BEFORE: Typical Conditions along SR 99

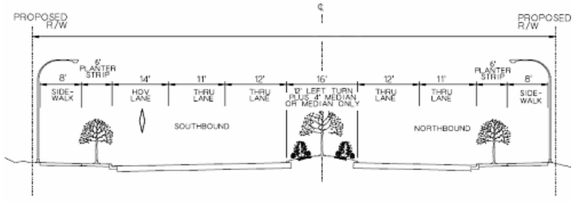
Arterials such as SR 99 are typically characterized by an unattractive street-scape with high accident rates and severities.

The cross section through SeaTac consisted of five lanes with a center two-way left-turn lane (TWLTL). There were wide, paved shoulders without sidewalks, minimal access control, transit stops with few crosswalks, and unsightly overhead utility lines. The posted speed limit is 40-45 mph, with average daily traffic volumes between 27,000 and 49,000 within the 2-mile project section.

AFTER: Redevelopment Projects

The redevelopment projects incorporate changes in the roadway geometry, access control, and signalization. Specific features in SeaTac include:

- Five through lanes with a business access & transit (BAT) lane in the southbound direction
- Sidewalks and street trees
- Landscaped medians with turn pockets
- Signal improvements for vehicles and pedestrians
- Underground utilities
- Driveway definition and consolidation



Tradeoffs in the Urban Context

Some of the elements in these projects may be viewed as presenting drawbacks. For example, medians reduce opportunities for mid-block movements, which may increase the number of accidents at intersections and concentrate other conflicts at mid-block left turn lanes. The potential safety impacts of placing trees within the Design Clear Zone include an increase in the likelihood of severe injuries involving tree collisions given the speed of the facility, the effects that trees may have on pedestrian crossing behavior, and the impact the trees may have on drivers' sight distances.

The CSD process focuses on balancing tradeoffs. Some of the tradeoffs evaluated in this research are outlined below:

- Medians
  - Eliminate conflicts in TWLTL
  - May deter pedestrian mid-block crossings or serve as a "refuge"
  - Reduce opportunities to access businesses adjacent to the road
- U-turn/left-turn pockets
  - Provide access to businesses
  - Introduce new movements into the traffic stream
- Trees in medians and along sidewalks
  - Aesthetic definition of the streetscape
  - Introduce fixed objects within the Design Clear Zone
  - May reduce visibility
  - Require maintenance

Each of the elements included present varying effects that must be balanced to achieve a safe, efficient, and attractive facility that meets the needs of the varied users.

The research questions explored include:

- How do changes in the clear zone and access control affect safety?
- What are the tradeoffs within the urban context?
- How do we improve pedestrian safety?
- What innovative, aesthetic designs maintain safety?
- Do research findings warrant changes to policy?
- How do we develop performance measures for flexibility?

Analysis Plan

The research for this project is occurring in two distinct quantitative forms: 1) the analytical process of comparing crash frequencies and severities and determining significant differences, and 2) the development of multi-variate statistical models to demonstrate the factors that contribute to the frequency or severity of crashes

An additional measure of safety investigated is the landscape maintenance reports from the City of SeaTac. These data illustrate different aspects of tree collision frequency and severity than the accident data are able to capture.

The data consist of accident reports from three years prior to construction and following project completion. Detailed geometric and traffic data were also collected for before and after conditions.

Findings

Findings from the first two phases of SeaTac's redevelopment project analyses are shown and indicate no statistically significant change in frequency or severity of crashes. Crashes in the combined study area increased slightly, while SeaTac Phase 1 showed a slight decrease.

	Before	After	%change
Fatal	4	1	-75.0%
Disabling	18	16	-11.1%
Evident	61	91	49.2%
Possible	164	148	-9.8%
PDO	294	308	4.8%
Total	541	564	4.3%

	Before	After
Average Daily Traffic (ADT)	36,962	37,184
Accident Rate*	6.227	5.676
Fatal Accident Rate*	5.042	1.253
Fixed Object Collision Rate*	4.034	3.884

* accident rates = accidents per million/100 million /10 million vehicle miles traveled, respectively

A shift in crash locations occurred, with fewer mid-block and increased intersection crashes. U-turn crashes increased after construction, from four to 35 within three years. These changes relate directly to the access control effects of the medians.

	Inter-section	Drive-way	Side-swipe	Left Turn	Angle	Rear End
Before	60%	18%	12%	9%	3%	41%
After	80%	6%	11%	30%	2%	33%

The number of crashes reporting striking a fixed object decreased in the Phase 1 roadway segment but increased in the Phase 2 segment. When trees were involved, the small size of the trees appears to have limited the severity of the resulting crash, increasing the likelihood that they would be classified as "property damage only."

The findings shows that placing trees in narrow medians and near road segments with turning movements resulted in high levels of tree strikes.

Multi-Variate Models

The multi-variate models developed follow the Poisson and multinomial logit forms. Negative binomial models were also investigated, but the data were not found to be overdispersed. One set of models included all of the data along the project sections. The second set of models excluded the accidents occurring at intersections. These accidents were excluded because it was believed that they might skew the data given the high proportion of accidents occurring at intersections and the lack of trees at these locations.

The crash frequencies are modeled with Poisson models. The available variables were investigated in a variety of combinations. The variables investigated most closely included average annual daily traffic (ADT), intersection indicator, presence of driveways on one or both sides of the road, level of access control, horizontal and vertical curvature, widths and types of medians, types of turn lanes, and presence of trees.

Crash injury severity models were developed using the multinomial logit (MNL) method. The injury severities were split into three discrete choice/outcome categories: property damage only (PDO), injury crashes (evident, disabling, and fatal injuries), and possible injuries. One of the limitations in the data that lead to this structure is the low frequency of fatal and disabling injury crashes. By combining all injury levels there are sufficient data to estimate coefficients.

The most significant model results are shown below.

Frequency Model Results

- Curb, landscaped median, and the lane-separation variables each tend to reduce the accident frequency
- Bus-stop indicator significantly increases accidents in the Before conditions, but the variable is not significant in the After model
- Number of trees per section indicate a reduction of accidents when intersections are included
- Trees along the east sidewalk increase the frequency of accidents in the mid-block model

Severity Model Results

- When a pedestrian or bicyclist is involved, there is an increased probability of injury, typically to the non-motorized traveler
- The lane separation variable tends to reduce injury accidents Before, but contributes to a higher probability of injuries After
- Fixed objects associated with increased injuries Before, and reduced possible injuries After
- The variable for trees along the west side is associated with increased property-damage accidents

Tree Maintenance and Collisions

SeaTac supplied supplementary maintenance information about median intrusions and tree maintenance activities. The frequency of tree incidents offers qualitative insights into the potential future impacts of median and roadside trees once they have reached maturity.

- The City of SeaTac provided maintenance records for median trees between 1997 and 2003.
- Within the 3-year analysis timeframe, 36 trees were replaced, ~90% due to vehicle strikes
- A total of 8 trees were related to collisions reported to the police, and only one resulted in an injury.

This maintenance data indicates that approximately 24 additional trees were impacted during unreported collisions. These incidents represent interactions between vehicles and trees, even if they did not result in sufficient damage to the vehicle or occupant to warrant being reported to the police as a collision.

Interpretation

The primary location for tree strikes is within the narrow medians adjacent to left-turn lanes. The rate of unreported tree incidents could result in an increased injury experience as the trees grow larger and become more rigid. This is of primary importance, and the research will follow these developments closely.

Given these routes are often high transit, pedestrian, and bicyclist use facilities, multi-modal safety is a priority. This analysis indicates that the number of pedestrian and bicycle crashes decreased following construction of the projects, and that the changes implemented at bus stops has resulted in increased safety at bus stops. While these results are encouraging, the mid-block crossing behavior of pedestrians continues with the landscaped medians serving as a "refuge". The refuge may result in a safety benefit for the pedestrians, however it can also create a false sense of security as they believe they are visible to oncoming traffic and cross unsafely.

Though the total number of trees per section decreases the frequency of accidents, the authors suggest that this is due to the relationship between the location of trees and intersections – specifically that there are more trees at locations with the least possibility for conflicting movements. On the other hand, the relationship shown in the model excluding intersections relating trees on the east sidewalk with increased accident frequency, may illustrate an interaction between access points, visibility, and the presence of trees. Trees on the west sidewalk increase the likelihood of property damage accidents, likely due to the small size of the trees and the infrequent access points on the west side.

Next Steps

The In-Service Evaluation of Landscaped Medians will extend at least through 2010, in order to collect data from additional cities implementing similar streetscape redevelopment projects. Collecting data from these project areas will likely increase the variation in some variables (such as number of lanes, median type, frequency/spacing of trees, etc), which may shed light on additional effects and interactions of variables. Varied median designs and features will allow for a comparison of the safety impacts of these designs, leading to a better understanding of what elements are more safe within this high-speed urban corridor context.

In subsequent phases of SeaTac's redevelopment project, they no longer plant trees within narrow medians (<6'). Instead, they have created a cobble-stone surface finish for the narrowest portions of

medians, transitioning to shrubs, and then varied native plant and tree species.

Des Moines has implemented a different type of safety measure. Along the landscaped medians they have installed a low profile barrier. This barrier type has been approved by FHWA as crash worthy for speeds up to 45mph.

Conclusions and Recommendations

In summary we see that trees within narrow medians are struck most frequently, and placement of trees within medians adjacent to turn-lanes is not advised. Sight distance should also be considered carefully to ensure that trees do not obscure pedestrians, mid-block turn lanes, or driveways.

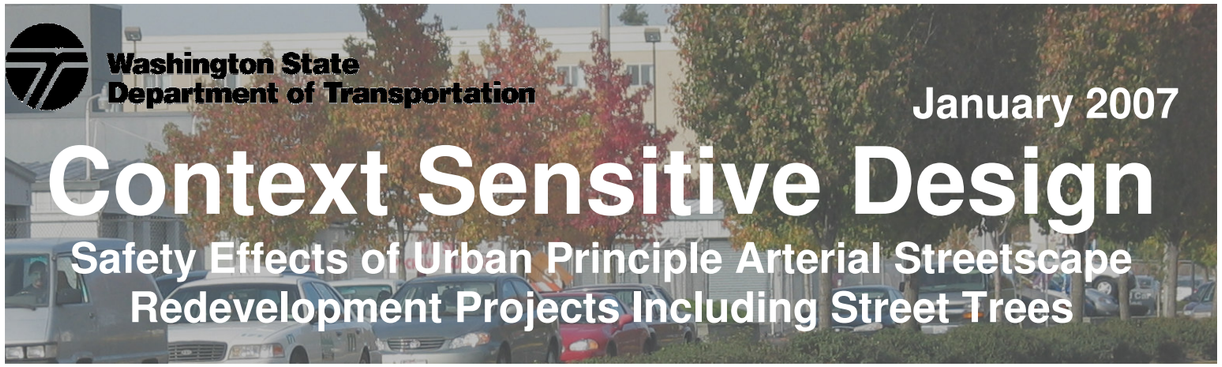
Concern remains regarding the placement of trees within the Design Clear Zone, and further research will illustrate the best design practices for landscaping medians and roadsides within the high-speed urban highway context.

For more information, contact

Anna St. Martin, E.I.T.
WSDOT StMartA@wsdot.wa.gov

John Milton, Ph.D., P.E.
WSDOT MiltonJ@wsdot.wa.gov

Mark Hallenbeck
TRAC tracmark@u.washington.edu



Washington State Department of Transportation

January 2007

Context Sensitive Design

Safety Effects of Urban Principle Arterial Streetscape Redevelopment Projects Including Street Trees

Background

This folio summarizes the safety performance of landscaped medians and other streetscape improvements on State Route (SR) 99 in Washington State. Findings contained in this folio are based on a before-and-after in-service evaluation of streetscape improvements made in SeaTac, Washington.

Purpose:
To evaluate various median landscaping plans in order to better define safe and attractive streetscape options on high-speed urban highways.

Due to concerns for the safety of the traveling public, and in an effort to increase the attractiveness of the local communities, cities along arterials like SR 99 have proposed and are implementing streetscape redevelopment plans. SeaTac was the first city to propose this type of streetscape redevelopment in Washington State. Of specific interest is whether the aesthetically pleasing landscaped designs change the accident rates and characteristics of these arterials.

In-Service Evaluation

The Washington State Department of Transportation (WSDOT) adopted an in-service evaluation process to evaluate a broad range of collision, environmental, operational, and maintenance situations in the high-speed urban highway context.

WSDOT formed agreements with cities including SeaTac, Des Moines, Federal Way, Kent, Shoreline, Mukilteo, and Kenmore to evaluate their innovative designs. This evaluation is intended to help WSDOT and its partner cities understand the overall impacts and benefits of these context-sensitive designs. The research findings will inform policy makers by illustrating both quantitative and qualitative measures of design tradeoff impacts within the urban context.

CSD Philosophy/Policy Setting

The Context Sensitive Design (CSD) philosophy aims to develop projects that are sensitive to the specific conditions within the project area. CSD is influenced by the local culture and desires, and develops projects with input from highway users, local communities, and designers.

Past research indicates a minimum "clear zone" is needed to protect travelers from striking fixed objects such as trees. Much of the research for fixed object collision frequency and severity is based on data from the rural highway context. WSDOT desires to evaluate the effects of clear zone design guideline deviations within an urban context, and to develop innovative design solutions.

The CSD approach is not license to lower the level of safety standards used in highway design, simply to achieve the desired aesthetic qualities – regardless of the needs and context of the facility. On the other hand, at times context-sensitive designs implement non-standard design solutions based on optimizing the tradeoffs. These solutions are developed by investigating the varied needs of the users and stakeholders, and objectively balancing these needs. Focusing exclusively on any one user group or design objective (such as livability or mobility) will inevitably lead to designs that are not optimal.