In-Service Evaluation of Major Urban Arterials with Landscaped Medians–Phase II

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IN-SERVICE EVALUATION OF MAJOR URBAN ARTERIALS WITH LANDSCAPED MEDIANS— PHASE II

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16. ABSTRACT:

Because of undesirable characteristics of some major arterials such as State Route (SR) 99 north and south of Seattle several cities are implementing redevelopment plans. These redevelopment proposals for SR 99 and other state routes include landscaped medians, many with trees placed close to the roadway in either the median or shoulder areas. However, WSDOT's clear zone width criterion may not always be met when trees are placed within curbed medians. To address this potential conflict, WSDOT chose to adopt an in-service evaluation process that would study collision, environmental, operational, and maintenance experiences in the field.

A report was prepared in 2007 that summarized an analysis of two of the 13 median treatment projects. That report also provided *before* data and condition information on all median sections. This report summarizes the analysis of five additional sections. Because of changes in the methodology, previously reported accident rates were recalculated to be consistent with the *after* data from this analysis. Data from the *before* and *after* periods were also analyzed at two control locations where no median treatments were installed.

Total, fatal, fixed object, pedestrian/bicycle, tree, curb/median and U-turn accident rates were analyzed. The percentages of intersection-related, driveway-related, and other accidents were analyzed. Overall, accidents decreased significantly for the treatment locations, but no other types of accidents showed significant changes at either the treatment or the control locations, except for the percentage of other types of accidents at the control locations, which increased significantly.

It appears that the installation of landscaped medians does not have a detrimental effect on safety and may result in an overall decrease in accidents, conclusions consistent with those of the first phase.

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EXECUTIVE SUMMARY

Because of undesirable characteristics of some major arterials such as State Route (SR) 99 north and south of Seattle, several cities are implementing redevelopment plans. These redevelopment proposals include landscaped medians, many with trees placed close to the roadway. However, WSDOT's clear zone width criterion may not always be met when trees are placed within curbed medians. To address this potential conflict, WSDOT chose to adopt an in-service evaluation process that would let the cities install the medians while it studied collision, environmental, operational, and maintenance experiences in the field.

A report was prepared in 2007 that summarized an analysis of two of the 13 median treatment projects. That report also provided before data and condition information on all median sections. This report summarizes the analysis of five additional sections. Because of changes in the methodology, previously reported accident rates were recalculated to be consistent with the after data from this analysis. Data from these before and after periods were also analyzed at two control locations where no median treatments were installed. Center two-way, left-turn lanes remained in operation on these control sections.

Overall, fatal, fixed object, pedestrian/bicycle, tree, curb/median and U-turn accident rates were analyzed. The percentages of intersection-related, driveway-related, and other accidents were analyzed. Overall accidents decreased significantly for the combined treatment locations, but no other types of accidents showed significant changes at either the treatment or the control locations, except for the percentage of other types of accidents at the control locations, which increased significantly. An analysis of overall accident rates by segment indicated significant decreases at three of the five treatment locations, whereas the changes at the other treatment locations and the control locations were not significant.

Given the data, it appears that the installation of landscaped medians can be expected to reduce overall accidents without increasing specific types of accidents, such as curb/median or tree accidents, that might be expected to increase as a result of placing fixed objects in proximity to the roadway. Unfortunately, the installation of these medians did not show any beneficial effect on the rates of pedestrian or bicycle accidents, which might have been expected to decrease with the addition of a refuge area in the middle of the roadway.

These conclusions are consistent with those of the first phase. The Phase 1 study noted a shift in accident location, with fewer mid-block accidents occurring while the number of intersection accidents increased. Similar accident location shifts occurred in this study, but they were not statistically significant. The Phase 1 study found an increase in U-turn accidents in the after period. U-turn accident rates also increased in this study, but the increase was not statistically significant.

Interviews were conducted with three local agencies: Federal Way, Mukilteo, and Shoreline. City staff had positive comments about the landscaped medians. Their communities and elected officials were pleased with the improved aesthetics and local "Main Street" feel. In general, agencies reported that they had learned that aesthetics can be improved without affecting transportation service. This has been a paradigm shift for many road designers, and the cities plan to, or would like to, install more of these median treatments.

I. INTRODUCTION

In the 1990s, a number of cities in the Puget Sound region expressed interest in changing the roadway characteristics of major arterials operating under their control. The desired changes included the addition of street trees and other landscape and streetscape improvements. These improvements were intended to improve the aesthetics of the city, calm traffic, and encourage safe pedestrian movements. The desired effect of all of this was an increase in economic growth along these corridors.

Some of the proposed improvements, such as placing small trees within the roadway right-of-way, are not common engineering practice within the state. As a result, the cities that wanted to make these improvements entered into an agreement with WSDOT to study the effects of these changes to ensure that the benefits expected did, in fact, occur and that no significant detrimental effects were experienced.

An initial study of the effects of placing trees in medians was conducted by comparing three years of *before* and *after* data for several roadway sections on SR 99 in the city of SeaTac. These results were published in February 2007 in the WSDOT research report "In-Service Evaluation of Major Urban Arterials with Landscaped Medians–Conditions as of 2004," WA-RD 636.1 (St. Martin, et al, 2007). This second phase of the study continues the evaluation of major urban arterials with landscaped medians. A third, and final, phase of this evaluation will be conducted in 2010.

BACKGROUND

Transportation agencies are attempting to implement designs that are sensitive to local landforms, culture, and desires. "Context Sensitive Designs/Context Sensitive Solutions" (CSD/CSS) may entail implementing local design solutions that are not typical of the regional design standards and practices typically adopted by federal or state transportation agencies.

Current design standards have been adopted in an attempt to enhance the safety of roadway users. Interest has grown in installing landscaping along urban facilities with a speed limit of 35 to 45 mph as a way to enhance safety and improve aesthetic characteristics. However, strict application of design standards may preclude the use of these desired landscaped treatments. Prominent among these standards is one that specifies a "clear zone." The clear zone defines the width of the roadside that should be clear of fixed objects. The cities' redevelopment proposals for SR 99 and other state routes include landscaped medians, many with trees placed close to the roadway. Thus, WSDOT's clear zone width criterion may not always be met when trees are placed within curbed medians. The justification for deviating from some standards (such as the clear zone) in order to enhance aesthetics is the prediction that the locations for which the deviations are proposed will not experience the same consequences as those in which clear zone testing has been conducted.

To evaluate the effects of deviating from these design standards, WSDOT proposed an in-service evaluation process that would assess real world experience that could not be fully replicated in a traditional test environment. WSDOT initiated the In-Service Evaluation of Landscaped Medians Agreement with cities along SR 99 and other roadways, in part, to study the overall effects of various "context sensitive" designs. The process allows these types of projects to be constructed, with the explicit agreement that the cities will cooperate with data collection efforts as well as mitigation strategies if they are deemed necessary.

This project continued the previous evaluation of landscaped median treatments by evaluating accident occurrences on five roadway sections on SR 99 and SR 525. It compared accident rates and types on these treatment sections with those on two control sections where no medians were installed. (A center, two-way, left turn lane runs the length of both control sections.) Various accident types that have the potential to be

affected by the median treatment were examined. Some *before* period accident data for roadway sections that were published in the previous report were recalculated by using a revised methodology and data.

A third and final phase of this study will evaluate the remaining roadway sections that were identified when this study started and, which, because of their construction schedules, were not ready for evaluation at this time.

PROJECT DESCRIPTION

Arterials such as SR 99 north and south of Seattle and SR 525 in Mukilteo have characteristics that are considered by many cities to be undesirable. High traffic volumes, high speeds, and increasingly intense levels of land use along these routes have led numerous cities to create comprehensive plans that include redevelopment of the highway facilities. SR 99 has a significant regional function as an alternative, parallel route to Interstate 5, while simultaneously providing access to local businesses, services, and residents. SR 525 is a regionally important route because of the access that it provides to the Washington State Ferry dock in Mukilteo.

The project sections along SR 99 that were included in the evaluation process were within the cities of Des Moines, Federal Way, SeaTac, and Shoreline. Also included was a section on SR 525 through Mukilteo. State routes 99 and 525 are classified as urban arterials. Each route has high traffic volumes, high speeds, and experiences accident rates involving vehicles and pedestrians that are above the statewide average for facilities of this classification. The high accident rate has been a significant motivation for the landscaped treatment projects. Although these corridors do not have pedestrian-friendly facilities or amenities, there is a significant level of pedestrian traffic along many sections. Much of the pedestrian traffic is associated with bus routes through the corridors. Many pedestrians cross SR 99 at unmarked mid-block locations, as opposed to walking to the nearest signalized intersection. There is also a significant percentage of

truck traffic. Another reason for the landscaped treatments has been the unattractive streetscape.

The typical cross-section of SR 99 consists of five lanes, with a center, two-way left turn lane (TWLTL). In general, the paved shoulders are wide, with sidewalks at only a few locations. Access to commercial and private properties is minimally controlled. At a few locations there is no TWLTL, or there is a low, asphalt-covered median and C-curb separating traffic. In addition, many intersections have dedicated right and left turn lanes. In general, the aspect is of a wide, uncontrolled asphalt streetscape with cars moving in every direction. There is almost no provision for the comfort, safety, and ease of pedestrians, though many pedestrians travel through and across the SR 99 corridor. The land use is primarily strip commercial development

The typical SR 525 section is a two-lane, undivided highway with no access control and variable width shoulders. The sections of commercial development are more spread out than along SR 99, with some sections having a more rural or residential character.

These streetscapes are incompatible with city and community comprehensive plans, and given the need for safety improvements, cities chose to initiate boulevard-type streetscape redevelopment plans. The resurgence of the boulevard street section is an attempt to smooth traffic flow, reduce vehicle speeds, create an environment that is attractive to pedestrians, and foster a sense of community. A typical element of this type of redevelopment is roadway vegetation, often consisting of street trees.

Changes proposed by the cities included improvements in three general areas: roadway, roadside, and pedestrian facilities. Proposed improvements to the roadway included converting two-way left turn lanes into landscaped medians with left turn/ U-turn pockets, widening the roadway, adding business access and transit (BAT) lanes through some project sections, installing street lighting, and making signal

improvements. Improvements to the roadside environment included consolidating and defining driveways/access points, putting utilities underground, and upgrading storm water collection and detention. To enhance the pedestrian zone, cities proposed the installation of sidewalks and pedestrian features such as lighting, improved crossing points, new or improved transit stops, and aesthetic treatments such as landscaping and street trees.

ACCIDENT DATA

For the treatment locations, accident data were collected for the three years before project construction and as close to three years after construction as possible. The *after* time periods varied from three years, eleven months to two years, eight months. For the control locations, the *before* period was three years and the *after* period was four years. Because no medians were installed at the control locations, there is really no *before* or *after* period; however, these terms are used to refer to the control section time periods that are comparable to those for the treatment locations.

TRAFFIC CHARACTERISTICS

Traffic volume data were obtained from the Annual Traffic Reports (WSDOT 2001 through 2007). Gathering sufficient data to show variations in traffic flow along the highway sections within the analysis timeframe was important for the statistical modeling process. When sufficient data were not available for all years of the analysis, growth rates were computed to extrapolate the available data. Use of as many average daily traffic (ADT) values as possible increased the quality of these estimated data.

Speed studies were conducted on the study section in 2008 and an attempt was made to compare the results with the results of the speed studies conducted during the previous phase. These are discussed in section IV.

CHANGES TO THE PHASE 1 METHODOLOGY

The data and methodology used in this phase differed significantly from those used in Phase 1. First, the analyzed segments were extended to include the closest intersections. While the previous study (St. Martin, et al. 2007, p. 11) noted that "including or excluding an intersection inappropriately will affect the modeling analysis and accident rates significantly," the aim of this study was to determine whether there were significant changes in intersection- or driveway-related accidents that may have been due to the addition or extension of the median.

Second, the accident data analysis focused solely on accident types that might be expected to change as a result of the installation of landscaped medians, rather than roadway geometrics. The data collection and analysis were, therefore, simplified to make it easier to compare the third phase analysis with this analysis.

Accident rates were calculated by using the equations WSDOT uses to report yearly accidents statistics. These equations are shown in Appendix A. The Phase 1 study used the same formulas but excluded the section length if it was less than 1 mile (in effect, making the section length equal to 1). Rates calculated in this study were based on the actual section lengths, so the accident rates for some sections were not comparable with those of the first study. However, using the actual section length to calculate rates was the only way to make comparisons between sections with lengths that varied from less than 1 to almost 3 miles.

II. THE STUDY SITES

The treatment locations are listed in Table 1 along with two control locations where no medians were installed. This table includes general accident and traffic characteristics for the before period of data collection (1999 through 2001), as well as each segment's milepost limits. "Phases" within individual projects refer to separate projects that have typically been constructed end-to-end with other phases within the same city or neighboring cities. Each phase has been constructed independently but includes many of the same general features.

Table 2 lists traffic volumes, accident counts, the *after* period dates, and accident rates for these state highway segments in the *after* periods.

Overall accident rates are presented for each segment. Further discussion of these rates occurs in section III. Because of the low numbers of the specific types of accidents, these accidents were compiled into treatment and control groups and analyzed in a separate section. Intersection, driveway, and other accidents were analyzed in the same manner.

Specific accident types, expected to be affected by the installation of medians, are listed for each section. The numbers are not comparable because the durations of the *before* and *after* periods were not the same. The accident rates, which are comparable, are discussed later in the report.

TREATMENT SECTIONS

Federal Way Phase 1

Phase 1 of the City of Federal Way redevelopment project extended from S. 310th Street to S. 324th Street (MP 9.68 to 10.44), a distance of 0.76 mile. Improvements included the widening of the existing five-lane roadway to a seven-lane section, including

Table 1. Traffic and Accident Characteristics Prior to Project Construction

Location	SR/Milepost	Median in *before* period	ADT	Accidents[1]	Overall Accident Rate per MVM[2]
Federal Way – Phase 1	SR 99/9.68 – 10.44	TWLTL	27,400	382	16.75
Federal Way – Phase 2	SR 99/8.65 – 9.68	TWLTL	27,800	303	9.66
Federal Way – Phase 4 (control)	SR 99/10.57 – 11.24	TWLTL	26,150	68	3.49
Des Moines	SR 99/15.49 – 16.51	TWLTL	28,800	253	7.87
SeaTac – Phase 3	SR 99/19.47 – 20.68	TWLTL	32,100	360	8.46
Shoreline – Phase 2 (control)	SR 99/41.59 – 43.56	TWLTL	33,887	517	7.07
Mukilteo	SR 525/3.04 – 5.99	No median	24,300	438	5.58

[1] 1999 - 2001
[2] Per million vehicle miles

Table 2. Traffic and Accident Characteristics following Project Construction

Location	ADT	Accidents	*After* Period	Overall Accident Rate per MVM
Federal Way – Phase 1	27,000	409	2/01/04 – 12/31/07	13.99
Federal Way – Phase 2	28,750	191	2/01/05 – 12/31/07	6.08
Federal Way – Phase 4 (control)	27,250	131	1/01/04 – 12/31/07	4.84
Des Moines	27,000	236	2/01/05 – 12.31/07	8.05
SeaTac – Phase 3	25,750	171	8/01/04 – 12/31/07	4.41
Shoreline – Phase 2 (control)	34,938	588	1/01/04 – 12/31/07	5.85
Mukilteo	31,700	325	4/01/05 – 12/31/07	3.46

two general-purpose lanes and one business access and transit (BAT) lane in each direction (beginning south of the intersection with S. 312th Street), and installation of a landscaped median with provisions for left turn and U-turn movements at intersections and designated mid-block locations. The median included trees planted within some sections. The landscaping plans precluded planting trees within narrow medians near intersections or along mid-block left turn lanes.

Other elements included curbs, gutters, and sidewalks along both sides of the roadway. A 6-ft. planter strip separated the 8-ft. sidewalk from the roadway in most locations, providing room for street trees and other landscaping. All overhead utility distribution lines were buried with the exception of high-voltage electricity transmission lines, which were relocated to new poles.

This construction was completed in January 2004.

Accident Types

Between 1999 and 2001, before Phase 1 of the SR 99 project was constructed in Federal Way, 382 accidents occurred within the 0.76-mile section. The following is a list of the numbers of accidents of types that might have been affected by median installation during that period:

- Fatal accidents = 0
- Pedestrian/Bicycle = 12
- Fixed objects (includes ditch, curb, medians) = 8
- Curb and median only = 3
- Trees = 0
- Opposite direction, one left turn, one right turn (U-turn) = 4

Between February 2004 and the end of 2007, after trees were planted, 409 accidents occurred within the same 0.76-mile section. The following numbers of accidents occurred within the same accident types:

- Fatal accidents = 1
- Pedestrian/Bicycle = 16
- Fixed objects (includes ditch, curb, medians) = 9
- Curb and median only = 1
- Trees = 3
- Opposite direction, one left turn, one right turn (U-turn) = 5

Accident Rates

Prior to project construction, the traffic volumes along Federal Way's Phase 1 section varied between approximately 22,000 and 32,000 vehicles per day (vpd), with an average volume of 27,400 vpd. Average daily traffic in the *after* period was similar—about 27,000 vpd.

For Federal Way Phase 1 before redevelopment, the overall accident rate was 16.75 accidents per million vehicle-miles (mvm). After redevelopment, the rate decreased to 13.99 accidents per mvm.

Accident Locations

Table 3 shows the numbers and percentages of intersection-related and driveway-related accidents in the *before* and *after* periods. (Note that the *before* and *after* periods were not the same length, so the accident numbers are not comparable.)

Table 3: Federal Way – Phase 1

	Intersection-Related	Driveway-Related	Other
Before	242 (63.4%)	70 (18.3%)	70 (18.3%)
After	290 (70.9%)	66 (16.1%)	53 (13.0%)

Federal Way Phase 2

Phase 2 of the City of Federal Way redevelopment project extended from 16th Avenue S. to S. 324th Street (MP 8.65 to 9.68), a distance of 1.03 miles. The improvements made in Phase 1 were extended to the south.

Construction was completed in January 2005.

Accident Types

NOTE: Because the Federal Way Phase 1 and Phase 2 segments are adjacent to each other, the accidents for the dividing intersection (S. 324th Street) are included in the analyses of both sections.

Between 1999 and 2001, before Phase 2 of the SR 99 project was constructed in Federal Way, 303 accidents occurred within the 1.03-mile section. The following numbers of accidents occurred among relevant accident types:

- Fatal accidents = 1
- Pedestrian/Bicycle = 10

- Fixed objects (includes ditch, curb, medians) = 6
- Curb and median only = 1
- Trees = 0
- Opposite direction, one left turn, one right turn (U-turn) = 2

Between February 2005 and the end of 2007, after trees were planted, 191 accidents occurred within the same 1.03-mile section. The following numbers of accidents occurred:

- Fatal accidents = 0
- Pedestrian/Bicycle = 2
- Fixed objects (includes ditch, curb, medians) = 4
- Curb and median only = 1
- Trees = 0
- Opposite direction, one left turn, one right turn (U-turn) = 4

Accident Rates

Prior to project construction, the traffic volumes along Federal Way's Phase 2 section varied between approximately 22,000 and 32,000 vpd, with an average volume of 27,800 vpd. Average daily traffic in the *after* period was similar—about 28,750 vpd.

For Federal Way Phase 2 before redevelopment, the overall accident rate was 9.66 accidents per mvm. After redevelopment, the rate decreased to 6.08 accidents per mvm.

Accident Locations

Table 4 shows the numbers and percentages of intersection-related and driveway-related accidents in the *before* and *after* periods.

Table 4: Federal Way – Phase 2

	Intersection-Related	Driveway-Related	Other
Before	140 (46.2%)	69 (22.8%)	94 (31.0%)
After	140 (73.3%)	18 (9.4%)	33 (17.3%)

Des Moines

The Des Moines Pacific Highway (SR 99) redevelopment project extended from the Kent- Des Moines Road to S. 216th Street (MP 15.49 to 16.51), a distance of 1.02 miles. The improvements involved widening the existing five-lane road to a seven-lane section that included two general-purpose lanes in each direction, one business access transit (BAT) lane in each direction, and a landscaped median with mid-block left turn pockets and left turn lanes at the intersections. The median treatment used in this section was an 18-inch, low profile barrier. The project also installed two new traffic signals at S. 220th Street and S. 224th Street, curbs, gutters and sidewalks, pedestrian and street lighting, and a new storm drainage system.

The construction was completed in January 2005.

Accident Types

Between 1999 and 2001, 253 accidents occurred within the 1.02-mile section. The following numbers of accidents occurred among relevant accident types:

- Fatal accidents = 1
- Pedestrian/Bicycle = 12
- Fixed objects (includes ditch, curb, medians) = 14
- Curb and median only = 2
- Trees = 1
- Opposite direction, one left turn, one right turn (U-turn) = 2

Between February 2005 and 2007, after trees were planted, 236 accidents occurred within the same 1.02-mile section. The following numbers of accidents occurred:

- Fatal accidents = 1
- Pedestrian/Bicycle = 3
- Fixed objects (includes ditch, curb, medians) = 9
- Curb and median only = 0

- Trees = 0
- Opposite direction, one left turn, one right turn (U-turn) = 2

Accident Rates

Prior to project construction, the traffic volumes along the Des Moines section varied between approximately 25,000 and 32,000 vpd, with an average volume of 28,800 vpd. In the *after* period, traffic volumes varied between 26,000 and 29,000 vehicles per day, with an average of 27,000 vpd.

For the Des Moines segment, the overall accident rate was 7.87 accidents per mvm in the period prior to construction. During the *after* period, the rate increased to 8.05 accidents per mvm.

Accident Locations

Table 5 shows the numbers and percentages of intersection-related and driveway-related accidents in the *before* and *after* periods.

Table 5: Des Moines

	Intersection-Related	Driveway-Related	Other
Before	168 (66.4%)	41 (16.2%)	44 17.4%)
After	150 (63.6%)	39 (16.5%)	47 (19.9%)

SeaTac Phase 3

This section of SR 99, called International Boulevard, extends from S. 170th Street, past the SR 518 ramp to almost the Tukwila city limits (MP 19.47 to 20.68), a distance of 1.21 miles. The redevelopment project included replacing the two-way, left turn lane in the five-lane section with a landscaped median. The project also installed curbs and gutters, consolidated and defined access points, buried utilities underground, and added sidewalks. Because of the large number of tree strikes that occurred after redevelopment on the Phase 1 and Phase 2 segments, the city decided to modify its

landscaping plans. As a result, trees were not planted in medians next to left-turn pockets or within the influence area of intersections.

Construction was completed in July 2004.

Accident Types

Between 1999 and 2001, before Phase 3 of the International Boulevard project was constructed, 360 accidents occurred within the 1.21-mile section. The following numbers of accidents occurred among relevant accident types:

- Fatal accidents = 0
- Pedestrian/Bicycle = 6
- Fixed objects (includes ditch, curb, medians) = 7
- Curb and median only = 0
- Trees = 1
- Opposite direction, one left turn, one right turn (U-turn) = 2

Between 2004 and 2007, after trees were planted, 171 accidents occurred within the 1.21-mile section. The following numbers of accidents occurred:

- Fatal accidents = 0
- Pedestrian/Bicycle = 2
- Fixed objects (includes ditch, curb, medians) = 7
- Curb and median only = 1
- Trees = 3
- Opposite direction, one left turn, one right turn (U-turn) = 2

Accident Rates

Prior to project construction, the traffic volumes along SeaTac's Phase 3 section varied between approximately 31,000 and 37,000 vpd, with an average volume of 32,100 vpd. The average volume after construction was 25,750 vpd.

For SeaTac Phase 3 before redevelopment, the overall accident rate was 8.46 accidents per mvm. After redevelopment, the overall accident rate decreased to 4.41 accidents per mvm.

Accident Rates

Table 6 shows the numbers and percentages of intersection-related and driveway-related accidents in the *before* and *after* periods.

Table 6: SeaTac – Phase 3

	Intersection-Related	Driveway-Related	Other
Before	264 (73.3%)	37 (10.3%)	59 (16.4%)
After	135 (78.9%)	13 (7.6%)	23 (13.5%)

Mukilteo

The section of SR 525 included in this study extends west from I-5, past SR 99 to the City of Mukilteo. It continues through town to the terminal for the Washington State Ferry to Whidbey Island. The study section started at Lincoln Way and ended at 92nd Street SW (MP 3.04 to 5.99), a distance of 2.95 miles.

The redevelopment work involved widening the roadway from two to four lanes and adding a landscaped median with low growing vegetation and trees. A low profile barrier (18 inches high) was placed in the locations where trees were planted. Medians without trees were delineated with a standard 6-inch curb. Provisions for U-turns were made at intersections and a few mid-block left turn pockets. Also installed were sidewalks, bike lanes, and improved lighting and drainage. Roadside trees were also planted in a landscaping strip between the roadway and the sidewalk.

Accident Types

At nearly 3 miles long, the Mukilteo segment was the longest of this analysis. Between 1999 and 2001, 438 accidents occurred within the 2.95-mile section. The following numbers of accidents occurred among relevant accident types:

- Fatal accidents = 1
- Pedestrian/Bicycle = 3
- Fixed objects (includes ditch, curb, medians) = 19
- Curb and median only = 3
- Trees = 0
- Opposite direction, one left turn, one right turn (U-turn) = 0

Between April 2005 and 2007, after trees were planted, 325 accidents occurred within the same 2.95-mile section. The following numbers of accidents occurred:

- Fatal accidents = 1
- Pedestrian/Bicycle = 9
- Fixed objects (includes ditch, curb, medians) = 17
- Curb and median only = 8
- Trees = 0
- Opposite direction, one left turn, one right turn (U-turn) = 2

Accident Rates

Prior to project construction, the traffic volumes along the Mukilteo section varied between approximately 19,000 and 34,000 vpd, with an average volume of 24,300 vpd. In the *after* period, traffic volumes varied between 19,000 and 43,000 vehicles per day, with an average of 31,700 vpd.

For the Mukilteo segment, the overall accident rate was 5.58 accidents per mvm in the period prior to construction. During the *after* period, the rate decreased to 3.46 accidents per mvm.

Accident Locations

Table 7 shows the numbers and percentages of intersection-related and driveway-related accidents in the *before* and *after* periods.

Table 7: Mukilteo

	Intersection-Related	Driveway-Related	Other
Before	216 (49.3%)	62 (14.2%)	160 36.5%)
After	214 (65.8%)	43 (13.2%)	68 (20.9%)

CONTROL SECTIONS

Federal Way Phase 4

Federal Way Phase 4 extends from S. 310th Street to 18th Avenue S. (MP 10.57 to 11.24), a distance of 0.67 mile. It is one of two control segments where no median was constructed. The roadway consists of a total of five lanes with the center lane operating as a two-way, left turn lane. The control segments were analyzed for comparison with segments where enhancements were implemented.

Accident Types

Between 1999 and 2001, 68 accidents occurred within the 0.68-mile section. The following numbers of accidents occurred among relevant accident types:

- Fatal accidents = 0
- Pedestrian/Bicycle = 3
- Fixed objects (includes ditch, curb, medians) = 3
- Curb and median only = 0
- Trees = 0
- Opposite direction, one left turn, one right turn (U-turn) = 0

Between 2004 and 2007, after trees were planted elsewhere, 131 accidents occurred within the same 0.68-mile section. The following numbers of accidents occurred:

- Fatal accidents = 1
- Pedestrian/Bicycle = 12

- Fixed objects (includes ditch, curb, medians) = 4
- Curb and median only = 1
- Trees = 0
- Opposite direction, one left turn, one right turn (U-turn) = 0

Accident Rates

During the three-year *before* period, the traffic volumes along Federal Way's Phase 4 section varied between approximately 25,000 and 28,000 vpd, with an average volume of 26,150 vpd. In the *after* period, traffic volumes varied from 25,000 to 30,000 vehicles per day, with an average of 27,250 vpd.

For Federal Way Phase 4, the overall accident rate was 3.49 accidents per mvm for the *before* period. During the *after* period, the rate increased to 4.84 accidents per mvm.

Accident Locations

Table 8 shows the numbers and percentages of intersection-related and driveway-related accidents in the *before* and *after* periods. These accidents were compiled into treatment and control groups and are discussed in a separate section.

Table 8: Federal Way – Phase 4

	Intersection-Related	Driveway-Related	Other
Before	48 (70.6%)	4 (5.9%)	16 (23.5%)
After	74 (56.5%)	18 (13.7%)	39 (29.8%)

Shoreline Phase 2

The City of Shoreline's Aurora Corridor Project will redevelop a total of 3 miles of Aurora Avenue North (SR 99) that run through the City. Shoreline Phase 2 extends from N. 165th Street to N. 205th Street (MP 41.48 to 43.56), a distance of 2.08 miles. Because of a miscommunication that was not discovered until the data analysis had been completed, the limits used in this analysis started at N. 167th Street (MP 41.59) and extended to the same end point. The distance of this study section was 1.97 miles. This

section is one of two control segments where no median was constructed. The roadway consists of a total of five lanes, with the center lane operating as a two-way, left turn lane. The control segments were analyzed for comparison with segments where enhancements were implemented.

Accident Types

Between 1999 and 2001, 517 accidents occurred within the 1.97-mile section. The following numbers of accidents occurred among relevant accident types:

- Fatal accidents = 1
- Pedestrian/Bicycle = 16
- Fixed objects (includes ditch, curb, medians) = 13
- Curb and median only = 5
- Trees = 1
- Opposite direction, one left turn, one right turn (U-turn) = 1

Between 2004 and 2007 (the *after* period), 588 accidents occurred within the same 1.91-mile section. The following numbers of accidents occurred:

- Fatal accidents = 2
- Pedestrian/Bicycle = 23
- Fixed objects (includes ditch, curb, medians) = 25
- Curb and median only = 5
- Trees = 3
- Opposite direction, one left turn, one right turn (U-turn) = 1

Accident Rates

During the three-year *before* period, the traffic volumes along the Shoreline section varied between approximately 28,000 and 37,000 vpd, with an average volume of almost 33,900 vpd. In the *after* period, traffic volumes varied between 32,000 and 39,000 vehicles per day, with an average of almost 35,000 vpd.

For Shoreline, the overall accident rate was 7.07 accidents per mvm for the *before* period. During the *after* period, the rate decreased to 5.85 accidents per mvm.

Accident Locations

Table 9 shows the numbers and percentages of intersection-related and driveway-related accidents in the *before* and *after* periods.

Table 9: Shoreline – Phase 2

	Intersection-Related	Driveway-Related	Other
Before	277 (53.6 %)	70 (13.5%)	170 (32.9%)
After	325 (55.3%)	70 (11.9%)	193 (32.8%)

III. DATA ANALYSIS

ACCIDENT RATES

Accident rates were calculated by using the standard WSDOT methodology described in Appendix A. (Except in this case the actual section length was used.) The following rates were calculated for both treatment and control locations:

1) Overall accidents (per million vehicle-miles)
2) Fatal accidents (per 100 million vehicle-miles)
3) Revised fixed object accidents – including ditch, curb and median accidents (per 10 million vehicle-miles)
4) Tree accidents (per 10 million vehicle-miles)
5) Pedestrian and bicycle accidents (per 10 million vehicle-miles)
6) Curb and median accidents (per 10 million vehicle-miles)
7) U-turn accidents – Opposite direction, one left turn, one right turn accidents (per 10 million vehicle-miles).

These accident rates were tested to determine whether the differences were significant by using both a non-parametric test and a parametric test: the Wilcoxon Signed Rank Test and the Paired T-Test, respectively. Both of these tests are used to determine significant differences in measurements of the same type conducted at two different times—before and after improvements have been made, for example. Where the two tests differed in the determination of significance, greater weight was given to the results of the Paired T-Test. The treatment locations (those with landscaped medians installed) and control locations (those without landscaped medians) were analyzed separately, and then the results were compared. The results are discussed by accident type below.

Overall Accident Rates

Both tests showed no significant difference in the overall accident rate for the combined control locations between the *before* and *after* periods (Table 10). The Wilcoxon Signed Rank test did not show a significant difference between the *before* and *after* periods for the combined treatment locations. However, the Paired T-test showed a significant difference at the 95 percent confidence level.

Table 10: Overall Accident Rates – per million vehicle-miles

Treatment Location	Before	After		Control Location	Before	After
FW-Ph. 1	16.75	13.99		FW-Ph.4	3.49	4.84
FW-Ph.2	9.66	6.08		Shoreline Ph.2	7.07	5.85
DM	7.87	8.05				
ST-Ph.3	8.46	4.41				
Mukilteo	5.58	3.46				
MEAN	9.66	7.20			5.28	5.35
Significance: W/Paired-T		N Sig/Sig				N Sig/N Sig

W= Wilcoxon Signed Rank test/Paired-T= Paired-T test

Overall Accident Rates by Segment

A regression analysis was conducted for each roadway segment by using the yearly overall accident rates to determine whether there were significant changes in accidents at each location. The test determined whether changes in slope for the regression lines between years in the *before* and *after* periods were statistically significant. Table 11 shows the results of this analysis.

The decreases in overall accident rates at three of the treatment segments—Federal Way Phase 2, Des Moines, and Mukilteo—were significant at the 95 percent confidence level. The decreases at the two remaining treatment segments were not

significant. The increase in accident rate at the Federal Way Phase 4 control location and the decrease at the Shoreline Phase 2 control location were also not significant.

Fatal Accident Rates

Both tests showed no significant differences in the fatal accident rates at either the control or the treatment locations between the *before* and *after* periods (see Table 12).

One fatal accident involved a "curb, raised traffic island, or raised median," and it occurred at one of the control locations (Shoreline Phase 2, SR 99 at milepost 43.56) in the *before* period (January 3, 1999). None of the other fatal accidents involved trees, medians, fixed objects, or U-turns.

Table 11: Overall Accident Rate Analysis by Segment

Treatment Location	z_{slope}	p-value	Sig/N Sig	Control Location	z_{slope}	p-value	Sig/N Sig
FW-Ph.1	0.916	0.360	N Sig	FW-Ph.4	-0.314	0.753	N Sig
FW-Ph.2	-4.123	0.000	Sig	Shoreline-Ph.2	0.748	0.455	N sig
DM	-2.142	0.033	Sig				
ST-Ph.3	-0.296	0.767	N Sig				
Mukilteo	7.061	0.000	Sig				

Table 12: Fatal Accident Rates – per 100 million vehicle-miles

Treatment Location	Before	After		Control Location	Before	After
FW-Ph. 1	0.00	3.34		FW-Ph.4	0.00	3.70
FW-Ph.2	3.19	0.00		Shoreline-Ph.2	1.37	1.99
DM	3.11	3.32				
ST-Ph.3	0.00	0.00				
Mukilteo	1.27	1.32				
MEAN	1.51	1.60			0.69	2.85
Significance: W/Paired-T		N Sig/N Sig				N Sig/N Sig

Revised Fixed Object Rates, Including Ditch, Curb, and Median Accidents

Both tests showed no significant difference in the revised fixed object accident rates at the control locations between the *before* and *after* periods (see Table 13). The Wilcoxon Signed Rank test showed a significant difference in the revised fixed object accident rates between the *before* and *after* periods at the treatment locations at the 95 percent confidence level. The Paired-T test, however, showed that the difference was not significant.

Table 13: Revised Fixed Object Rates, Including Ditch, Curb, and Median Accidents – per 10 million vehicle-miles

Treatment Location	Before	After		Control Location	Before	After
FW-Ph. 1	3.51	3.00		FW-Ph.4	1.38	1.32
FW-Ph.2	2.59	1.67		Shoreline-Ph.2	4.61	6.45
DM	5.84	4.01				
ST-Ph.3	2.62	2.45				
Mukilteo	9.40	6.44				
MEAN	4.79	3.51			3.00	3.89
Significance: W/Paired-T		Sig/N Sig				N Sig/N Sig

Tree Accident Rates

Both tests showed no significant differences in the tree accident rates between the *before* and *after* periods at either the treatment or control locations (see Table 14).

Pedestrian and Bicycle Accident Rates

Both tests showed no significant differences in the pedestrian and bicycle accident rates between the *before* and *after* periods at either the control or the treatment locations (see Table 15). Pedestrian accidents alone were analyzed in a similar manner, and the

results were the same. (Note that these rates were not calculated by using pedestrian or bicycle volumes. If pedestrian or bicycle traffic through these sections had increased substantially, the result would have been an improvement in safety. There were no indications, however, that this increase occurred.)

Table 14: Tree Accident Rates – per 10 million vehicle-miles

Treatment Location	Before	After		Control Location	Before	After
FW-Ph. 1	0.00	1.00		FW-Ph.4	0.00	0.00
FW-Ph.2	0.00	0.00		Shoreline-Ph.2	0.35	0.77
DM	0.42	0.00				
ST-Ph.3	0.37	1.05				
Mukilteo	0.00	0.00				
MEAN	0.16	0.41			0.18	0.39
Significance: W/Paired-T		N Sig/N Sig				N Sig/N Sig

Table 15: Pedestrian and Bicycle Accident Rates – per 10 million vehicle-miles

Treatment Location	Before	After		Control Location	Before	After
FW-Ph. 1	5.26	5.48		FW-Ph.4	1.38	3.97
FW-Ph.2	4.32	0.84		Shoreline-Ph.2	5.67	5.93
DM	5.01	1.43				
ST-Ph.3	2.25	0.70				
Mukilteo	1.48	3.81				
MEAN	3.66	2.45			3.53	4.95
Significance: W/Paired-T		N Sig/N Sig				N Sig/N Sig

Curb and Median Accident Rates

Both tests showed no significant differences in the curb and median accident rates between the *before* and *after* periods at either the control or the treatment locations (see Table 16).

U-Turn Accidents – Opposite Direction, One Left Turn, One Right Turn

Both tests showed no significant differences in the U-turn accident rates between the *before* and *after* periods at either the control or the treatment locations (see Table 17).

ACCIDENT LOCATION ANALYSIS

The same statistical tests were conducted to determine whether there were significant differences among the proportions of intersection, driveway, and other accidents between the control and treatment locations. The results are shown below.

Intersection-Related Accidents

Both tests showed no significant differences in the percentage of intersection related accidents between the *before* and *after* periods at either the control or the treatment locations (see Table 18).

Table 16: Curb and Median Accident Rates – per 10 million vehicle-miles

Treatment Location	Before	After		Control Location	Before	After
FW-Ph. 1	1.32	0.33		FW-Ph.4	0.00	0.33
FW-Ph.2	0.43	0.42		Shoreline-Ph.2	1.77	1.29
DM	0.83	0.00				
ST-Ph.3	0.00	0.35				
Mukilteo	1.48	3.03				
MEAN	0.81	0.83			0.89	0.81
Significance: W/Paired-T		N Sig/N Sig				N Sig/N Sig

Table 17: U-Turn Accidents – Opposite Direction, One Left Turn, One Right Turn – per 10 million vehicle-miles

Treatment Location	Before	After		Control Location	Before	After
FW-Ph. 1	1.75	1.70		FW-Ph.4	0.00	0.00
FW-Ph.2	0.86	1.67		Shoreline-Ph.2	0.35	0.26
DM	0.83	0.98				
ST-Ph.3	0.75	1.20				
Mukilteo	0.00	0.89				
MEAN	0.84	1.29			0.18	0.13
Significance: W/Paired-T		N Sig/N Sig				N Sig/N Sig

Table 18: Intersection-Related Accidents– Percentage of Total Accidents

Treatment Location	Before	After		Control Location	Before	After
FW-Ph. 1	63.3	70.9		FW-Ph.4	70.6	56.5
FW-Ph.2	46.2	73.3		Shoreline-Ph.2	53.6	55.3
DM	66.4	63.6				
ST-Ph.3	73.3	78.9				
Mukilteo	49.3	65.8				
MEAN	59.72	70.50			64.90	55.90
Significance: W/Paired-T		N Sig/N Sig				N Sig/N Sig

Driveway-Related Accidents

Both tests showed no significant differences in the percentage of driveway-related accidents between the *before* and *after* periods at either the control or the treatment locations (see Table 19).

Table 19: Driveway-Related Accidents – Percentage of Total Accidents

Treatment Location	Before	After		Control Location	Before	After
FW-Ph. 1	18.3	16.1		FW-Ph.4	5.9	13.7
FW-Ph.2	22.8	9.4		Shoreline-Ph.2	13.5	11.9
DM	16.2	16.5				
ST-Ph.3	10.3	7.6				
Mukilteo	14.2	13.2				
MEAN	16.36	12.56			10.45	12.80
Significance: W/Paired-T		N Sig/N Sig				N Sig/N Sig

Other Accidents

The Wilcoxon Signed Rank test showed no significant difference in the percentage of other types of accidents between the *before* and *after* periods at the control locations (see Table 20). The Paired-T test showed a significant difference at the 95 percent confidence level. Both tests showed no significant difference in the percentage of other types of accidents between the *before* and *after* periods at the treatment locations.

Table 20: Other Accidents– Percentage of Total Accidents

Treatment Location	Before	After		Control Location	Before	After
FW-Ph. 1	18.3	13.0		FW-Ph.4	23.5	29.8
FW-Ph.2	31.0	17.3		Shoreline-Ph.2	32.9	32.8
DM	17.4	19.9				
ST-Ph.3	16.4	13.5				
Mukilteo	36.5	20.9				
MEAN	23.92	16.92			24.70	31.30
Significance: W/Paired-T		N sig/N Sig				N Sig/Sig

IV. SPEED STUDIES

Speed studies were conducted during the Phase 1 study at various locations on SR 99 and SR 525. The data from those speed studies are shown in Table 21. Speed studies were also conducted as part of this project, and the data from those studies are shown in Table 22. Unfortunately, the results from the two sets of studies are not comparable because the previous speed studies did not provide a mean speed or an 85th percentile speed value. The results of the Phase 1 speed studies indicated that the speed limits were consistent with the 85th percentile speeds on those roadway sections. There did not appear to be any obvious differences in the 85th percentile speeds measured during the periods before and after construction.

The more recent speed studies were all conducted in 2008, after installation of the landscaped median treatments. All of the speed limits seem consistent with the measured 85th percentile speeds.

In summary, while it is not possible to determine significant differences in *before* and *after* speeds by using statistical analyses, it also does not appear that the median treatments resulted in major changes in speeds on either SR 99 or SR 525.

Table 21: Speed Studies from Phase 1 Report

SR	MP	Location	Year	Period	Speed Limit	85th Percentile
99	9.69 - 10.59	Federal Way	2005	After	40	39-43
99	14.24 - 15.49	Kent	2002 to 2004	Before	45	43-48
99	15.49 - 16.51	Des Moines	2000	Before	45	47-50
99	15.49 - 16.51	Des Moines	2005	After	45	44-47
99	16.52 - 17.52	SeaTac	2000 to 2002	Before	45	46-52
99	19.63 - 19.77	SeaTac	2000	Before	45*	46-48
99	19.63 - 19.77	SeaTac	2005	After	45*	43-47
99	40.47 - 41.48	Shoreline	2001 to 2003	Before	40	40-47
525	3.14 - 6.04	Mukilteo	1999	Before	40	45-47
525	3.14 - 6.04	Mukilteo	2005	After	40	45-48
99	9.69 - 10.59	Federal Way	2005	After	40	39-43
99	14.24 - 15.49	Kent	2002 to 2004	Before	45	43-48
99	15.49 - 16.51	Des Moines	2000	Before	45	47-50
99	15.49 - 16.51	Des Moines	2005	After	45	44-47
99	16.52 - 17.52	SeaTac	2000 to 2002	Before	45	46-52
99	19.63 - 19.77	SeaTac	2000	Before	45*	46-48
99	19.63 - 19.77	SeaTac	2005	After	45*	43-47
99	40.47 - 41.48	Shoreline	2001 to 2003	Before	40	40-47
525	3.14 - 6.04	Mukilteo	1999	Before	40	45-47
525	3.14 - 6.04	Mukilteo	2005	After	40	45-48

* Speed limit between S. 152nd and S. 200th Streets changed from 45mph to 40mph on 2/19/2003

Table 22: Phase 2 Speed Studies – Conducted between June 11, 2008, and June 25, 2008

SR	MP	Location	Direction	Time	Speed Limit	Mean	85th Percentile
99	8.82	Jct S. 336th St./ North leg	SB	1100-1135	40	37.50	40.33
99	8.82	South leg	NB	1030-1115	40	39.67	42.78
99	10.37	Jct S. 312th St./ North leg	SB	0925-1020	40	37.85	40.57
99	10.37	South leg	NB	1205-1245	40	34.55	39.60
99	16.28	Jct S. 220th St./ North leg	SB	1053-1127	45	38.26	42.29
99	16.28	South leg	NB	1135-1206	45	39.59	44.39
99	18.20	Jct S. 188th St./ North leg	SB	1445-1525	40	34.48	37.17
99	18.20	South leg	NB	1405-1440	40	37.19	40.24
525	3.99	Jct 121St. SW/ South leg	NB	1605-1635	40	41.00	43.66
525	3.99	Jct 121St. SW/ South leg	SB	1640-1700	40	38.25	40.63

V. DISCUSSION OF RESULTS

Table 23 summarizes the results of the statistical analysis of the accident data. It appears that the installation of landscaped medians resulted in a statistically significant decrease in overall accident rates at the treatment locations, whereas the control locations experienced no significant change in accident rates. Analysis of overall accident rates by segment indicated significant decreases at three of the five treatment locations, whereas the changes at the other treatment locations and the control locations were not significant.

Table 23: Summary of Results

Accident Rates		
Accident Types	Treatment	Control
Overall	Significant decrease*	Non-significant
Fatal	Non-significant	Non-significant
Revised Fixed Object	Non-significant**	Non-significant
Tree	Non-significant	Non-significant
Pedestrian/Bicycle	Non-significant	Non-significant
Curb/Median	Non-significant	Non-significant
U-Turn	Non-significant	Non-significant

Percentages		
Locations	Treatment	Control
Intersections	Non-significant	Non-significant
Driveways	Non-significant	Non-significant
Other	Non-significant	Significant increase*

*Wilcoxon Signed Rank (Non-parametric) test is Non-significant. Paired T-Test is Significant and is given more weight.

** Wilcoxon Signed Rank (Non-parametric) test is Significant. Paired T-Test is Non-significant.

The only type or location category of accidents that experienced a significant change was the percentage of other accidents at the control locations. These experienced a significant increase, whereas the change at the treatment locations was not significant.

Given the data, it appears that the installation of landscaped medians can be expected to reduce overall accidents without increasing specific types of accidents, such as curb/median or tree accidents, that might be expected to increase as a result of placing fixed objects in proximity to the roadway. Unfortunately, the installation of these medians did not show any beneficial effect on the rates of pedestrian or bicycle accidents, which might have been expected to decrease with the addition of a refuge area in the middle of the roadway.

These conclusions are consistent with the conclusions of the Phase 1 study. That study found, "No dramatic changes in accident frequency or severity were observed. Accident frequency for the combined study area decreased slightly, but accident frequency within the SeaTac Phase 2 road segment actually increased slightly. Neither change was statistically significant." (St. Martin, et al. 2007) The Phase 1 study noted a shift in accident location, with fewer mid-block accidents occurring while the number of intersection accidents increased. Although there were similar shifts in accident locations in this study, they were not statistically significant. The Phase 1 study found an increase in U-turn accidents in the *after* period. U-turn accident rates also increased in this study, but the increase was not statistically significant.

VI. LOCAL AGENCY INPUT

Interviews were conducted with three local agencies: Federal Way, Mukilteo, and Shoreline. Three agencies provided tree maintenance information for Phase 2. This section summarizes the information obtained from those interviews and maintenance records.

LOCAL AGENCY PERSPECTIVE

City staff had positive comments about the landscaped medians. Their communities and elected officials were pleased with the improved aesthetics and local "Main Street" feel. In general, agencies reported that they had learned that aesthetics can be improved without affecting transportation service. This has been a paradigm shift for many road designers, and the cities plan to, or would like to, install more of these median treatments.

TREE TYPES, MAINTENANCE, AND DESIGN ISSUES

The types of trees used by local agencies for landscaped medians varied widely, and therefore, success with the aesthetics and longevity of the plantings varied. A meeting of different agency staff to discuss lessons learned regarding types of plantings, landscape design, and maintenance could prove beneficial.

Federal Way

Federal Way planted the following types of trees: Armstrong maple, flowering pear, skymaster oak, and incense cedar. All trees were planted in November 2004. When the trees were measured during installation, the diameters ranged from 1.9 to 4.9 inches (caliper measurements at 4-ft high). After approximately one year, the diameter of the trees was the same. As of May 2008, the diameter of the trees ranged from 2 to 6 inches.

The width of the median in Federal Way ranged from 16 to 24 feet, although that did not seem to influence the type of tree planted.

There were few tree strikes. Those that did occur usually involved trees on the roadside and not in the median.

Because of the popularity of the medians, maintenance continues to be a high priority for the city. However, there are some issues with scheduling maintenance work. Federal Way uses a private contractor, and it is now scheduling this work during off-peak hours because it typically involves a lane closure.

Median installations like this make it important to adequately size the length of the left turn pockets. There is no extra storage as there is with a two-way, left turn lane adjacent to the left turn pocket.

Mukilteo

No installation report was available for Mukilteo. However, Mukilteo Public Works Director Larry Waters indicated that the maintenance needs for the landscaped medians have varied. Mukilteo used sand instead of topsoil for most of the medians, which has contributed to problems of sand getting in the street and on sidewalks.

Winter snow and ice control activities are tough on the median plants. Plows or snow blowers pile the snow on the plants, and sand and gravel applied to improve traction get thrown onto the median, where they bury the plants.

Mukilteo has also found that many of the plants are too big for the medians and require a fair amount of annual maintenance to prevent them from becoming overgrown. Like other local agencies, it found that it has to close a lane to do maintenance. Irrigation has been a major problem for the landscaped medians, and some narrower areas have dried out and will eventually have to be replanted. The city is considering using concave medians, in contrast to the usual mounded median. The median surface would be below

curb level so that water would drain into the median, and natural storm drainage would help with irrigation.

SeaTac

SeaTac planted a combination of sweet gum and pear trees with diameters ranging from 2 to 7 inches. About twelve trees had to be replaced in 2006, although the reasons are unknown. SeaTac staff members were not available for an interview.

Shoreline

In Shoreline, three types of maple trees were planted: parkway maple, Pacific sunset maple, and Karpick maple. The City of Shoreline installed trees between approximately 145th Street and 165th Street during the Phase 1 improvement project in November and December of 2006. The trees were clustered in certain areas instead of spacing them equal distances apart on the median.

At installation, the diameters of the trees ranged from 2.5 to 4.5 inches. There was little change in the size of the trees almost two years later. Shoreline planners noted that it was more difficult to support vegetation on the narrower landscaped medians toward the south end of the study area, as the plantings became overly dry. In addition, several trees toward the northern end of the study area became diseased.

Shoreline has started irrigating the planting strips and tries to use drought tolerant plants where possible. It has found that native plantings often do not work well in an urban street environment. Other maintenance issues have included weeds in the soil mix and substandard landscaping work performed by the contractor. The city is working to amend future contracts so that more attention is paid to landscape maintenance post-construction.

Like Mukilteo, Shoreline would like to change to using concave medians below curb level to keep water within the curb and to build more natural storm drainage into future landscaped medians.

In order to avoid conflicts between U-turning and right turning vehicles, Shoreline installed upstream U-turn pockets to separate vehicles making these movements from intersection traffic.

SAFETY

Federal Way and Shoreline found that the number of collisions had decreased despite the higher number of lanes and increased traffic volumes. Prior to installing the medians, Federal Way staff had reviewed research from the Florida and Georgia departments of transportation that concluded that this type of road configuration made the road safer. Its experience has been consistent with those national findings.

Pedestrian safety did not appear to be a problem, according to various agencies. Some felt that there was a net improvement for pedestrians, as the medians gave people a refuge when they crossed the street, precluding them from having to stand in a two-way, left turn lane. In Shoreline, planners installed two new pedestrian bridges where pedestrians frequently across. In addition, they set back the sidewalks about 4 feet from the curb. This creates a more pleasant environment, and there are fewer dips in the sidewalk from driveways. They also installed continuous sidewalks so that people don't have to cross the street multiple times. This encourages people to stay on one side of the road.

One localized issue reported by Federal Way engineers was an increase in collisions between cars making a U-turn and drivers making a right-hand turn at a red light. To help people discern who has the right-of-way, they have installed some signage at the intersection. However, they recommended that this should be clarified in statute by the legislature.

CHALLENGES WITH IMPLEMENTATION

Dealing with concerns from local businesses was often seen as the most significant challenge. Businesses were concerned that the medians would decrease customer access, negatively affect right-of-way, and block views from the street. In addition, surviving the construction is often the hardest part for businesses. Lost business tended to recover after construction was complete, but sometimes more slowly than desired.

Shoreline found that sales tax revenue actually increased in some areas after the medians were installed, except during construction. The businesses that tended to be negatively affected were “impulse” businesses, such as fast-food restaurants and car dealerships. The city believed that it was able to mitigate the access issue by adding strategic U-turn breaks in the medians.

VII. REFERENCES

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APPENDIX A: ACCIDENT RATE CALCULATIONS

The WSDOT computes accident rates on the basis of the "exposure" of a roadway section. The exposure is based on the length of the section, the traffic volume along the section, and the duration of the analysis. Calculating accident rates in this way allows for comparisons between highway sections of different lengths and traffic volumes. The equations WSDOT uses in the *Washington State Highway Accident Report* (1996) for overall and fatal accident rates are presented below:[3]

$$AccidentRate = \frac{(\#ofAccidents) \times (1Million)}{(SectionLength^{*}) \times (AADT^{**}) \times (365Days)}$$ **Equation 1**

$$FatalAccidentRate = \frac{(\#ofFatalAccidents) \times (100Million)}{(SectionLength^{*}) \times (AADT^{**}) \times (365Days)}$$ **Equation 2**

A similar rate was used to calculate fixed object, tree, pedestrian/bicycle, curb/median, and U-turn accident rates for each of the project segments before and after median installation and for the control locations. This rate is represented below:

$$FixedObjectCollision\ Rate = \frac{(\#ofFixedObjectAccidents) \times (10Million)}{(SectionLength^{*}) \times (AADT^{**}) \times (365Days^{1})}$$ **Equation 3**

[3]For these analyses, divide the rates by the number of years in the analysis period.
* St. Martin, et al, 2007 calls for Section Lengths of less than 1.0 mile to be excluded from these formulas. Actual section lengths were used in this analysis so that comparisons could be made for sections shorter than 1.0 mile.
**AADT = Annual Average Daily Traffic