Final Research Report
Agreement T4118, Task 39
Landscape Phase 3

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

by

Mark E. Hallenbeck
TRAC Director

Peter M. Briglia Jr.
Research Engineer Principal

Zachary N. Howard
Graduate Research Assistant

Anna St. Martin
Graduate Research Assistant

Washington State Transportation Center (TRAC)
University of Washington, Box 354802
University District Building
1107 NE 45th Street, Suite 535
Seattle, Washington 98105-4631

Washington State Department of Transportation Technical Monitor
Barbara Briggs
Area Operations Engineer
Traffic Operations Office, Northwest Region

Prepared for
The State of Washington
Department of Transportation
Lynne Peterson, Secretary

June 2013

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
WA-RD 636.3		

4. TITLE AND SUBTITLE	5. REPORT DATE
IN-SERVICE EVALUATION OF MAJOR URBAN ARTERIALS WITH LANDSCAPED MEDIANS— PHASE III	June 2013
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Mark E. Hallenbeck, Peter M. Briglia Jr., Zachary N. Howard, Anna St. Martin	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. WORK UNIT NO.
Washington State Transportation Center (TRAC) University of Washington, Box 354802 University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631	11. CONTRACT OR GRANT NO. Agreement T4118 Task 39
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Research Office Washington State Department of Transportation Transportation Building, MS 47372 Olympia, Washington 98504-7372 Project Manager: Rhonda Brooks, 360-705-7945	Draft Research Report
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT:

Several cities have implemented redevelopment plans that include the re-design of major regional arterials in order to raise the quality of life of those living, working, and shopping along, or near the arterial. Many of these redevelopment efforts include landscaped medians with trees placed close to the roadway including in the median. WSDOT's clear zone width criterion may not always be met when trees are placed within medians. To address this potential conflict, an in-service evaluation process was adopted to study collision, environmental, operational, and maintenance experiences in the field.

This report updates earlier work published in 2007 and 2009. It examines before and after periods for all 13 roadway sections identified by WSDOT for review. Some of these 13 sections contain trees in medians with no protection, others are sections that contain raised medians but no trees, and others are control sections.

The study finds that the presence of small trees in the median did not significantly increase crash rates, crash severity, or injury crash rates. Crash rates decreased at statistically significant levels for both types of median treatment locations. No significant difference was found when comparing median treatments with and without trees. At test sites, crash rates remain stable six years after the treatments were completed, indicating that the safety benefits first observed remain in place over time. It appears that adding small trees to landscaped medians does not have a detrimental effect on safety. Installation of medians and access control as part of a more general increase in access control generally result in a decrease in midblock crashes, but an increase in crashes occurring at intersections where turning movements are allowed in large part because turns are concentrated at those locations. These increases are a fraction of the midblock gains, resulting in improved safety overall.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Trees, highway safety, aesthetic design, Context Sensitive Design, urban design, accident rates, injury severity	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None		

DISCLAIMER

TABLE OF CONTENTS

TABLES

Table *Page*

FIGURES

Figure *Page*

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 added access control to roadways that often had minimal access control before the project. The street improvements generally included the addition of medians, protected turn pockets, and sidewalks in areas that did not have those geometric features. As part of these streetscape improvements, several jurisdictions also included the addition of street trees and other landscape improvements. These changes were intended to improve the aesthetics of the city, calm traffic, and encourage safe pedestrian movements. The desired outcomes included economic growth in neighborhoods along those arterials and, with that growth, more and safer pedestrian travel along and across 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 changes entered into an agreement with the Washington State Department of Transportation (WSDOT) to study their effects to ensure that the benefits expected did, in fact, occur and that the landscaping caused no significant detrimental effects.

An initial study of the effects of placing trees in medians was conducted on several roadway sections on SR 99 in the city of SeaTac. Three years of data were collected before the street improvements took place, and these data were compared with three years of data collected after the improvements had been completed. 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. A second phase of the study continued the evaluation by examining seven additional sites, two of which were control sites where medians were constructed but where trees were not planted. The results of that phase of the project were reported in 2009 in the report "In-Service Evaluation of Major Urban Arterials with Landscaped Medians—Phase 2," WA-RD 636.2. This report completes the safety evaluation by comparing crash rates at an additional four sites, as well as comparing the ongoing crash rates at the previously reported locations. Two of the four new sites have trees, while the other two are additional control sections.

BACKGROUND

Transportation agencies are attempting to implement roadway designs that are sensitive to local landforms, culture, and desires. These "context sensitive designs/context sensitive solutions" (CSD/CSS) may entail selecting and implementing design solutions for local areas that would not be adopted on the basis of regional design standards or procedures currently applied by federal or state transportation agencies.

While current highway design standards were adopted in an attempt to enhance the safety of roadway users, those standards can reflect a one-dimensional view of roadway use, rather than a more holistic view of the interaction between drivers and their vehicles within a modern urban landscape. As a result of viewing roads more holistically, cities have recently been pushing to install landscaping along urban facilities that have speed limits of 35 to 45 mph as a way to improve the aesthetic characteristics of their arterials. To maintain safety, the cities have selected specific trees and design treatments to allow those landscaped medians to maintain or enhance the safety of both motor vehicles and the pedestrians and bikes using the arterial.

Unfortunately, strict application of existing design standards may preclude the installation of these desired landscaped treatments. Prominent among these standards is one that specifies a "clear zone." The design clear zone defines the width of the roadside that should be clear of fixed objects. Several city redevelopment proposals for SR 99 and other state routes included medians with trees placed close to the roadway. However, placing trees within curbed medians may not meet WSDOT's clear zone width criterion. Beyond enhancing aesthetics, the justification for deviating from the design clear zone standard is the prediction that the locations of the proposed deviations will not experience the same consequences as those in which clear zone analysis was 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 were not well represented in previous assessments of design clear zone. In part, WSDOT initiated the In-Service Evaluation of Landscaped Medians Agreement with cities along

SR 99 and other roadways to study the overall effects of various "context sensitive" designs. The process allowed these types of projects to be constructed, with the explicit agreement that the cities would cooperate with data collection efforts, as well as mitigation strategies if they were deemed necessary.

This report continues the previous evaluation of landscaped median treatments by describing an evaluation of accident occurrences on 13 roadway sections on SR 99, SR 522, and SR 525. The evaluation compared crash rates and crash types on treatment sections, on control sections where no medians were installed, and on sections where trees were placed in medians but behind barriers. Various crash types that had the potential to be affected by the median treatments were examined.

PROJECT DESCRIPTION

Arterials such as SR 99 north and south of Seattle, SR 525 in Mukilteo, and SR 522 have characteristics that are considered by many cities to be undesirable. High traffic volumes and high speeds are not viewed as positive traits as land uses along those routes intensify. These changes in development intensity have led numerous cities to create comprehensive plans that include redevelopment of the highway facilities to include more resident-, pedestrian-, and bicycle-friendly treatments. However, as alternative, parallel routes to roads such as Interstate 5, roads like SR 99 retain a significant regional mobility function while they must simultaneously provide access to local businesses, services, and residents. As the major arterial providing east/west travel around the north end of Lake Washington, SR 522 serves a similar combination of local access and regional mobility needs. SR 525 is a regionally important route because of the access that it provides to the Washington State Ferry dock in Mukilteo.

The project evaluated sections along SR 99 that were within the cities of Des Moines, Federal Way, Kent, SeaTac, and Shoreline. Also included in this study were a section of SR 522 through Kenmore and a section of SR 525 through Mukilteo. State Routes 99, 522, and 525 are classified as urban arterials. Each route has high traffic volumes and high speeds, and each experiences crash rates involving vehicles and pedestrians that are above the statewide average for facilities of this classification. High crash rates have been a significant motivation for landscape treatment projects. Although these corridors have historically not had 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, particularly on SR 99 and SR 525. In addition, these streetscapes have also been considered unattractive, which is detrimental to the redevelopment plans the cities have for land adjacent to, or nearby, these regional roadways.

The typical historic cross-section of SR 99 within the metropolitan region consisted of five to seven lanes, including a center, two-way left turn lane (TWLTL). In general, the paved shoulders were wide, with sidewalks present at only a few locations. Figure 1 shows an example of a typical roadway section with TWLTL and minimal access control.

Figure 1: Example of a Two-Way Left Turn Lane (TWLTL) with Limited Access Control[1]

Access to commercial and private properties was minimally controlled. At a few locations there was no TWLTL or a low, asphalt-covered median and C-curb (see Figure 2) separating the two directions of traffic. At many intersections, dedicated right and left turn lanes existed. In general, the aspect was of a wide, uncontrolled asphalt streetscape

---

[1] Image from Google Maps, © Google, 2010

with cars moving in every direction. There was almost no provision for the comfort and safety, of pedestrians, though many pedestrians travel through and across the SR 99 corridor. The land use was, and remains, primarily commercial strip development.

Figure 2: Example of a C-Curb[2] Separating Directions of Traffic

The typical SR 522 section through Kenmore was similar to that of SR 99 except that it also contained a right side business-access-and-transit (BAT) lane in both directions for most of the study section. Another difference between the Kenmore section of SR 522 and the SR 99 sections was that development in Kenmore is almost exclusively on the north side of the roadway, with a major, regional, grade separated bike trail located on the south side of the roadway.

---

[2] Image taken by Oran Viriyincy. http://www.flickr.com/photos/viriyincy/3686571748/in/set-72157620791151097#/

The typical SR 525 section was a two-lane, undivided highway with relatively uncontrolled access 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 were incompatible with city and community comprehensive plans, and given the need for a variety of improvements, cities chose to initiate boulevard-type streetscape redevelopment plans. The choice of the boulevard style street design was an attempt to smooth traffic flow, reduce vehicle speeds, create an environment that was attractive to pedestrians, safely accommodate bicycles, and foster a sense of community in the neighborhoods bordering these roads.

As part of the streetscape improvements, changes to the roadway environment occurred in three general areas: roadway, roadside, and pedestrian facilities. Improvements to the roadway included converting two-way left turn lanes into landscaped medians with left turn/U-turn pockets, widening the roadway, adding 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 pedestrian facilities, cities installed sidewalks and pedestrian features such as lighting, improved crossing points, improved or added new transit stops, and added aesthetic treatments such as landscaping and street trees.

The key element of this study was the nature of the landscaping changes. At several locations cities wished to place small trees ("street trees") in the roadway right-of-way. While there is no standard definition of a "street tree," they are commonly defined as trees placed within the general roadway environment to provide a visually pleasing aesthetic but without creating a traffic hazard. They are generally selected from tree species that are hardy in the local environment, require minimal amounts of care, and do not grow to a large diameters in order to limit the hazard they pose to motorists in crashes.

In some cases trees were planted in "unprotected" locations, while in other locations, the median in which the trees were placed contained a low wall that separated the street trees from traffic. This latter design is specifically intended to limit the potential involvement of street trees in vehicle crashes. This study compared the crash histories of the sections of road that had street trees without protection to those sections with trees located behind protection, and to those from a set of control sections where no trees were planted within the right-of-way.

CRASH DATA

For this study update, crash records were collected from the three years before project construction and from at least three years after construction had been completed. For the test sections where construction was completed before the end of 2004, three additional years of data are reported. These additional years of data allowed the comparison of not only *before* and *after* conditions, but also evaluation of whether the *after* conditions remained stable over time.

TRAFFIC CHARACTERISTICS

Traffic volume data were obtained from the WSDOT Annual Traffic Reports (WSDOT 2001 through 2010). Speed studies were conducted in both directions of travel on five of the study sections in 2008. Speed data were collected at similar locations in 2011, as well as at two additional locations on SR 99. The results from these studies are discussed later in this report. (See the “Vehicle Speeds section of the “Findings”).

The roadway locations studied in this project are listed in Table 1. The table describes the general crash and traffic characteristics for the *before* period of data collection, as well as each segment’s milepost limits. “Phases” within individual projects refer to separate construction projects that were built (typically) end-to-end with other phases within the same city or neighboring cities. Each phase was constructed independently but included many of the same general features.

Street trees without barrier protection were planted along sections of SR 99 in the City of SeaTac, Federal Way (phases 1 and 2) and Shoreline (Phase1 only). Trees were placed behind low barriers in Des Moines on SR 99, in Kenmore on SR 522, and in Mukilteo on SR 525. No trees were planted in the medians on SR 99 in Kent, in Shoreline Phase 2, or in Federal Way in the Phase 4 section.

Table 1. Traffic and Crash Characteristics Before Project Construction

Location	SR/Milepost	Median in *Before* Period	ADT	Vehicle Crashes (3 years)	Overall Crash Rate per MVM[3]
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	3.54
Kent (control)	SR 99/12.93 – 15.48	TWLTL	26,000	355	4.89
Des Moines (trees behind barrier)	SR 99/15.49 – 16.51	TWLTL	28,800	253	7.87
SeaTac – Phase 4	SR 99/16.52 – 17.52	TWLTL	28,500	198	6.34
SeaTac – Phase 2	SR 99 / 17.53 – 18.35	TWLTL	36,500	114	3.47
SeaTac – Phase 1	SR 99 / 18.35 – 19.47	TWLTL	37,500	366	7.96.
SeaTac – Phase 3	SR 99/19.47 – 20.68	TWLTL	32,100	360	8.46
Shoreline – Phase 1	SR 99 / 40.47 – 41.48	TWLTL	36,000	330	8.29
Shoreline – Phase 2 (control)	SR 99/41.59 – 43.56	TWLTL	33,887	522	7.14
Mukilteo (trees behind barrier)	SR 525/3.04 – 5.99	No median	24,300	438	5.58
Kenmore (trees behind barrier)	SR 522 6.45 / 7.49	TWLTL BAT lanes	40,000	253	5.55

[3] Per million vehicle miles

II. ANALYSIS METHODOLOGY

CRASH RATES

The number of crashes in each test section was obtained by totaling the crashes reported in the Police Traffic Collision Report and maintained at the WSDOT Statewide Travel and Collision Data Office. Crash rates were calculated by using the standard WSDOT methodology, described in Appendix A.[4] The following rates were calculated for both treatment and control locations:

1) overall crashes (per million vehicle-miles)
2) fatal crashes (per 100 million vehicle-miles)
3) fixed object crashes—including ditch, curb, and median crashes (per 10 million vehicle-miles)
4) tree-involved crashes (per 10 million vehicle-miles)
5) pedestrian- and bicycle-involved crashes (per 10 million vehicle-miles)
6) curb and median crashes (per 10 million vehicle-miles)
7) injury crashes (per 10 million vehicle-miles).

To determine whether differences observed were statistically significant, these crash rates were tested with a non-parametric test, the Wilcoxon Signed Rank Test.[5] This test is used to determine significant differences in measurements of the same type taken at two different times—before and after improvements have been made, for example. It was used in this study because crash rates differed significantly between sections, and thus changes in those rates were not directly comparable (in a parametric test sense) between different segments (controls versus treatments). Consequently, before and after comparisons were made within each study section. These results were then compared between sections.

The results are discussed by crash type in the next section.

---

[4] Note that for comparing *before* and *after* conditions, this project did not "double count" crashes that occurred at the terminal intersection between contiguous sections. In the Phase 2 report, crashes occurring at these intersections were included in both contiguous roadway test sections in order to determine whether limiting the number of access points had "pushed" crashes to the terminal intersections. This Phase 3 study looked only at the total number of crashes and used contiguous milepost boundaries between segments.

[5] http://en.wikipedia.org/wiki/Wilcoxon_signed-rank_test (retrieved Nov. 2011)

III. FINDINGS

Table 2 lists traffic volumes, crash counts, the initial *after* period dates, and crash rates for these state highway segments in both the initial three-year *after* period and, if sufficient time has past, the latest three-year period (2008-2010). It can be seen in Table 2 that both the total number of crashes and the crash rates for all roadway segments in which trees were planted decreased in comparison to their *before* condition. In some cases, these values changed substantially. For example, on the Federal Way Phase 2 section, crashes declined 30 percent during the first three years after the streetscape was changed, and the site maintained that lower rate through the following three years. Crashes within the SeaTac Phase 3 corridor dropped more than 45 percent in the first three years, and that crash rate then dropped in half again in the three subsequent years.

Four of the six comparison sections also showed a decline in both total crashes and crash rates. (One of the exceptions was Federal Way Phase 4, a control section without medians of any kind. The other exception, Des Moines, experienced a decrease in the number of crashes but a slight increase in crash rates because of slightly lower measured traffic volumes.) A good example of the majority of comparison sections is the Kent section of SR 99 from S. 272nd St. to SR 516. This test section included many of the same streetscape improvements (better access control, landscaping) as the median test sections with trees, but the Kent section improvements did not include trees in the median. This section of SR 99 also showed a substantial reduction in crashes (more than 30 percent).

A simple conclusion from Table 2 is that the general streetscape improvements successfully reduced crash rates in the test sections and that the trees themselves did not result in an increase in crashes.

More detailed analysis of the crash histories of these sections is included in the following sections of this report. This report presents data only from 2000 through 2010 and thus does not revisit the SeaTac Phase 1 and Phase 2 results. Readers interested in the initial before/after analysis can find that analysis in the Phase 1 report. (See: "In-Service Evaluation of Major Urban Arterials with Landscaped Medians—Conditions as of 2004," WSDOT WA-RD 636.1, 2004.) This report does describe changes in the

SeaTac Phase 1 and Phase 2 sections over the last ten years to illustrate the continued performance of those early treed median roadway sections.

CRASH RATES

The changes in crash rates for the study sections are summarized in Table 3. Table 3 shows crash rates before and after treatments were completed. The table also shows crash rates for the control sections during similar time periods. Overall crash rates for all of the roadway sections that included unprotected trees in medians as part of the new controlled access streetscape decreased in the three-year *after* period. Of the six control sites, four showed decreased crash rates during the first three-year *after* period, and two showed slight increases. One of the two sections showing an increase was a pure control section (no significant change in streetscape occurred during the study period). The other—Des Moines, which has protected trees in the new landscaping—experienced a decrease in total crashes but a slight increase in crash *rates* because of a decrease in traffic volumes on the roadway section. In the most recent three-year period of this study, the Des Moines crash rates declined below the *before* rates.

While the small number of test sections within both the "test" and "control" groups limits the statistical reliability of test comparisons, it is important to note that the reduction in overall crash rates for all of the treed median sections was larger than the crash rate reduction observed in any of the control sections, including the control sections that contained new medians and small trees behind barriers. If looked at on the basis of percentage reduction, the performance of the treed medians was generally similar to that of the control sections with trees behind median barriers. Given the limited sample size and the design of the experiment, it is not possible to conclude with statistical significance that the treed sections were "safer" than the sections with trees behind barriers or no trees, but it is possible to conclude that the treed median sections did perform as well as the more conventional designs.