NCHRP 20-7 Guide to Benchmarking Operations Performance Measures
Traffic Flow Performance Measures - Pilot Test Results

4.x Traffic Flow Performance Measures

Traffic flow performance measures directly quantify the flow characteristics of the roadway based on physical measurements. Traffic flow performance measures encompass the following:

- Travel Time – Facility & Trip
- Speed
- Recurring & Non-Recurring Delay
- Extent of Congestion – Spatial & Temporal
- Throughput – Person & Vehicle
- Travel Time - Reliability

At the base of each of these measures is the need for sensor data that quantifies travel-time, speed, and/or volume. As such these measures share common data collection methods and sensor detection technology. Pilot test results are first summarized by the data collection issues common to all measures, and then by data compilation and reporting aspects specific to individual measures. In most pilot test scenarios a single data collection process provided the data from which multiple traffic flow performance measures were calculated.

4.x.1 Traffic Flow Data Collection

Table 4.x.1 summarizes various attributes of the data collection systems used to obtain the speed, travel-time, and/or volume data needed to compile the various traffic flow performance measures. A variety of technologies were employed in the pilot testing. The table contains a description of the type and extent of facilities, the technology employed, and the performance measures calculated. A brief summary of purpose, extent, and data collection issues encountered at each location are noted below. The Appendices contain the full submittal from each organization, as well as contacts for additional information.

Colorado DOT

The Colorado DOT (CDOT) has been gathering travel time information on primary commute and recreational routes using floating car methods since 2000. In 2007 routes exhibiting volume to capacity ratios in excess of 0.85 were included in the travel time data collection process. CDOT contracts with a private firm to collect travel time using floating car methods. A minimum of eight floating car runs are made to characterize the AM and PM peak, and a mid-day off-peak period for commute routes. From this data, CDOT reports travel time, delay, throughput, and plans to estimate spatial extent of congestion beginning with the 2007 data set. Partial results are currently available. Full data and reports are due at the end of the year.

Florida DOT, District 4

FDOT District 4 is commencing operation of a new system in which volume, occupancy, and speed data will be obtained from sensors spaced every ½ mile within two freeway corridors. Travel times will be reported in 15 minute intervals for ~40 miles of interstate freeways spanning I-95 and I-595 near Miami. Traffic flow performance measures will be reported automatically on the SunGuide website along with their existing incident management performance reports.

Florida DOT, District 5

The Florida Department of Transportation District Five (FDOT D5) monitors travel time on 135 centerline miles of principle arterials in Central Florida. Travel times are measured from reading and matching automated toll tags from a system of readers deployed specifically for travel time monitoring on the arterial network. Data from this system is used in the area's 511 information network. Travel time data from this network was used to pilot test extent of congestion measures, both spatial and temporal, for an arterial network. The pilot test revealed the inadequacy of the 'unconstrained travel time' definition as applied to arterials. This prompted additional investigation resulting in a revised definition applicable to signalized arterials.

Georgia Regional Transportation Authority (GRTA)

GRTA submitted data and sample reports for travel time and travel time reliability measures on their network of freeways in the Atlanta metropolitan area. The Georgia DOT maintains a network of video-based fixed sensors at 1/3 mile intervals. Speed data from these sensors is used to calculate travel times on the network. The data collection and reporting processes have been in place since 2002, and the measures are published annually in the Transportation MAP report. The archive provides suitable data from which to effectively quantify the growth in congestion on a yearly basis.

Maricopa Association of Governments (MAG)

MAG provided sample data and compiled performance measure information for a network of heavily traveled freeway commuter routes in the Phoenix metropolitan area. The data used by MAG comes from a network of fixed sensors deployed and maintained by the Arizona DOT. Deployed since 2000, quality control and maintenance expense concerns required re-evaluation of the data collection system in 2005. As a result MAG now receives data with guaranteed accuracy on a network of 58 sensors out of the originally deployed 500 sensors. From such data, MAG has begun to report speed, travel-time, extent of congestion, and throughput measures beginning with 2006 sensor data.

Maryland State Highway Administration (MSHA)

MSHA through its Coordinated Highway Action Response Team (CHART) program maintains a system of about 70 speed detectors throughout the Baltimore – Washington DC metropolitan area since 2002. The primary application of the data from the system is a color-coded speed map available on the CHART web site (www.chart.state.md.us). Speed data from this system was piloted tested as a means to estimate travel time. The exercise revealed data quality issues that must be addressed in order to estimate travel time with sufficient accuracy for display on changeable message signs.

Overland Park, Kansas

Overland Park collects travel time data on its system of coordinated arterials each year using the floating car method. The primary purpose of the data is to evaluate signal timing. Data has been collected since 1994 and the results are reported yearly as an assessment of signal operations within the city. During at least two years, travel time data was also collected during periods when the traffic signals were not coordinated. This allowed the traffic division to observe and quantify the overall benefit of signal coordination. All floating car data is collected using staff resources.

Southern Nevada Regional Transportation Commission (RTC)

The Nevada DOT, working in cooperation with the Southern Nevada RTC, has successfully installed freeway monitoring devices on 15 centerline miles of freeway in the Las Vegas metropolitan area. Although work continues on installing these devices in other corridors, the RTC is capable of archiving the data and then retrieving it for performance measure calculations.

Data from eight centerline miles of I-15 between two system interchanges (I-215 and US 95 / I-515) were used for pilot testing purposes. In addition to the freeway detectors, this freeway section is equipped with ramp meters, closed circuit TV cameras, and dynamic message signs. The performance measures were compiled by RTC staff proficient in understanding freeway performance measures using desktop database and spread sheet tools. It is intended that the data sets and procedures created during the pilot test would from a functional sample from which production procedure could be modeled and implemented in the center's data processing system.

Virginia DOT (VDOT)

The pilot test data submitted from VDOT arises from two separate data collection systems. The primary data used for statewide monitoring comes from 216 continuous count stations distributed throughout the state that are polled every 15 minutes. This data is used to report speed and various throughput measures. A speed index performance measure developed by the University of Virginia is compiled using data from the continuous count stations. The speed index is used in conjunction with throughput data as aggregate measures of system performance. The second data collection system reported is a network of fixed sensors on I-66 in Northern Virginia. This system is used to assess speed, travel time and extent of congestion measures in that corridor.

Wasatch Front Regional Council (WFRC)

The Utah DOT operates a sensor network in the Salt Lake City and Ogden metropolitan areas from which performance measures will be calculated. The Utah DOT is in the process of acquiring analysis software which will have the capability to calculate performance measures based on available data. While still awaiting installation of the system, the WFRC provided a description of the anticipated performance measures, sample data, and example calculations to be implemented.

Washington DOT

The Washington DOT (WSDOT) tracks mobility performance data for 35 important commutes in the Central Puget Sound region and two commutes in Spokane. WSDOT reports on average travel time, 95% reliable travel time, traffic volume, the duration of peak period congestion, and the percent of weekdays when average travel speeds fall below 35 mph. These routes are tracked for changes in traffic conditions on a yearly basis.

WSDOT primarily relies on loop detectors embedded in pavement to collect traffic data. WSDOT has amassed a large archive of speed and volume data. This data is continuous in time, 24 hours per day 365 days per year, broad in geographic coverage, available for individual lanes or sets of lanes, and available in increments of time as short as five minutes. In the Puget Sound region, operational data are collected from more than 4,000 induction loops embedded in the pavement of the highway system at roughly 360 highway locations providing volume and occupancy data. Speed estimated from single loops is accurate to 5 or 10 mph in free-flow steady speed conditions. WSDOT also has 100 dual loop installations in the Puget Sound region, capable of providing speed data accurate to within 1 or 2 mph at ordinary driving speeds. The Washington State Transportation Center (TRAC) has developed detailed quality control procedures used to detect loop failures, exclude bad data, and support the level of accuracy that is needed for traffic management and for reporting traffic conditions.

TABLE 4.x.1 Summary of Data Collection for Traffic Flow Performance Measures

Volume, Occupancy, Speed, and Travel Time Data Collection													
Agency	Type of Facilities	Data Collection Method or Technology	Extent of Data Collectoin / Study Area	History of Data Collection	Sampling Parameters	Performance Measures Assessed							Notes
						Speed	Travel Timie	TT - Reliability	Recurring Delay	Non-Recurring Delay	Extent of Congestion	Throughput	
Colorado DOT	Commuter & Recreational Corridors	Floating car	68 corridors (Length: 1 - 54 mi)	Since 2000 on some corridors	8 runs for each period		✓		✓		✓	✓	Data collection for 2007 estimated at $318,000.
Florida DOT District 4	Freeway	Fixed Sensors Side-fire Radar	Two interstate corridors ~40 miles in lenth, I95 & I 595	Initiated 2007	Data is polled every 20 seconds	✓	✓					✓	Initial applications will be color coded maps and travel time on signs
Florida DOT District 5	Arterial	Probe vehicle Toll Tag Transponders	135 mile arterial network, representing 74 corridors	Initiated 2007	Travel time from matched toll tags each minute		✓				✓		---
Georgia Regional Transportatoin Authority (GRTA)	Freeway	Fixed Sensors: Video Based	16 birectional corridors (Length: 4 - 15 mi)	Reported since 2002	Aggregated to 15 minute intervals		✓	✓					Primary technical challenge was a calculation algorithm to account for high degree of sensor outages
Maricopa Assoication of Government (MAG)	Freeway	Fixed Sensors: Passive Accoustic Detectors & Loops	6 corridors (Length: 8 - 10 mi)	Since 2000	Reported in 15 minute intervals	✓	✓	✓			✓	✓	AZ DOT provides data to MAG. Quality and maintenance concerns addressed in 2005 resulting in a higher quality data at the expense of a smaller network of
Maryland SHA	Freeway	Fixed Sensors: Side Fire Radar	70 Detectors throughout the Baltimore - DC area	Since 2002	5 minutes	✓	✓						Data quality control issues prevents use of sensor data for performance measures
Overland Park, KS	Arterial	Floating car	25 corridors (Length: 0.25 - 3 mi)	1994 to 2007	10 runs per direction		✓						Data collection requires 150 hours of staff time yearly
Southern Nevada Regional Transportaton Commission	Freeway	Fixed Sensors: Side Fire Radar & Loop Detectors	8 centerline miles on I-15 in Las Vegas between I-215 at the south and US 95 at the north	Since Sept 2006	Aggregated to 15 minute intervals		✓	✓	✓		✓	✓	Data sets and procedures from the pilot test are intended to be used asa function sample for future production implemenation.
Virginia DOT	Freeway	Fixed Sensors: Dual Loops	Statewide monitoring from 216 permanent count stations	Archive available since 2003	Polled every 15 minutes	✓						✓	Costs for permanent count stations are available
		Fixed Sensors: Loop	6 corridors on I66 in Northern VA (Length: 7 - 11 miles each)				✓				✓		---
Wasatch Regional Front Council (WFRC)	Freeway	Fixed Sensors	---	---	Continuous	✓	✓		✓			✓	Utah DOT is currently implementing new analysis software. WFRC provided sample calculations of recommended/intended measures
Washington DOT	Freeway	Fixed Sensors: Loop Detectors 4000 Single Loop 100 Dual Loop	35 commuting corridors (Length: 7 - 25 mi)	At least since 2002	Polled every 20 seconds, aggregated to 5 minutes	✓	✓	✓			✓	✓	WSDOT uses an extensive quality control plan for maintenance, calibration, and error checking developed by University of Washington TRAC.

The methods and technology for collecting traffic flow data for performance measures purposes is contrasted in Table 4.x.2. Three primary methods are represented in the pilot test submittals; fixed sensor, floating car, and vehicle probe technologies.

A fixed sensor refers to any type of electronic sensing device installed in a specified location to collect speed, volume and/or occupancy data. They are ‘fixed’ in that they measure traffic attributes at a single point in along the roadway. Data based on fixed sensors is predominant in the pilot studies. Many metropolitan areas have deployed fixed sensor networks as part of their ITS infrastructure investments beginning in the late 1990s. Although a variety of technologies are available, inductive loops are the oldest and most prevalent type of fixed sensor not only for operations purposes, but also in continuous count stations that typically serve planning and engineering applications. Single loop configurations directly measure volume and occupancy. Speed is inferred from single loop configurations by assuming an average vehicle length. As noted by WSDOT, single loops provide a speed estimate that is accurate to 5 or 10 mph in free-flow steady speed conditions. These accuracies are indicative of any technology whose base measurements are volume and occupancy. Inaccuracies arise not from the electronic sensing equipment, but from the uncertainties inherent in converting volume and occupancy into speed data. Dual loop arrangements measure speed directly, achieving accuracies of 1 to 2 mph.

Contrast of Data Collection Methods														
Method	Sub-Method	Base Measurements	Typcial Sampling Paragmeters	Freeway Use	Arterial Use	Performance Measures Supported							Costs	Primary Deployment Issues
						Speed	Travel Timie	TT - Reliability	Recurring Delay	Non-Recurring Delay	Extent of Congestion	Throughput		
Fixed Sensor	Single Loops	Volume & Occupancy	5 Minute	✓		X	X	X	X	X	X	X	$7500 to $20000 per site depending on availability of existing structures	Costs, Sensor Density, Maintenance, Quality Control
	Dual Loops	Volume, Occupancy, & Speed	5 Minute	✓		X	X	X	X	X	X	X		
	Cross-Fire Radar	Volume, Occupancy, & possibly Speed	5 Minute	✓		X	X	X	X	X	X	X		
	Video Cameras	Volume, Occupancy & Possibly Speed	5 Minute	✓		X	X	X	X	X	X	X		
Floating Car	GPS Instrumented	Travel Time	8-10 Runs per year, per corridor	✓	✓	X	X		X		X		Budget $300 to $500 per mile	Minimum Sampling Parameters
Vehicle Probe	Toll-Tag Transponder	Travel Time	1-5 minute	✓	✓	X	X	X	X	X	X		$15000 per site per direction (exclusive of structures)	Density of Toll-Tags and Cost of Equipment
	Fleet GPS Data		5 - 15 minutes	✓	?	X	X	X	X	X	X		$500 - $1000 / mile / year	Data Latency and Sampling Density
	Cell Phone Probes		1-10 minutes	✓	?	X	X	X	X	X	X		$500 - $1000 / mile / year	Accuracy, Privacy, and Business Model Sustainability

TABLE 4.x.2 Contrast of data collection methods and technology in support of performance measures

Data from fixed sensor networks share common attributes. Because speed is measured at a particular point in the roadway, fixed sensors are effective only in places where spot speed measurements are a good indicator of overall traffic flow. This assumption is valid in most freeway environments. The progression and quality of traffic flow on arterials, however, is dependent primarily on signal delay at intersections. Spot speed measurements either between signals or at intersections provide insufficient information to assess travel time or delay on arterials. As such, fixed sensors networks are not recommended for assessing space-mean speed or travel time on arterial networks as reflected in Table 4.x.2. (Note: Fixed sensors are still effective to measure volume on such roadways.)

Installation costs for fixed sensor network are estimated between $7500 and $20,000 per site. The range in cost is due primarily to extent to which existing infrastructure, such as poles and sign trusses, can be used to mount sensing devices. Methods and technology that allow for reuse of existing infrastructure, though more expensive, may prove the more cost effective overall. The density of fixed sensors ranged from 1/3 mile up tot 3 miles on some networks, with ½ mile and 1/3 mile being the most prevalent. The relationship between sensor density and accuracy of travel time measurements has been researched in previous studies, as well as the relationship between travel time accuracy and the type of algorithm to convert spot speed measurements to travel time. However, the pilot test indicated that most organizations use a relatively simple method for conversion from speed to travel time, and that the primary challenge for obtaining accurate travel time estimates were related to quality control issues as will be discussed later. Indeed, the primary benefit from high density sensor networks was redundancy in the event of often frequent sensor outages.

Fixed Sensor Spacing		
Agency	**Sensor Spacing**	**Data Collection Method or Technology**
Florida DOT District 4	1/2 mile	Side-fire Radar
Georgia Regional Transportatoin Authority (GRTA)	1/3 mile	Video Based
Maricopa Assoication of Government (MAG)	2-3 miles	Passive Accoustic Detectors & Loops
Maryland SHA	1.5 to 3 miles	Side Fire Radar
Southern Nevada RTC	1/3 mile	Side Fire Radar & Loop Detectors
Washington DOT	1/2 mile	Loop Detectors 4000 Single Loop 100 Dual Loop

Table 4.x.x Fixed sensor spacing

Information from the pilot test indicated that a proactive, well-funded, maintenance and quality control program is required to insure the usability of data from such networks. In its absence, confidence in measurement accuracy quickly erodes. Pilot test results submitted by WSDOT, MAG (Arizona DOT), GRTA (Georgia DOT), and MSHA, all organizations with multiple years of experience operating and maintaining sensor networks, all reflect on this issue. WSDOT uses a number of procedures to identify loop failures quickly and flag suspect data in its analysis programs. GRTA's travel time algorithm uses a complex averaging methodology to obtain travel time from speed sensor data provided by the Georgia DOT. The primary reason for the complex algorithm is the high rate of sensor outages within the network. Azirona DOT (the supplier of base data to MAG), recently downsized the number and extent of sensors in the Phoenix area in order to guarantee the accuracy of data on a smaller network within a limited budget. Upon investigating the use of speed data from MSHA's network of fixed sensors deployed since 2002 as the basis for travel time estimates, data quality issues were identified that required resolution in order to estimate travel time within allowable error limits.

The two remaining methods reported in the pilot tests directly measured travel time by tracking a sample of the vehicles in the traffic stream. Travel time data collection performed by CDOT and Overland Park, Kansas relied on floating car data collection methods. The dates and times of sampling are chosen carefully to be representative of average conditions for the period of interest. Sample size (the number of floating car runs within a given period of interest) are carefully chosen to insure that the results are statistically representative of population. The analysis of travel time variance presented in section 3 and included in Appendix ## are directly applicable. Floating car methods are not adaptable to assess travel time reliability and non-recurring delay due to the amount of data required.

Floating car and vehicle probe methods provide direct measures of travel time. As such, these methods are applicable to arterials as well as to freeway environments as indicated in Table 4.x.2. Test sites utilizing either floating car or vehicle probe methods included arterial networks. However, unlike fixed sensors, such methods lack volume data which must be collected using other methods if needed. The pilot test results from Florida District 5 provides a case study of state-of-the-art vehicle probe technology supporting performance measures on an arterial network. The toll-tag probe data allowed for continuous monitoring of travel time and calculation of extent of congestion.

Although not reflected in the pilot test data, technology advancements in vehicle probe techniques are providing additional alternatives to fixed sensor networks. These alternatives include travel time data services derived either from fleet GPS data probes or cell phone probe techniques. Attribute summaries for Fleet GPS data and Cell Phone Probe technology are included in Table 4.x.2 based on recent projects at the Wisconsin DOT, I-95 Corridor Coalition and the Georgia DOT. All of these projects are relatively new, but do represent deployments, and not just research initiatives. Although still considered unproven, such technologies are theoretically capable of monitoring traffic flow on larger geographic extents at a much reduced cost and without the need to deploy additional sensing equipment in the right-of-way. Both are considered viable for freeway data collection based on demonstration results and recent deployment results. Although these newer technologies are theoretically capable for use on arterials, this has yet to be verified with field results.

4.x.2 Speed, Travel Time and Throughput Performance Measures

Speed, travel time, and throughput form the base data from which to calculate the remaining traffic flow performance measures such as delay, extent of congestion, and reliability. As such, issues related to compilation and reporting of these measures also impact the compilation and reporting of derivative measures.

4.x.2.1 Travel Time - Facility

Table 4.x.3 summarizes the pilot test results for those organizations reporting Travel Time – Facility as a performance measure. Key outcomes of the pilot test results for travel time include:

- Travel time is foremost indicator of the quality of traffic flow. All organizations that submitted any type of traffic flow data developed travel time perforcements measures (or indicated that travel time would be a primary output in the case of Southern Nevada RTC and WFRC.)
- Travel time is a prime indicator of congestion. The primary application of the travel time measure for half of the pilot test submittals was for congestion tracking.
    - Travel time is typically summarized in 15 minute intervals during peak periods of traffic, such as AM and PM rush hours.
    - Peak periods differ for various regions and networks. Most coincide with typical AM/PM commute patterns, but exceptions exist particularly for regions with large recreational industries such as Colorado and LasVegas. Peak periods must be assessed individually.
- Direct measures of travel time are effective on arterial networks. The data submitted by Florida District 5, Overland Park, and Colorado measured performance on signalized arterials for various applications. Spot speed measurements are not effective on arterials as an estimated of space-mean speed, a surrogate for travel time.
- All travel time data submitted was for either freeway or arterial performance. No end-to-end travel time data, as addressed in the 'Travel Time – Trip' performance measure were reported.

As an indicator of congestion, travel time was typically reported annually using 15 minute aggregation intervals during peak hours to convey the growth and location of congested areas. A simple, but effective graphical display of congestion monitoring using travel times measures is used by GRTA in its annual Transporation MAP report available online at http://www.grta.org under the "Mobility" section. A sample of the graphic is reproduced in Figure 4.x.1 for a specific commute route. The format effectively conveys the growth in congestion both in terms absolute travel time and in the spread of the peak period from year to year.

Travel Time Performance Measure Summary						
Agency	**Type of Facilities**	**Primary Application**	**Reporting Frequency & History**	**Periods of Reporting**	**Reporting Costs**	**Notes**
Colorado DOT	Urban & commuter corridors	Congestion Tracking	Annually	Peak hours: 7 AM - 9 AM, 4 PM - 6 PM; Off-peak hours:11 AM - 1 PM	Reporting costs included in data collection contract of $318000	---
	Recreational corridors			Peak hours: 11:30 AM - 5:30 PM; Off-peak hours: 9:30 AM - 11:30 AM, 5:30 PM - 7:30 PM		---
Florida DOT District 4	~40 Miles from I-95 nd I-595 near Miami	Traveler Information - travel time via SmartGuide website	In development	Continuous - Realtime	---	---
Florida DOT District 5	135 centeraline miles of arterials in central Flordia (Orlando area)	Traveler Information through the 511 System	Continuous through the 511 system	Continuous - Realtime	---	Extensive travel time reporting on a large arterial network
Georgia Regional Transportatoin Authority (GRTA)	16 major freeway commuting corridors in the Atlanta metropolitan area	Congestion Tracking	Annual Report since 2002, available on the internet	Travel time is reported every 15 minutes for the AM Peak: 6 AM -10 AM and PM Peak: 3 PM - 7 PM	$12,000 consulting fees plus an additional 80 staff hours annually	Exceptional clarity in use of graphics to display annual growth of travel time
Maricopa Assoication of Government (MAG)	6 heavy volume freeway commuter corridors in the Phoenix metro area	Congestion Tracking	Annual Congestion Report	Peak hours: 5 AM - 10 AM, 2 PM - 7 PM	62 staff hours annually	---
Maryland SHA	Freeway network in the Baltimore - DC metro area	Travel time on Changeable Message Signs	Under development	Continuous - Realtime	---	---
Overland Park, KS	Network of arterials in the city of Overland Park, KS	Assessment of Signal Coordination	Yearly Reporting since 1994	Travel Time is sampled yearly with floating cars, and reported for the AM Peak: 7 AM - 9 AM PM Peak: 4:30 PM - 6 PM	70 hours/year of staff time to compile annual report	Data also includes travel time without signal coordination
Southern Nevada RTC	Potion of freeway network in LasVegas, NV	Congestion Tracking	The RTC is experimenting with various measures and reporting methods. Pilot results will serve as functional examples for production.			Data from the sensor network is currently reported as a distribution over speed and volume ranges.
Virginia DOT	I-66 in Northern Virginia	Traveler Informaiton: Travel time on website	Under development	AM & PM Peak, and 24 hour	$15,000 initial cost plus $50,000/year in staff time	---
Washington DOT	Freeway communting routes, 52 in the Puget Sound area, and two in Spokane	Congestion Performance Measures	Annually	Peak hours: 6 AM - 9 AM, 3 PM - 7 PM	---	Consistent, statewide monitoring and reporting methodology via the Grey Notebook
WFRC	Freeway network	Congestion Tracking	Utah DOT is currently implementing new analysis software. WFRC provided sample calculations of recommended/intended measures			---

Table 4.x.3 Summary of Travel Time Performance Measures during Pilot Testing

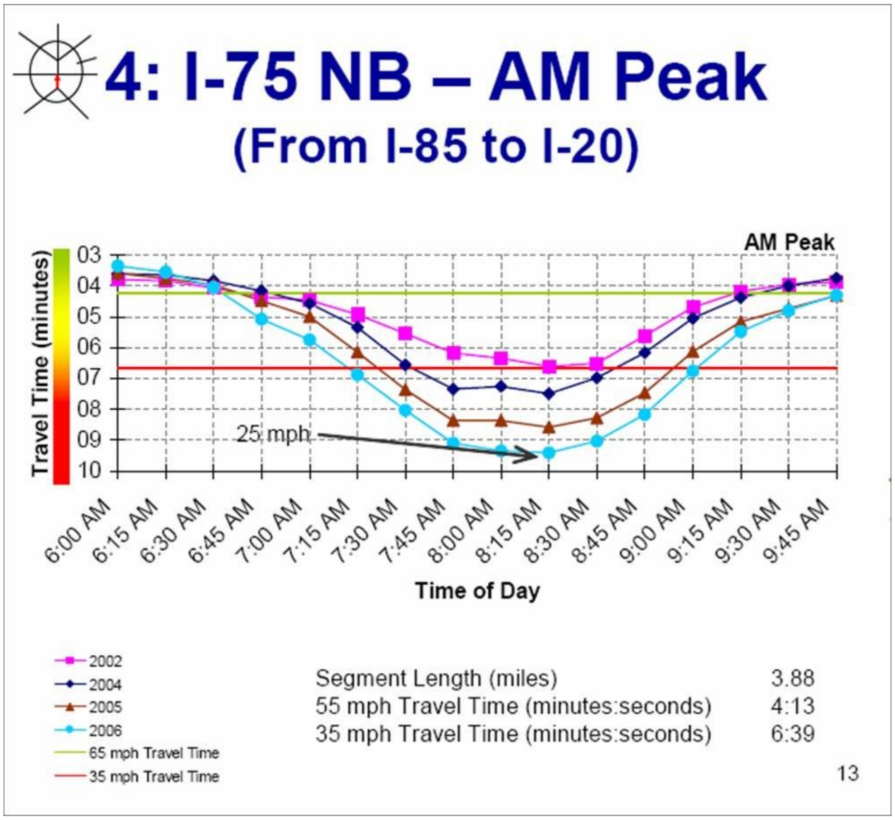

Figure 4.x.1 Illustration of travel time performance measure taken from the Transportation MAP report published annually by GRTA.

4.x.2.2 Speed

Table 4.x.4 summarizes the pilot test results for those organizations reporting Speed as a performance measure. Key outcomes of the pilot test results for speed include:

- The primary application was the use of speed data from a fixed-sensor network to color code a speed map to provide traveler information on a public web site. Speed data from Virginia DOT's continuous count stations is used to calculate a speed index. This is a metric developed by the University of Virginia specifically for implementation by VDOT as an indicator of statewide congestion. [See "Speed Index: A Scaleable Operations' Performance Measure Based on Available Data", TRB 2006 Annual Meeting CD-ROM]
- Data from continuous count stations are reused for congestion monitoring purposed. Both VA and MSHA use or intend to use continuous count stations that traditionally serve the planning community for operations purposes.

SPEED			
Agency	**Primary Application**	**Type of reporting**	**Notes**
FDOT D4	Real-time speed map on web site	Continuous - web based	---
Maricopa Assoication of Government (MAG)	Real-time speed map on web site	Continuous - web based	Additional applications include annual mobility report, calibrating/validating travel demand forecasting models
Maryland SHA	Real-time speed map on web site	Continuous - web based	Maryland is investigating use of continusous count station data for operations purposes
Virginia DOT	Statewide congestion monitoring with use of Speed Index	Annual Congestion Report	Data comes from the continuous count stations and is available to operations in real time at 5 minute intervals

Table 4.x.4 Pilot test results for Speed as a Performance Measure

4.x.2.3 Throughput Measures: Vehicle & Person

Table 4.x.5 contains a summary of the results submitted for throughput measures. Table 4.x.5 lists only those organizations with active reporting systems. WFRC, Florida District 4 indicated the intent of reporting throughput measures, but these systems are still in development. Methods and technology to collect volume counts for vehicles are well established. Throughput metrics, particularly in the planning environment, are used to support long range planning, travel demand modeling, HPMS and other applications.

Key outcomes of the pilot test results for throughput measures include:

- Volume data is essential for the computation of other measures.
- Vehicle throughput as an operational performance measure is an effective indicator of facility utilization WSDOT uses vehicle throughput to assess lost capacity due to congestion and is reported annually as part of the Gray Notebook. The measure is used to graphically illustrate locations on the freeway network where congestion diminished existing freeway capacity.
  Person throughput measures require periodic, location specific occupancy surveys to obtain customized occupancy factors to apply to traffic volume counts.
- Person throughput measures are effective to assess performance of HOV lanes.

Throughput - Vehicle & Person							
Agency	Vehicle Throughput			Person Throughtput			
	Extent	Utility	Cost	Extent	Occupancy Factors	Utility	Cost
Colorado DOT	72 hour counts using tube/radar in conjunction with the floating car runs for 68 corridors (urban, commuter, & recreational)	Included in the corridor report and necessary for delay calculations	Included in the floating car data collectoin contract of ~$318K				
Maricopa Assoication of Government (MAG)	Same network and exent as other measures, 26 locations on 6 selected corridors	Annual mobility report, calibrating/validating travel demand forecasting model	---	Same network and exent as other measures, 26 locations on 6 selected corridors	Manually collected vehicle occupancy data on each freeway detector location in 2006 - 2007.	Data has been reported on the MAG annual freeway mobility report, MAG regional traffic counts database and HPMS database.	---
Southern Nevada RTC	~ 8 mile portion of freeway network in LasVegas, NV	The RTC system is still in development. The system reports throughput as percentages in various volume ranges per section on a hourly basis to help identify congestion patterns.	---				
Virginia DOT	Statewide, 216 dual loop count stations	Used in conjunction with speed index to assess system's performance. Develop factors to create AADT and VMT estimates	---				
Washington DOT	Data is currently collected on most major freeways in the Puget Sound Region at approximately ½ mile intervals.	Volume measures are used to assess maximum throughput productivity, a primary congestion metric. Vehicle throughput is used in the Gray Notebook report distributed once/year.	Vehicle volume processing is a negligible percentage of the overall regional loop data collection system budget. This analysis is conducted annually as part of WSDOT's Performance Measurement work and consists of staff analysis time.	Selected locations are monitored each year throughout the Puget Sound region freeway network, on I-5, I-405, I-90, SR520, and SR167. Data are collected from both HOV and GP lanes	Based on up to thirty 30-minute peak period field counts per unique location/ travel direction /lane type during the Spring and Summer. Transit/vanpool ridership are based on all peak period ridership data from one transit service provider.	Three annual reporting mechanisms: (1) Gray Notebook external performance reporting document (2) a Seattle-area HOV lane system evaluation report (3) a Seattle-area freeway usage and performance monitoring report Person throughput estimates are also used by WSDOT to support a variety of HOV analyses, and as part of white papers and brochures.	$176K/year for occupancy data $6K/year for analysis and reporting

Table 4.x.5 Pilot test result for Throughput – Vehicle and Throughput – Person

4.x.3 Extent of Congestion Measures – Spatial and Temporal

Table 4.x.6 summarizes the pilot test results for Extent of Congestion Measures. Extent of Congestion, either Spatial or Temporal are derivative measures primarily of travel time. Volume data may be used for weighting purposes in the calculations. Key outcomes of the pilot tests of Extent of Congestion include:

- Extent of Congestion measures as defined by NTOC were only recently implemented (as with the Maricopa Association of Governments) or being experimentally tested. No organization has a history of reporting Extent of Congestion measures as originally defined by NTOC prior to 2007.
- Some organizations have comparable measures that attempt to capture the geographic and time extents of congestion. Various thresholds and definitions for congestion are in use. A commonly used metric is the percent of time speed falls below 35 MPH as demonstrated in the WSDOT gray notebook reports. Assuming an unconstrained travel time equivalent to 60 MPH, a corresponding increase in travel time would be ~70%.
- Graphics used in reports frequently plot either a travel time or speed index versus time of day as an indicator of extent of congestion along a corridor.
- For arterial networks, the proposed definition of 'unconstrained travel-time' was inadequate. Attempts to define unconstrained travel time based on off-peak periods fail due to varying signal timing strategies throughout the day. Off-peak travel time may be substantially greater if signal timings are chosen to maximize access to side streets.
- Using data submitted from Florida District 5, a definition of unconstrained travel for arterials equal to 30% greater than the speed limit equivalent travel time produced good results. See Figure 4.x.2 for graphical example.
- Travel time increases and speed reduction factors are reciprocals which can cause confusion and inconsistencies in computation. Referring to Figure 4.x.3, a 30% reduction in speed corresponds to an approximate 43% increase in travel time.

Extent of Congestion - Spatial & Temporal

Agency	Facility Type	Spatial	Temporal	Description of Data Set	Definition of Unconstrained Travel Time	Congestion Threshold	Reporting
Colorado DOT	Arterial & Freeway	✓		As part of the 2007 report, spatial extent of congestion during peak periods will be calculated			
Florida District 5	Arterial 135 miles of arterial centerline data	✓	✓	135 Centerline Miles of arterials in the Orlando metropolitan area. 2006 travel times from automated toll-tag technology are used to estimate extent of congestin measures	1.3 times the travel time at posted speed	30% Greater than unconstrained travel time	Experimental Results
Maricopa Assoication of Government (MAG)	Freeway 6 major commuter corridors	✓	✓	Using 2006 data from Tuesdays, Wednesday and Thursday (155 core days), spatial congestion is estimated for each corridor for every 15 minutes during peak periods. Temporal Congestion is defined as the percentage of peak period during which spatial congestion congested time periods out of the entire peak period. Monthly averages.	85th Percentile of off-peak travel time	30% Greater than unconstrained travel time	Results have been used in the MAG annual freeway mobility report. However, the previous congestion definition was based on speeds, using "speed<=35 mph and speed<=50 mph" as the thresholds for severe congestion and congestion respectively.
Southern Nevada RTC	Freeway Portion of LasVegas freeway system	✓	✓	In Development, to be reported as part of the RTC-FAST system			
Virginia DOT	Freeway I66 in Northern Virginia	✓	✓	In Development, to be reported on the VDOT Dashboard			
Washington DOT	Freeway 44 Mile Section of I5 passing through Seattle	✓	✓	Extent of congestion was assessed on I5 using data sets from 2004 and 2006 for comparison and contrast	Posted Speed	70% of Posted Speed	Reports Percent of Days when speeds were less than 35 MHP on specified commuter routes in the Gray Notebook, extent of congestion as per NTOC definition was experimental

Table 4.x.6 Pilot test result for Extent of Congestion – Spatial and Temporal

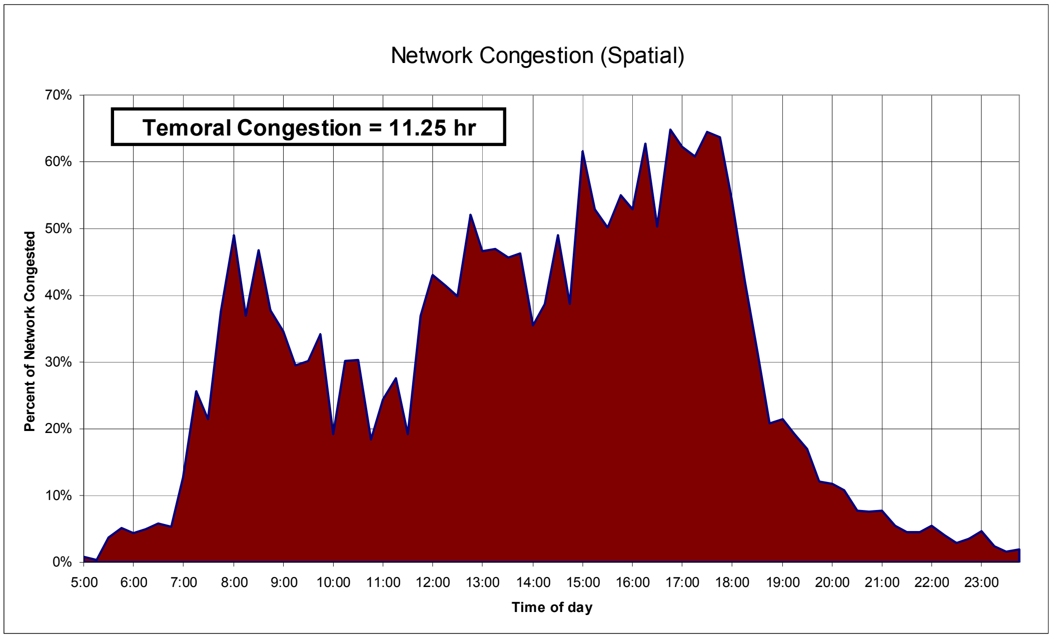

Figure 4.x.2 Temporal Extent of Congestion on FDOT District arterial network based on an unconstrained travel time 30% greater than the speed limit equivalent travel time.

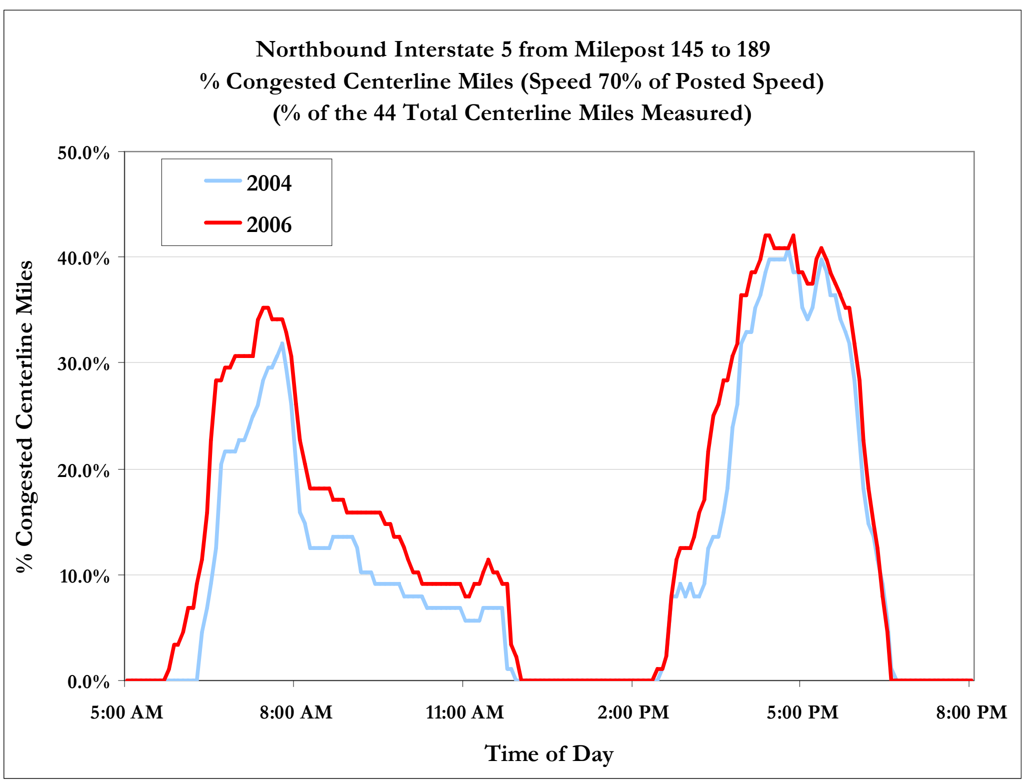

Figure 4.x.3 Sample of spatial extent of congestion based on alternative definition from WSDOT.

4.x.4 Travel Time - Reliability

Table 4.x.7 summarizes the information submitted during the pilot test concerning the Travel Time – Reliability measure. Key outcomes of the pilot tests of Travel Time – Reliablity include:

- All organizations implemented the reliability measure in full agreement with the definition. The explicit nature of the definition of travel time reliability provides for consistent implementation across various organizations.
- Metrics for reporting reliability in the pilot data included 95th percentile travel time, Planning Time Index (PTI), and Buffer Time Index (BTI).

Travel Time Reliability								
Agency	Type of Facilities	Reporting Frequency & History	Periods of Reporting	Unit of Measure Reported			Reporting Costs	Notes
				95% Travel Time	Planning Time Index (PTI)	Buffer Time Index (BTI)		
Georgia Regional Transportatoin Authority (GRTA)	16 major freeway commuting corridors in the Atlanta metropolitan area	Annual Report since 2002, available on the internet	15 minute intervals during peak periods: 6 AM -10 AM and 3 PM - 7 PM			✓	$12,000 consulting fees plus an additional 80 staff hours annually for all measures	
Maricopa Assoication of Government (MAG)	6 heavy volume freeway commuter corridors in the Phoenix metro area	Annual Congestion Report	15 minute intervals during peak periods: 5 AM - 10 AM and 2 PM - 7 PM	✓	✓		62 staff hours annually (all measures)	Included asa standard measure in travel time reporting
Southern Nevada RTC	Portion of freeway network in LasVegas, NV	In Development, sample calculation from pilot study will servce a functional sample for later production.					---	
Washington DOT	Freeway communting routes, 52 in the Puget Sound area, and two in Spokane	Annual report and also on its interactive "Calculate Your Commute" website.	5 minute intervals during peak periods: 6 AM - 9 AM and 3 PM - 7 PM The five-minute interval with the highest average travel time value is used for reporting of reliability measures.	✓			---	Reports reliability stats only on commutes experiencing congestion, 38 of the 52 routs in the 2007 report.

Table 4.x.7 Pilot test result for Travel Time - Reliability

4.x.5 Recurring and Non-Recurring Delay

Table 4.x.8 summarizes the information submitted during the pilot test concerning delay measures. Key outcomes of the pilot tests of Delay measure include:

- Delay is the only measure from which to assess a monetary value for the adverse effects of congestion.
- Varying definitions of unconstrained travel time. WSDOT uses a travel time equivalent of maximum throughput, which is approximately 51 MPH. Colorado uses off-peak travel times which creates problems for arterial networks. WFRC intends to use posted speed, or equivalent based on functional class of roadway.
- Metrics and aggregation level of reporting vary.
- No samples of Non-recurring Delay were submitted in the pilot tests.

Recurring Delay				
Agency	**Facility Type**	**Measures Reported**	**Definition of Unconstrained Travel Time**	**Reporting**
Colorado DOT	Arterials & Freeways Commuter and recreation corridors	Annual vehicle hours per route Annual person hours per route Annual congestion cost per route	Travel time during off-peak period	Annual reports for each corridor
WFRC	Freeway system in and about Salt Lake City and Ogden Ares	Individual vehicle delay per mile (sec /mile) Total vehicle delay per lane-mile (veh-min/lane-mile or min/mile)	Based on posted speed or functional class or roadway	System currently in development
Southern Nevada RTC	Freeway Portion of LasVegas freeway system	In Development		
Washington DOT	Statewide monitoring of major commuter routes	Vehicle hours per day per mile Vehicle hours per day per metro area Statewide - daily and annual vehicle hours of delay Annual cost of delay on state highways	Optimal flow speed (~51 mph) Posted Speed	Annual reports as part of the Gray Notebook

Table 4.x.8 Pilot test result for Recurring Delay