010	.080	.189
	N	181	181	181	181	181	181	181	176	176	176	181
RETQRTMI	Pearson Correlation	.306	.180	1	.137	.013	.450	-.003	.063	.218	-.117	.139
	Sig. (2-tailed)	.000	.015	.	.065	.867	.000	.964	.407	.004	.122	.062
	N	181	181	181	181	181	181	181	176	176	176	181
DUHLFMI	Pearson Correlation	.216	.234	.137	1	.171	.166	.239	.509	.427	.090	.511
	Sig. (2-tailed)	.003	.002	.065	.	.021	.025	.001	.000	.000	.232	.000
	N	181	181	181	181	181	181	181	176	176	176	181
HWYGRCRY	Pearson Correlation	-.040	.043	.013	.171	1	.012	.155	.028	.069	-.018	.082
	Sig. (2-tailed)	.592	.565	.867	.021	.	.869	.037	.711	.364	.815	.272
	N	181	181	181	181	181	181	181	176	176	176	181
HWYFSTFD	Pearson Correlation	.246	.184	.450	.166	.012	1	.027	.125	.172	-.031	.118
	Sig. (2-tailed)	.001	.013	.000	.025	.869	.	.715	.099	.023	.679	.113
	N	181	181	181	181	181	181	181	176	176	176	181
SCHOOL	Pearson Correlation	-.010	-.013	-.003	.239	.155	.027	1	.184	.088	.048	.270
	Sig. (2-tailed)	.889	.859	.964	.001	.037	.715	.	.014	.247	.531	.000
	N	181	181	181	181	181	181	181	176	176	176	181

Table 14 (continued): Pearson Correlations for Pal and Non-PAL Sample Points on All State Facilities in King County

		PAL	BUS250	RETQRT MI	DUHLFMI	HWY GRCRY	HWY FSTFD	SCHOOL	24HR_ VOL	LAN_OP	CSPD_OP	INTSECT
24HR_VOL	Pearson Correlation	.177	.228	.063	.509	.028	.125	.184	1	.695	.380	.217
	Sig. (2-tailed)	.019	.002	.407	.000	.711	.099	.014	.	.000	.000	.004
	N	176	176	176	176	176	176	176	176	176	176	176
LAN_OP	Pearson Correlation	.271	.194	.218	.427	.069	.172	.088	.695	1	.255	.173
	Sig. (2-tailed)	.000	.010	.004	.000	.364	.023	.247	.000	.	.001	.022
	N	176	176	176	176	176	176	176	176	176	176	176
CSPD_OP	Pearson Correlation	.018	.132	-.117	.090	-.018	-.031	.048	.380	.255	1	-.037
	Sig. (2-tailed)	.814	.080	.122	.232	.815	.679	.531	.000	.001	.	.625
	N	176	176	176	176	176	176	176	176	176	176	176
INTSECT	Pearson Correlation	.087	.098	.139	.511	.082	.118	.270	.217	.173	-.037	1
	Sig. (2-tailed)	.243	.189	.062	.000	.272	.113	.000	.004	.022	.625	.
	N	181	181	181	181	181	181	181	176	176	176	181

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

LOGISTIC REGRESSION

Logistic regression is an appropriate statistical technique when using a non-continuous dependent variable, and especially when using a dichotomous dependent variable, as in this case (where the dependent variable signified whether a point was a PAL or not). The technique assessed other variables in terms of their power to predict the value of the dependent variable. In this case the probability that a site was a PAL divided by the probability it was a non-PAL sample site (an odds ratio) was linearly regressed against the vector of the predictor variables. Variable coefficients can be interpreted as a multiplicative effect on the odds ratio of a one-unit change in the variable. The intercept cannot be interpreted.

All variables in Table 5 were entered into the regressions.

MODEL 1: Results for PALs and Non-PAL Sample Points on All State Facilities in King County

Results are presented in tables 15, 16, and 17. Summary statistics for the model as a whole are presented in Table 15. With a chi-square of 71.5 and 10 degrees of freedom, the model as a whole was statistically significant below the 0.01 level. The Cox and Snell R Square is based on the –2 Log Likelihood of the model in comparison to a base model. It suggests the proportion of the variance in the dependent variable (whether a point is a PAL or not), which is explained by the independent predictor variables. In this case, it suggested that about a third of the variation was explained.

Table 15: Summary Statistics For Model with PAL and Non-PAL Sample Points on All State Facilities in King County

Chi-Square	Degrees of Freedom	Significance	-2 Log Likelihood	Cox and Snell R Square
71.5	10	.000	148.7	0.33

Table 16 presents a classification table for the number of observed and predicted PAL and non-PAL sample points. The table shows that the model classified 109 non-PALs correctly as non-PALs, while 11 non-PALs were classified incorrectly as non-PALs. About 91 percent of non-PALs were correctly predicted. Correct predictions for PALs were lower, with 32 out of 56 total PAL sites correctly classified. In other words, only 57 percent of PAL predictions were correct. Overall, however, 80 percent of points were correctly classified.

Table 16: Classification Table For Observed and Predicted PAL and Non-PAL Sample Points on All State Facilities in King County

Observed	Predicted		Percent Correct
	NON-PAL	PAL	
NON-PAL	109	11	90.8
PAL	24	32	57.1
Overall Percent			80.1

Table 17 shows the variables in the model. Only two variables were statistically significant: BUS250, the number of people boarding and alighting from a bus within 250 feet of the center of a PAL or sample points expressed in ten's of bus users; and RETQRTMI, the amount of building area in retail uses within one-quarter mile of the center of a PAL or sample points expressed in 100,000's of square feet. The third to last column, Exp(B), is the exponential function of the coefficient of the variable (Beta or B). In the case of BUS250, Exp(B) can be interpreted as the multiplicative change in the odds ratio from a one-unit change in B. Since one unit of BUS250 was 10 bus stop users, this suggests that increasing bus stop usage by 10 people would increase the odds that a point would be a PAL by 1.17 times. This finding supports the principal hypothesis of the study, that increased bus stop usage exposes pedestrians to traffic hazard and is related to the location of Pedestrian Accident Locations. The last two columns show the upper and lower bounds for the 95 percent confidence interval for the value of Exp(B).

Table 17: Variables in Model for PAL and Non-PAL Sample Points on All State Facilities in King County

VARIABLE	B	S.E.	Wald	df	Sig.	Exp(B)	95 % CI for Exp(B)	
							Lower	Upper
BUS250	.158	.03	23.02	1	.00	1.17	1.09	1.24
RETQRTMI	.398	.19	4.16	1	.04	1.48	1.01	2.18
DU1000	.128	.26	.23	1	.62	1.13	.67	1.90
HWYGRCRY	-.889	.70	1.58	1	.20	.41	.10	1.64
HWYFSTFD	.382	.45	.72	1	.39	1.46	.60	3.54
SCHOOL	.011	.48	.00	1	.98	1.01	.39	2.61
24HR_VOL	-.118	.11	1.00	1	.31	.88	.70	1.11
LAN_OP	.561	.29	3.56	1	.05	1.75	.97	3.13
CSPD_OP	-.030	.04	.54	1	.46	.97	.89	1.05
INTSECT	.040	.08	.23	1	.63	1.04	.88	1.22
Constant	-3.220	1.48	4.69	1	.03	.04		

RETQRTMI, another indicator of potential pedestrian activity, was also significant. The value of 1.48 for Exp(B) suggests that adding 100,000 square feet of retail uses (about the size of two grocery stores) would increase the odds that a point would be a PAL by about 1.5. It is worth noting that in addition to increased pedestrian activity, increased levels of retail activity may also be associated with large numbers of active driveways along highways. Active driveways, with vehicles turning across sidewalks or shoulders, would be expected to increase pedestrian hazard.

No other land use variables or roadway characteristics were significant. It should be emphasized, however, that this does not mean these types of variables do not play a role in the locations of pedestrian accidents but merely that this modeling effort did not show that they do.

MODEL 2: Results for SR99 PAL and Non-PAL Sample points

Results are presented in tables 18, 19, and 20. Summary statistics for the model as a whole are presented in Table 18. With a chi-square of 33.6 and 10 degrees of freedom, the model as a whole was statistically significant below the 0.01 level. The Cox and Snell R Square suggests that the model explained about a third of the variation in the dependent variable (very similar to the first model.)

Table 18: Summary Statistics For Model with SR99 PAL and Non-PAL Sample Points

Chi-Square	Degrees of Freedom	Significance	-2 Log Likelihood	Cox and Snell R Square
33.6	10	.000	76.9	0.34

Table 19 presents a classification table for the number of observed and predicted PAL and non-PAL sample points. The model classified about 86 percent of non-Pal sample points correctly, and about 61 percent of PAL points correctly (slightly better than the first model). Over all, about three quarters of points were correctly classified on the basis of the values of the independent variables.

Table 19. Classification Table for Observed and Predicted PAL and Non-PAL Sample Points: SR99

Observed	Predicted		Percent Correct
	NON-PAL	PAL	
NON-PAL	42	7	85.7
PAL	13	20	60.6
Overall Percent			75.6

Table 20 shows the variables in the model. In the case of SR 99, only bus stop usage was statistically significant. Unlike Model 1, retail activity (RETQRTMI) was not. Bus stop usage was significant below the 0.01 level. Exp(B) suggests that an increase of 10 bus stop users would increase the odds that a site would be a PAL by 1.16. This is similar to Model 1.

Table 20: Variables in Model for SR99 PAL and Non-PAL Sample Points

VARIABLE	B	S.E.	Wald	df	Sig.	Exp(B)	95 % CI for Exp(B)	
							Lower	Upper
BUS250	.15	.03	15.40	1	.00	1.16	1.07	1.25
RETQRTMI	.33	.24	1.82	1	.17	1.39	.86	2.25
DU1000	.05	.36	.01	1	.89	1.05	.51	2.14
HWYGRCRY	-.23	.89	.06	1	.79	.79	.13	4.59
HWYFSTFD	-.68	.68	1.00	1	.31	.50	.13	1.91
SCHOOL	.06	.63	.01	1	.91	1.06	.30	3.68
24HR_VOL	-.26	.18	2.17	1	.14	.76	.53	1.09
LAN_OP	.11	.41	.07	1	.78	1.11	.49	2.52
CSPD_OP	.01	.07	.06	1	.80	1.01	.88	1.16
INTSECT	.18	.13	1.80	1	.17	1.19	.92	1.55
Constant	-2.24	2.30	.94	1	.33	.10		

A comparison of means and standard deviations for the variables, presented in Table 11 and summarized in Table 21 below, explains these results. Again, there was little variation in these variables. In other words, there is great consistency in the physical environment for much of the length of SR 99. The route has similar housing unit densities; spacing of supermarkets, fast food restaurants, and schools; similar traffic volumes and speeds; similar numbers of lanes; and even similar intersection densities along most of its length. For example, about 75 percent of PAL and sample points were located on a highway segment with four traffic lanes, with almost all of the other points located along segments with six traffic lanes. To the degree that these types of characteristics contribute to pedestrian accidents, they do so along most of SR 99, and the lack of variation means that no statistically significant effect can be measured.

Other than bus stop usage, the only variable with notably different means between SR 99 PAL and sample points was the amount of retail space. Although not statistically significant in the model, this difference and the fact that the variable was statistically significant in Model 1 suggest that the variable deserves further consideration in future research.

Table 21: Comparison of Means and Standard Deviations for PAL and Non-PAL Sample

VARIABLE	SR99 PALs		SR99 Non-PAL	
	Mean	**Stnd Dev**	**Mean**	**Stnd Dev**
BUS250	20.3	23.3	3.3	6.7
RETQRTMI	1.52	1.7	.93	1.22
DUHLFMI	2032	876	1953	135
HWYGRCRY	0.15	0.36	0.16	0.37
HWYFSTFD	0.48	.51	0.45	.50
SCHOOL	0.30	.47	0.43	.50
24HR_VOL	56.1	21.3	57.6	26.8
LAN_OP	4.5	1.15	4.4	0.94
CSPD_OP	33.5	5.26	33.4	5.05
INTSECT	5.00	3.4	4.80	3.3

MODEL 3: Results for Non-SR 99 PAL and Non-PAL Sample points

Results are presented in tables 22, 23, and 24. Summary statistics for the model as a whole are presented in Table 22. With a chi-square of 63.6 and 10 degrees of freedom, the model as a whole was statistically significant below the 0.01 level. The Cox and Snell R Square suggests the model explained almost half of the variation in the dependent variable. This is substantially higher that for the first two models.

Table 22: Summary Statistics For Model with Non-SR99 PAL and Non-PAL Sample Points

Chi-Square	Degrees of Freedom	Significance	-2 Log Likelihood	Cox and Snell R Square
63.6	10	.000	41.03	0.49

Table 23 presents a classification for the number of observed and predicted PAL and non-PAL sample points. The model classified all but 4 of 71 sample points, or about 94 percent correctly. In comparison to the first two models, the percentage of correct prediction for PAL sites was high, with 17 of 23, or 74 percent, predicted correctly. The overall percentage of correct prediction was about 90 percent.

Table 23: Classification for Observed and Predicted PAL and Non-PAL Sample Points: Non-SR 99

Observed	Predicted		Percent Correct
	NON-PAL	**PAL**	
NON-PAL	67	4	94.4
PAL	6	17	73.9
Overall Percent			89.4

Table 24 shows the variables in the model. The model showed four variables to be statistically significant at the 0.05 level. First, bus stop usage was significant, with an Exp(B) suggesting that an increase in usage by 10 people would increase the odds that a site was a PAL by 1.5. This is consistent with both previous models and, again, supports the principal hypotheses of the study that bus stop usage is related to pedestrian collisions. This is an important finding and suggests that safety improvements should be targeted for areas with high transit use.

Table 24: Variables in Model for Non-SR 99 PAL and Non-PAL Sample Points

VARIABLE	B	S.E.	Wald	df	Sig.	Exp(B)	95 % CI for Exp(B)	
							Lower	Upper
BUS250	.41	.18	5.03	1	.02	1.51	1.05	2.17
RETQRTMI	.98	.52	3.48	1	.06	2.68	.95	7.54
DU1000	.28	.65	.19	1	.66	1.33	.36	4.84
HWYGRCRY	-5.65	2.68	4.45	1	.03	.00	.00	.67
HWYFSTFD	.04	1.07	.00	1	.96	1.04	.12	8.57
SCHOOL	3.27	1.89	2.97	1	.08	26.31	.64	1079.54
24HR_VOL	.62	.29	4.52	1	.03	1.86	1.05	3.29
LAN_OP	2.72	1.30	4.36	1	.03	15.27	1.18	197.37
CSPD_OP	.01	.06	.08	1	.77	1.01	.89	1.15
INTSECT	.25	.27	.90	1	.34	1.29	.76	2.20
Constant	-17.56	7.14	6.03	1	.01	.00		

Also significant was the dummy variable HWYGRCRY, indicating the presence of a grocery store along the highway in a PAL or near a sample point. This finding is difficult to interpret, however. First, the coefficient beta was negative, indicating that the odds were lower that a site would be a PAL if it had a grocery store. This is contrary to the hypothesized direction of effect, and without a more detailed exploration of site conditions associated with grocery stores, it is difficult to speculate why this might be the case. Second, the multiplicative change in odds that a site would be a PAL with the addition of a grocery store as expressed by Exp(B) was extremely small, at 0.003 with a 95 percent confidence interval ranging from 0.000 to 0.670.

The final two significant variables were both related to traffic and roadway conditions rather than pedestrian generators. The variable 24hrVOL indicated daily traffic volumes expressed in 10,000's of vehicles. Thus, the Exponential function of the coefficient, Exp(B), suggested that the addition of 10,000 vehicles a day would increase the odds that a site would be a PAL by 1.8. The direction of this effect is as hypothesized.

Also as hypothesized, highways with more travel lanes, as expressed by LAN_OP, were more likely to be associated with PALs. The exponential function of the variable's coefficient suggested that for each new lane on a road, the odds that the road would be classified as a PAL site were 15.3 times larger.

DISCUSSION

The three models showed consistency in the positive relationship between bus stop usage and PAL sites and thus supported the principal hypothesis of the study. This finding suggests that facilities with high transit usage should be targeted for pedestrian safety improvements, with specific engineering solutions adapted to specific site conditions.

The SR 99 model showed bus stop usage as the only statistically significant predictor of PALs. This is explained by the lack of variation in the other variables capturing pedestrian activity and road characteristics along the route. In addition to fairly high bus stop usage, SR 99 has substantial retail activity, large numbers of housing units located along it, four to six travel lanes, and high traffic volumes—all factors that likely contribute to the large number of collisions and Pedestrian Accident Locations found along this roadway.

With more variation in pedestrian generator and road characteristics variables, the non-SR 99 model suggested that additional factors are associated with pedestrian risk. Both traffic volume and the number of traffic lanes were statistically significant predictors of PALs. This is consistent with previous studies (Zeeger 1991). The model also showed that adding a traffic lane would have a potentially very large effect on the likelihood of creating a PAL location. As road widening is a standard, commonly used approach to adding vehicular capacity, the association between PALs and road width deserves immediate further study.

FUTURE RESEARCH

This study showed that bus stop usage is strongly associated with pedestrian collisions along state facilities. Less strong associations were shown to exist between PALs and retail location and size, traffic volume, and number of traffic lanes. The fact that PALS are predefined aggregations of pedestrian-vehicle collisions may explain the difficulty in capturing associations with pedestrian activity indicators and road characteristics. PALs are extremely useful as a planning tool in helping to direct planning efforts and safety dollars to specific locations along roadways. However, because PALs are at least 0.1 mile in length, or more than 500 feet long, they are less useful in examining specific site conditions. For example, it is not be possible to model pedestrians crossing the street in a PAL. Also, the length of a PAL tends to smooth out variations in housing densities, retail area characteristics, and other environmental attributes around collision sites. This reduces the statistical power of modeling efforts. Using spatial units of analysis that are smaller than that of PALs, and specifically modeling individual pedestrian-vehicle collisions, would allow the use of a continuous model, which could show more significant relationships among pedestrian generators, roadway conditions, and pedestrian collisions. Future research also needs to include actual rather than modeled data of traffic characteristics, as well as data on sidewalks, crosswalks, and signalization.

The power of current GIS technology and analysis makes it possible to use such small units of analysis across large study areas (Steiner 2002). New sources of data from both transportation and planning sectors will help increase the power of research results. We anticipate that the imminent release of WSDOT data on individual collisions on all state and non-state roadways will make such analyses possible. The very high societal costs of collisions involving pedestrians make it essential to develop tools that help define precisely where and how to invest safety dollars.

CONCLUSIONS AND APPLICATIONS

This study shows that the level of bus usage along state highways is associated with high rates of pedestrian-vehicle collisions. It suggests that facilities with high numbers of bus boardings or alightings need to be designed not only for cars, but also for pedestrians, allowing people to safely walk along and across the roadway.

These findings make immediate sense, and indeed may seem too obvious to require verification through statistical analysis. Yet this research is necessary to support the development of effective policies concerning the safety of pedestrians on high-volume traffic corridors. Such policies remain currently a weak element of highway and transit agency safety protocols. Both types of agencies tend to disregard transit riders as they walk. While highway agencies such as WSDOT are responsible for designing and operating safe roadways, their focus is on vehicular safety. Furthermore, while bus transit is an important consideration in roadway design and investment, the emphasis is on facilities for the transit vehicles themselves and not the riders before they get on or after they get off buses. Transit agencies, on the other hand, are responsible for the safety of riders in transit vehicles and at transit stops, but people walking along or across the road are outside of their purview.

This research addresses two aspects of future pedestrian safety. First, it examines the relationship between facility conditions (roadway configurations) and hazards as related to user volumes. At this point, highway safety design standards typically consider roadway design and not pedestrian volumes. Along wide roadways lined with strip-retail, bus stops with high ridership and, generally, all areas of active use by pedestrians must be identified, and roadway safety design standards must address the elevated risk of pedestrian-vehicle collisions in these locations. Highways with many high-volume pedestrian locations need to be designed as multi-modal facilities. This suggests that the major regional facilities within local urban and suburban communities must integrate motorized and non-motorized travel modes, with specific attention paid to the role of transit in shaping the demand for non-motorized travel on the facilities.

Second, in identifying areas of high bus stop usage as areas with high pedestrian accident rates, this research helps justify mandated inter-agency cooperation to plan and fund pedestrian safety improvements. State DOT, local jurisdiction, and transit staff must work together to identify facilities and locations where bus riders are at risk and take appropriate steps to ensure pedestrian safety at and beyond the bus stop.

As noted in the beginning of this report, pedestrian-vehicle collisions on state facilities account for hundreds of deaths and disabilities, which, in the State of Washington alone, amount to $100,000,000 in average yearly societal costs over a six-year period. This research suggests that reducing these costs would be possible by focusing on the safety of people accessing transit.

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