Washington State Department of Transportation

January 2008

WSDOT's Congestion Measurement Approach: Evaluating System Performance

Measuring Congestion at WSDOT

There are two main contributing factors in congestion growth in Washington State. First, more people within Washington's booming population want to travel on the same roads at the same time, which results in a decrease in the ability of the highway system to carry sufficient vehicles to meet demand (recurring congestion). Second, non-recurring causes of capacity loss, such as vehicle incidents and other roadside distractions, contribute to the uneven flow of traffic and reduced traffic throughput.

WSDOT uses embedded magnetic loops in highway pavement to determine traffic volume and relative speed, and then analyzes the data on its selected commute routes. Using this quality controlled data, WSDOT produces an annual congestion report that analyzes system performance by using a variety of performance metrics. In tracking and communicating performance results, WSDOT adheres to the congestion measurement principles the agency established. These principles call for the use of accurate, real-time data rather than modeled data in order to better communicate with the public, and using "Plain English" language and terminology that is meaningful to the public.

Left: Incident Induced Non-Recurrent Congestion on Southbound I-5 in Seattle. (A WSDOT Incident Response Truck is Working at the Scene.)

Right: Recurrent Congestion; Northbound I-405 in Seattle.

WSDOT's Congestion Measurement Principles:

- Use real-time measurements (rather than computer models) whenever and wherever possible.
- Use maximum throughput productivity as the basis for congestion measures.
- Measure congestion due to incidents (non-recurrent) as distinct from congestion due to inadequate capacity (recurrent).
- Show how reducing non-recurrent congestion from incidents will improve the travel time reliability.
- Demonstrate both long-term trends and short-to-intermediate-term results.
- Communicate about possible congestion fixes using an "apples-to-apples" comparison with the current situation (for example, if the trip takes 20 minutes today, how many minutes less will it be if WSDOT improves the interchange?
- Use "Plain-English" to describe measurements and results.

WSDOT's Congestion Measurement Thresholds

Based on 60 MPH Posted Speeds On State Highways

Condition	Highway Speed	Description
Posted Speeds	52 mph or above (Posted Speed)	Spacing varies based on speed and volume, but highway remains below maximum productivity
Maximum Throughput	51 mph-42 mph (about 85%-70% of Posted Speed)	Highway is achieving maximum productivity
Congestion	41 mph (below 70% of Posted Speed)	Highway is at less than maximum productivity because drivers are positioned at less than optimal spacing
Severe Congestion	35 mph or below (about 60% of posted speeds)	Speeds and spacing fall to below optimal, and the highway is well below maximum productivity

*Note: Maximum throughput figures are based on current technology and roadway geometrics. Improved vehicle and roadway technology could shift these thresholds upwards.

Key Congestion Performance Measures

Measure	Definition
Average Peak Travel Time/Minutes	The average travel time on a route during the peak travel period
95% Reliable Travel Time/Minutes	Travel time with 95% certainty (i.e. on-time 19 out of 20 work days)
Vehicle Throughput	Measures how many vehicles move through a highway segment in an hour
Lost Throughput Productivity/Percent (%)	Percentage of a highway's lost throughput due to congestion
Delay (Hours/Minutes)	The average total daily hours of delay per mile based on 85% of the posted speed, measured annually as cumulative (total) delay
Percent of Days That the Speed Falls Below 35 mph	Percentage of days annually that observed speeds fall below 35 MPH on key highway segments (also referred to as 'severe congestion')
Before and After (Travel Time Analysis)	Before and After analysis of performance of selected highway projects.
Duration of Congestion (Hours/Minutes)	The period when speeds fall below 70% of the posted limits
Maximum Throughput Travel Time Index: (MT^3I)	The ratio of peak commute period travel time compared to maximum throughput speed travel time

Travel Time Performance for Selected Central Puget Sound Commutes, 2006

					Travel Time (in min.)	Average Peak Travel Time, Based on Peak Time (in minutes)			95% Reliable Travel Time (in minutes)			Ratio of Peak Travel Time to Maximum Throughput Travel Time		Traffic Volume Peak Period	Duration of Congestion (hours and minutes that average speed falls below 70% of posted speeds)		
												MT³I					
Route	Route Description	Peak time	Length (Miles)	At Peak Efficiency	At Posted Speed	2004	2006	Change (%)	2004	2006	Change (%)	2004	2006	Change (%)	2004	2006	change (in minutes)
I-5	Everett to Seattle	7:25 AM	23.7	28	24	45	50	11%	73	81	11%	1.62	1.80	-3%	1:55	2:30	0:35
I-5	Seattle to Federal Way	4:35 PM	22.1	26	33	34	37	9%	49	56	14%	1.31	1.42	0%	1:15	1:55	0:40
I-90/I-5	Issaquah to Seattle	7:40 AM	15.5	18	15	22	26	18%	30	39	30%	1.21	1.43	+4%	*	1:20	1:20
I-5/SR 520	Seattle to Redmond	5:35 PM	14.7	17	15	29	30	3%	42	44	5%	1.68	1.73	-1%	2:10	3:15	1:05
I-5	SeaTac to Seattle	7:45 AM	12.9	15	13	23	27	17%	31	37	19%	1.51	1.77	-1%	2:15	3:30	1:15
I-5/SR 520/I-405	Seattle to Bellevue	5:35 PM	10.1	12	10	19	21	11%	30	32	7%	1.60	1.77	-1%	2:30	2:45	0:15

Data Source: WSDOT Traffic Operations and the Washington State Transportation Center (TRAC) at the University of Washington
Note: An asterisk (*) indicates that speeds did not fall below 70% of posted speed on a route; and n/a means that no information is available for a route.
2004 figures have been recalculated since their last publication in the 2005 annual congestion update, using a more refined data quality control process.

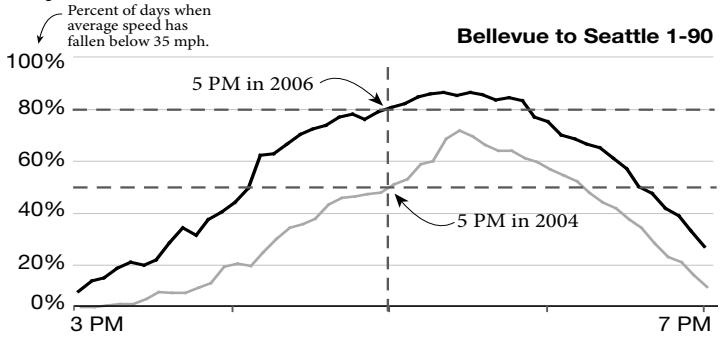
Measure Speed, Travel Times, and Reliability

Travel time and reliable travel time are measures that are important to commuters and businesses in Washington State. WSDOT tracks this performance data for the key commutes in the central Puget Sound region, the Spokane area, and the Vancouver area. The metrics used in travel time analysis include the 'Average Travel Time', '95% Reliable Travel Time', 'Traffic Volume', the 'duration of peak period congestion', and the 'percent of weekdays when average travel speeds fell below 35 MPH'. The performance of an individual route is evaluated compared to data from previous years.

Travel times are made available to the public and updated every five minutes on the WSDOT web site at http://www.wsdot.wa.gov/traffic/seattle/travel-times/.

Measuring Severe Congestion for AM and PM Commutes in the Central Puget Sound

Percent of Evening Commute for 2006 When Speeds Were Less Than 35 MPH Compared with 2004



Data Source: WSDOT Traffic Office

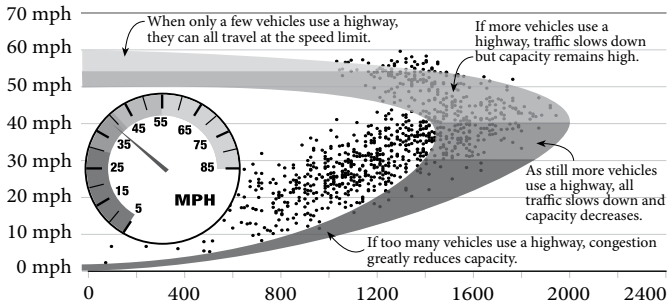
Measuring Traffic Volume

WSDOT examines two volume metrics for each commute route: volume during peak hours and the total daily volume. WSDOT continues to analyze factors such as the use of public transportation, population change and job growth, and fuel prices as they relate to volume and travel time changes. Volume and vehicle miles traveled (VMT) are two measures utilized by WSDOT to calculate the total number of vehicles and miles traveled on state highways in a given 5 minute interval, hour, week, or year. Volume data is recorded by the magnetic loop detectors, regularly spaced along highway segments, at 5 second intervals for much of the Puget Sound region. For a given commute route, the total yearly volume for each lane is summed and then multiplied by the length of the segment to give an estimated average VMT measure for the entire year. WSDOT uses this measure to better understand the number of trips taken for certain commute routes, as well as total miles traveled on the state highways and freeways to predict future demands and establish needs.

An Adaptation of the Speed/Volume Curve: Relating Speed and Volume

I-405 Northbound at 24th NE, 6-11 AM Weekdays in May 2001

Hourly Volume/Lane

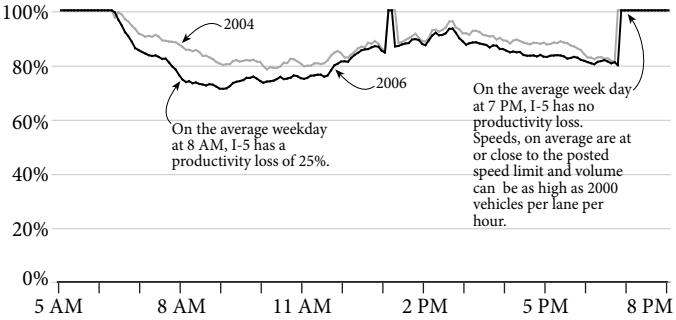


Evaluating Lost Throughput Productivity

Highways are engineered to move specific volumes of vehicles based on their size and design aspects. Many people are surprised to learn that highways do not operate at their maximum efficiency when vehicles are moving at 60 MPH (the average highway speed limit in Washington State). Maximum throughput, where the greatest number of cars passes through an individual lane every hour, actually occurs between 70%-85% of posted speeds (or 42-51 MPH). As congestion increases, speeds decrease and fewer vehicles pass through a corridor. Throughput productivity may decline from a maximum of 2,000 vehicles traveling at speeds of 40-50 MPH (100%) in a lane to as low as 700 (35%) when traveling less than 30 MPH.

Lost Vehicle Throughput Productivity: Example

Based on 1938 Vehicles per Lane per Hour (based on highest average five minute flow rate) Intersection of I-5 at I-90 in Seattle



WSDOT's goal is to achieve maximum throughput whenever possible, and this data provides important insights to system performance and mitigation strategies.

Measuring Delay

Delay (in hours) is a product of congestion and is a commonly used performance measure. Traditionally, delay has been calculated based on the difference between actual travel times and posted speed travel times. WSDOT uses maximum throughput standards as the measurement basis, rather then posted speeds, to assess relative delay against the highway's most efficient condition. WSDOT measures delay on the 35 key commute routes, and produces regional calculations of average delays.

Before and After Analysis of Congestion Project Results

The Washington State Legislature has passed two significant funding packages (the 2003 $1.5 billion Nickel and 2005 $8.5 billion Transportation Partnership Account funding packages) that will provide over $5.2 billion in funding for congestion relief projects. To measure the extent to which these investments are mitigating congestion, WSDOT is implementing Before and After project studies to analyze impacts on travel time and delay. On highway segments without in-pavement loop detectors, data will be collected through the use of Automated License Plate Recognition cameras. This technology will be used to calculate travel times and delay on the respective project locations and impacted highway segments and corridors. Vehicle volumes will be captured through the use of The Infra-Red Traffic Logger, a portable, non-intrusive traffic data collector capable of capturing vehicle volume, classification, and speed on multilane facilities. These Before and After studies will be modeled after WSDOT's existing practice for measuring the impacts of safety projects. The study will begin with ten selected projects in 2007 and be expanded to all capacity projects in the coming years.

Distinguishing Between Recurrent and Non-Recurrent Congestion is Difficult

WSDOT's desire to measure the effectiveness of its Incident Response program led to an effort to develop distinct measures of incident-related (non-recurring) and capacity related (recurring) congestion. Recurring congestion is defined as relatively predictable congestion caused by routine traffic volumes. Non-recurring congestion is defined as congestion caused by unpredictable or transient events such as accidents, inclement weather, special events, or construction.

Understanding and predicting how incidents will affect traffic flow and throughput is one of the toughest measurement challenges. Measurements currently in use to analyze congestion assist in gathering data about incidents, but there are few established national best practices to clearly distinguish how much of the delay is caused by recurrent (capacity induced) versus non-recurrent (incident induced) congestion. This is a handicap in measuring the specific effects of operational strategies such as Incident Response programs. WSDOT and the University of Washington's Transportation Center have been collaborating to research effective measurement methodologies along with national partners.

Measuring Operational Strategies

Incident Response

A large component of non-recurrent congestion on highways is caused by collisions, disabled vehicles, spills, and other events that impede the normal flow of traffic and can cause secondary incidents. For example, throughput capacity is reduced by 11% to 19% if a shoulder is blocked and 29% to 87% if one or more lanes becomes blocked. The WSDOT Incident Response (IR) teams partner with the Washington State Patrol to set up traffic control, assist in highway clearance and help coordinate pre-opening clean up operations.

Reducing the average clearance time for all incidents as well as eliminating all "over 90 minute" incidents are specific performance targets related to operational strategies. WSDOT also measures the specific clearance times for incidents involving fatalities, blockages, disabled vehicles, injury collisions and non-injury collisions, among other measures.

Percent of Lost Throughput Capacity Due to Lane or Shoulder Blocking Incidents

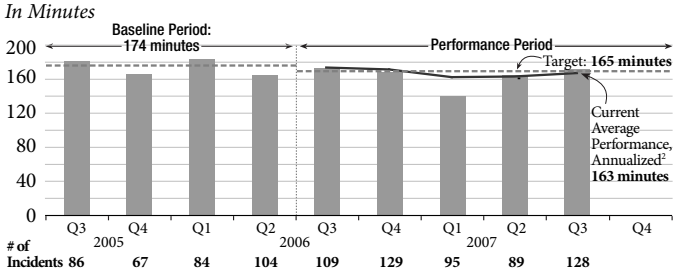
Based on highway capacity of 2000 vehicles per lane per hour

No. of Lanes	Shoulder Blocked	Lanes Blocked 1	2	3
2	19%	65%	100%	N/A
3	17%	51%	83%	100%
4	15%	42%	74%	87%
5	13%	35%	60%	80%
6	11%	29%	50%	74%

Data Source: Federal Highway Administration.

Cabinet Strategic Plan Goal: Reducing the Average Time for Incidents Lasting 90 Minutes or Longer on Nine Key Highway Segments[1]

In Minutes



Data Source: WSDOT Traffic Office and Washington State Patrol
Baseline Data Source: 2005--WSDOT Incident Response Tracking System; 2006--WSP-Computer Aided Dispatch System.
[1]*Selected Key Highway Segments*--I-5 (Oregon to Canadian Border), I-90 to North Bend, I-405, SR 18 to I-90, SR 16 to Purdy, SR 167, SR 520, SR 512, and I-205.
Clearance Time (for this measure only) is the time between first recordable awareness of an incident and all lanes open.
[2]Current Average Performance, annualized is the average quarterly duration of incidents lasting over 90 minutes for the performance tracking period for this measure.

WSDOT's IR program is continuously being enhanced to clear roadways more efficiently and further reduce clearance times. WSDOT and WSP have recently developed three new initiatives for which they will monitor benefits and impacts:

- Agreements with 14 county coroners to allow for off-site extrications of deceased accident victims.
- A pilot program that provides qualified heavy-truck towing companies with a $2,500 incentive for meeting the 90-minute clearance goal;
- An Instant Towing program that dispatches tow trucks and patrol officers simultaneously to eliminate wait times at the scene. If services are not needed, WSDOT pays the tow company a "dry run" fee of $25.

Measuring Operational Strategies (Continued)

Construction Work Zone Management

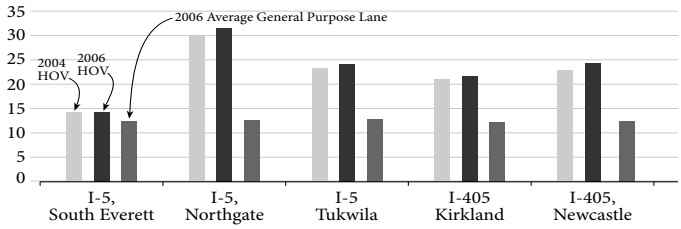
Highway construction is a necessity for the upkeep and improvement of critical facilities. However, it can contribute to noticeable declines in productivity and increase congestion. WSDOT is currently developing specific data tracking methods and measurement techniques to allow for a better assessment of the impacts of construction and traffic mitigation strategies. WSDOT has focused on public outreach about commute alternatives, as well as shifting construction activities to periods with the lowest recorded traffic volumes usually later at night and in the early morning.

High Occupancy Vehicle Lane Performance

The Washington State highway HOV system helps to maximize system productivity and provide reliable travel times and dependability for transit users and carpoolers. Approximately 200 miles of HOV lanes in central Puget Sound are monitored and measured. WSDOT tracks three important aspects of HOV lane performance: travel time and reliability benefit to users, and volume of people being moved via HOV lanes as compared to the general purpose lanes.

The performance standard for freeway HOV lanes is that for 90% of the time, the HOV lane should be able to maintain an average speed of 45 MPH or greater during the peak hour of the peak period. WSDOT continues to add HOV lanes and make refinements to improve the performance of existing lanes.

2004 and 2006 HOV Lane and General Purpose Lane Person Throughput Comparison
Total of AM and PM Peak Period Volumes
In Thousands



Note: Volumes are for peak period directions only.
Data Source: Washington State Transportation Center (TRAC).

HOV Direct Access Ramps

HOV lane direct access ramps allow buses, carpools, and vanpools to directly access the HOV lanes directly from park and ride lots and local streets. Direct access ramps make the highway system more efficient by reducing the amount of delay caused by vehicles crossing over as many as four lanes of traffic to get into HOV lanes. The graph above and to the right shows significant time savings at direct access ramp locations.

New Strategies for Capturing Travel Time Data

A cost-effective solution for gathering data on roadways (without loop detectors) is Automated License Plate Recognition (ALPR). A special camera scans the reflectivity of license plate tags to gather volume and speed statistics. ALPR will enable WSDOT to conduct system performance analysis as well as provide real-time travel speeds. This technology will also be used to collect travel time data in construction zones.

Direct Access Ramps Vehicle Volume and Time Savings for HOV Users After Implementation

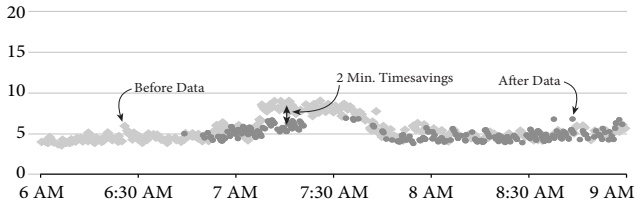
Direct Access Ramp Location	Transit Daily Volume	Total Daily Volume	Time Savings
Lynnwood	212	4100	4-8 minutes
Bellevue	292	3700	1-2 minutes
Ash Way	127	200	2-6 minutes
Federal Way	233	5600	n/a

Source: TRAC and WSDOT Northwest Region Office

Traffic Signal Re-Timing

Traffic signal synchronization is recognized as one of the most effective techniques for reducing congestion on arterials and on the arterials network. Some studies show that the benefit of reduced delay compared to the cost of synchronization may be as high as forty-to-one. The graph below shows results of a 'Before and After' study.

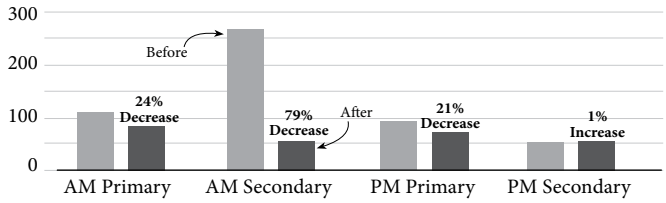
SR 532 Before and After Travel Times
Travel Times in Minutes by Time of Day
Eastbound SR 532 A.M. Travel Times at Mileposts 3.05 to 5.9, 2.85 Miles



Ramp Metering

The unsystematic merging of highway on-ramp traffic into the mainline highway is a chronic contributor to congestion. Ramp meters pace the incoming flow, so the merging takes on the quality of a smoothly functioning zipper. Ramp Metering improves flows as overall volumes increase both on the mainline and decreasing ramp and blocking incidents. This Seattle 'Before and After' case study of installed ramp meters (see graph below) showed decreases in observed braking actions and resulted in decreased travel times.

Ramp Meters Improve Traffic Flow
Tally of Observed Braking Actions
Merging Conflicts at Ramp to SR 167



Frequency of braking to avoid other cars at ramp from S. 214th St. to NB SR 167.

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