


SIS BOTTLENECK STUDY

TECHNICAL MEMORANDUM NO. 2

Methodology to Identify Bottlenecks

Table of Contents

List of Figures

List of Tables

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Methodology to Identify Bottlenecks

This technical memorandum summarizes the research efforts in the field of traffic congestion and bottlenecks and identifies the performance measures used by various agencies, Departments of Transportation (DOTs), and Metropolitan Organizations (MPOs) to quantify congestion. Using this information, a methodology to identify bottlenecks and congestion on Florida's Strategic Intermodal System (SIS) network is recommended.

2.1 Introduction

Demand for highway travel by Americans continues to grow as population increases. Congestion results when traffic demand approaches or exceeds the available capacity of the system. Extensive research has been completed in the field of traffic congestion and bottlenecks. This section provides an introduction to congestion and bottlenecks and how they can be identified and quantified.

2.1.1 Congestion and Bottleneck[1]

The Federal Highway Administration (FHWA) defines congestion as an excess of vehicles on a roadway at a particular time resulting in speeds that are slower - sometimes much slower - than normal or free flow speeds. Congestion is stop-and-go traffic. FHWA's research has shown that congestion is the result of six root causes often interacting with one another. The six contributing sources are:

- Limited physical capacity;
- Poor traffic signal timing;
- Traffic incidents;
- Work zones;
- Bad weather; and,
- Special events.

Nationally, a composite estimate of how much each of these sources contributes to total congestion is depicted in **Figure 2-1**. FHWA indicates that these estimates are a composite of many past and ongoing congestion research studies and are rough approximations.

Only the first and second sources contribute to recurring congestion; i.e., they are tangible in design and function, and therefore, candidates for remediation. The remaining sources of congestion are nonrecurring and random. In this context then, a bottleneck certainly constitutes congestion, but congestion is often more than a bottleneck.

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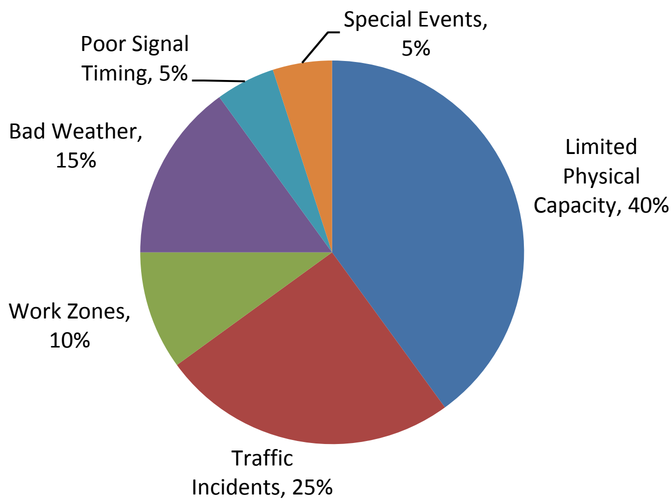
[1] FHWA Office of Operations: Localized Bottleneck Reduction Program

Figure 2-1 Sources of Congestion – National Summary



Source: http://www.ops.fhwa.dot.gov/aboutus/opstory.htm

Bottlenecks can be defined as a localized section of highway that experiences reduced speeds and inherent delays due to a recurring operational influence or a nonrecurring impacting event. Simply put, a bottleneck is a localized constriction of traffic flow. A bottleneck is distinguished from congestion because it occurs on a subordinate segment of a parent facility, and not pervasively along the entire facility. The term bottleneck is often used interchangeably as a catch-all definition including sometimes even meaning congestion. One should recognize the context, and distinguish it appropriately as a recurring or nonrecurring bottleneck.

2.1.2 Identifying a Bottleneck[2]

Recurring bottlenecks have an identifiable cause, resulting in recurring delays of generally predictable times and durations. The following conditions either exist or help to identify a recurring bottleneck condition:

- A traffic queue upstream of the bottleneck – the speeds within the queue are below free-flow conditions;
- A beginning point for a queue – a definable point exists that separates upstream and downstream conditions;
- Free flow traffic conditions downstream of the bottleneck that have returned to nominal or design conditions;
- Predictable recurring cause; and,
- Traffic volumes that exceed capacity.

[2] FHWA Office of Operations: Localized Bottleneck Reduction Program

Non-recurring bottlenecks are usually caused by amorphous, random events such as traffic incidents, bad weather or work zones.

2.1.3 Quantifying Congestion/Bottleneck[3]

Congestion on roadways has grown to critical dimensions in many areas of the United States. Congestion has many detrimental effects including lost time, higher fuel consumption, more vehicle emissions, increased accident risk, and greater transportation costs. Quantifying congestion is needed for analytical purposes, such as system evaluations and improvement prioritization, and for use by policy makers and the public.

National Cooperative Highway Research Program (NCHRP) Report 398 *Volume 1: Quantifying Congestion* presented methods to measure congestion on roadway systems. The report finds that while it is difficult to conceive of a single value that will describe all of the travelers' concerns about congestion, there are four components that interact in a congested roadway or system. These components are duration, extent, intensity and reliability. They vary among and within urban areas – smaller urban areas, for example, have shorter durations of congestion than larger areas.

- **Duration** – this is defined as the amount of time congestion affects the travel system.
- **Extent** – this is described by estimating the number of people or vehicles affected by congestion, and by the geographic distribution of congestion.
- **Intensity** – this is the severity of the congestion that affects travel. It is typically used to differentiate between levels of congestion on transportation systems and to define the total amount of congestion.
- **Reliability** – this key component of congestion estimation is described as the variation in the other three elements. Reliability is the impact of non-recurrent congestion on the transportation system.

2.1.4 Common Locations for Bottlenecks[4]

Bottlenecks are usually found at certain locations on roadways such as lane drops, weaving areas, freeway on and off ramps, interchanges, changes in highway alignments, narrow lanes or lack of shoulders, and traffic control devices.

- **Lane drops** – Bottlenecks can occur at lane drops, particularly at mid-segments where one or more traffic lanes ends or at a low-volume exit ramp. They might occur at jurisdictional boundaries, just outside the metropolitan area, or at the project limits of the last mega project. Ideally, lane drops should be located at exit ramps where there is a sufficient volume of exiting traffic.

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[3] National Cooperative Highway Research Program (NCHRP) Report 398 Volume 1: Quantifying Congestion

[4] Recurring Traffic Bottlenecks: A Primer – Focus on Low-Cost Operational Improvements, FHWA 2012

- **Weaving areas** – Bottlenecks can occur at weaving areas, where traffic must merge across one or more lanes to access entry or exit ramps or enter the freeway main lanes. Bottleneck conditions are exacerbated by complex or insufficient weaving design and distance.

- **Freeway on-ramps** – Bottlenecks can occur at freeway on-ramps, where traffic from local streets or frontage roads merges onto a freeway. Bottleneck conditions are worsened on freeway on-ramps without auxiliary lanes, short acceleration ramps, where there are multiple on-ramps in close proximity and when peak volumes are high or large platoons of vehicles enter at the same time.

- **Freeway exit ramps** – Freeway exit ramps, which are diverging areas where traffic leaves a freeway, can cause localized congestion. Bottlenecks are exacerbated on freeway exit ramps that have a short ramp length, traffic signal deficiencies at the ramp terminal intersection, or other conditions (e.g., insufficient storage length) that may cause ramp queues to back up onto freeway main lanes. Bottlenecks could also occur when a freeway exit ramp shares an auxiliary lane with an upstream on-ramp, particularly when there are large volumes of entering and exiting traffic.

- **Interchanges** – Freeway-to-freeway interchanges, which are special cases of on-ramps where flow from one freeway is directed to another. These are typically the most severe form of physical bottlenecks because of the high traffic volumes involved.

- **Changes in highway alignment** – Changes in highway alignment, which occur at sharp curves and hills and cause drivers to slow down either because of safety concerns or because their vehicles cannot maintain speed on upgrades. Another example of this type of bottleneck is in work zones where lanes may be shifted or narrowed during construction.

- **Tunnels/Underpasses** – Bottlenecks can occur at low-clearance structures, such as tunnels and underpasses. Drivers slow to use extra caution, or to use overload bypass routes. Even sufficiently tall clearances could cause bottlenecks if an optical illusion causes a structure to appear lower than it really is, causing drivers to slow down.

- **Narrow lanes/Lack of shoulders** – Bottlenecks can be caused by either narrow lanes or narrow or a lack of roadway shoulders. This is particularly true in locations with high volumes of oversize vehicles and large trucks.

- **Traffic control devices** – Bottlenecks can be caused by traffic control devices that are necessary to manage overall system operations. Traffic signals, freeway ramp meters, and tollbooths can all contribute to disruptions in traffic flow.

2.1.5 Performance Measures[5]

The above four components of a congested roadway system can be measured using several performance measures. Performance measures can be used with highway systems and segments to monitor the effectiveness of operational strategies and to assess the success of achieving targets commonly called yardsticks or benchmarks. Many agencies are now using performance measures to achieve operational efficiencies and to improve the reliability of highways.

Performance measures of operational effectiveness are used in the planning and systems engineering context to prioritize projects, provide feedback on the effectiveness of longer-term strategies, refine goals and objectives, and improve processes for the delivery of transportation services. Performance measures in planning are principally used in reporting trends, conditions, and outcomes resulting from transportation improvements. The Florida DOT's *Florida's Mobility Performance Measures Program* (2000) notes the following reasons for using performance measures:

> Citizens, elected officials, policy makers, and transportation professionals are seeking new ways of measuring the performance of the transportation system to answer the following questions:
>
> - How do we improve transportation to serve people and commerce in Florida?
> - What are we getting from our investment in transportation?
> - Are we investing in transportation as efficiently as possible?
>
> Performance measures are needed to answer these questions and to track performance over time. They also provide accountability and link strategic planning to resource allocation. By defining specific measures, the Florida Department of Transportation is able to measure the effectiveness of programs in meeting Department objectives.

2.2 Contemporary Practices to Measure Congestion

Several state departments of transportation (DOTs), metropolitan planning organizations (MPOs), and local governments collect a variety of highway performance measures. These measures are used for various reasons like responding to legislative mandates, preparing budget and funding allocations, improving quality of transportation services, preparing congestion management systems, safety management systems, etc.

The performance measures collected by the agencies usually not only include those related to mobility but also to other indicators like sustainability, safety, environmental quality, customer satisfaction, etc. This section summarizes some of the federal, state, and local agency practices in the areas of performance measures for the operational effectiveness of highway segments and systems as they pertain to congestion and bottlenecks.

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[5] *Performance Measures of Operational Effectiveness for Highway Segments and Systems*, NCHRP Synthesis 311, Transportation Research Board, National Research Council, Washington, D.C., 2003

2.2.1 National Performance Reports

2.2.1.1 Urban Congestion Reports by FHWA

The Federal Highway Administration's (FHWA) Office of Operations provides national leadership for the management and operation of the surface transportation system. Within the Office of Operations, the Localized Bottleneck Reduction (LBR) Program serves to bring attention to the root causes, impacts, and potential solutions to traffic bottlenecks.

FHWA produces Urban Congestion Reports (UCR) on a quarterly basis and characterizes emerging traffic congestion and reliability trends at the national and city level. The reports utilize archived traffic operations data gathered from state DOTs and a private traffic information company. The reports are currently using data from 19 urban areas in the U.S. The UCR includes only those roadways that are instrumented with traffic sensors for the purposes of real-time traffic management and/or traveler information. In many cities, this typically includes the most congested parts of the freeway system. The Report currently does not include congestion information on arterial streets.

The UCR uses the following three measures to quantify congestion and travel reliability information. In this report, the AM peak period is considered as 6 am to 9 am and the PM peak period is 4 pm to 7 pm on non-holiday weekdays. Additionally, the off-peak times are considered as 9 am to 4 pm on weekdays and from 6 am to 10 pm on weekends.

- **Congested Hours** – the average number of hours during specified time periods in which instrumented road sections are congested. For this measure, congestion is defined to occur when link speeds are less than 45 mph.

- **Travel Time Index** – the ratio of the average peak period travel time as compared to a free-flow travel time. The free-flow travel time for each road section is the 15th percentile travel time during traditional off-peak times, not to exceed the travel time at the posted speed limit (or 60 mph where the posted speed is unknown). For example, a value of 1.20 means that average peak travel times are 20% longer than free-flow travel times.

- **Planning Time Index** – the ratio of the total time needed to ensure 95% on-time arrival as compared to a free-flow travel time. The planning time index is computed as the 95th-percentile travel time of the month divided by the free-flow travel time for each road section and time period. For example, a value of 40% means that a traveler should budget an additional 8 minute buffer for a 20-minute average peak trip time to ensure 95% on-time arrival.

2.2.1.2 Urban Mobility Report by Texas Transportation Institute

Texas Transportation Institute (TTI) at Texas A&M University has been publishing Urban Mobility Reports annually since 1982. The Urban Mobility Report (UMR) procedures provide estimates of mobility at the area wide level. The approach that is used describes congestion in consistent ways allowing for comparisons across urban areas or groups of urban areas.

Until 2009, the UMR methodology used a set of estimation procedures and data provided by state DOT's and regional planning agencies to develop a set of mobility measures. Since 2010 the UMR is being prepared in partnership with INRIX, a leading private sector provider of travel time information for travelers and shippers. The travel speed data addresses the biggest shortcoming of previous editions of the UMR – the speed estimation process. UMR methodology uses the following input data to calculate the congestion performance measures for each urban roadway section:

- Volume and roadway inventory data from FHWA's Highway Performance Monitoring System (HPMS)
- INRIX's speed data
- National congestion constants like vehicle occupancy, average cost of time, etc.

The report calculates several congestion performance measures and ranks the urban areas based on the following measures:

- **Yearly delay per auto commuter** – the extra time spent traveling at congested speeds rather than at free-flow speeds.
- **Travel Time Index** – the ratio of travel time in the peak period to travel time at free-flow conditions. A Travel Time Index of 1.30 indicates a 20-minute free-flow trip takes 26 minutes in the peak period.
- **Wasted fuel** – extra fuel consumed during congested travel.
- **Congestion cost** – the yearly value of delay time and wasted fuel.

2.2.1.2 National Traffic Scorecard by INRIX

INRIX is a private provider of vehicle probe data which combines real-time data from traditional sensors, a crowd-sourced network of over 4 million GPS-enabled vehicles, historical traffic speeds database and hundreds of other traffic impacting factors like accidents, construction and other local variables.

INRIX has been publishing National Traffic Scorecard annually since 2007. These reports analyze and compare the status of traffic congestion throughout the top 100 metropolitan markets in the U.S. and the nation as a whole. The scorecards identify top congested metros, worst traffic bottlenecks and traffic trends and patterns using the following performance measures:

- **Travel Time Tax** – the percentage of extra travel time (vs. free flow) a random trip takes in the specific region and time period analyzed. A 10% tax means 10% additional trip time due to congestion.
- **Congested Hours** – is the number of hours of the week when a road segment's average hourly speed is half or less than its uncongested speed.
- **Bottleneck Factor** – is computed as the number of hours of congestion divided by the average speed when congested. This factor combines both the amount of time a road segment is congested and the intensity of congestion during those periods.

2.2.2 State DOT Practices

2.2.2.1 Florida Department of Transportation

In 2000, Florida DOT developed a framework for performance measurement designed to characterize mobility in a manner understandable to the general public and decision makers. The recommended mobility performance measures reflect mobility from the users' perspectives, based on the following:

- The quantity of the travel (number of persons served)
- The quality of travel (travelers' satisfaction with travel)
- The accessibility of travel (ability to reach the destination and mode choice), and
- The utilization of a facility or service (the quantity of operations with respect to capacity)

The mobility performance measures for Florida are currently being revised. **Table 2-1** illustrates the draft recommended mobility performance measures for transportation system reporting.

Table 2-1 DRAFT Recommended Mobility Performance Measures for Transportation System Reporting

	Mode	Quantity	Quality	Accessibility	Utilization
People	Highway	Vehicle miles traveled	Average travel speed	% population within 30min of jobs	Vehicles per lane mile
		Person miles traveled	Delay		% miles heavily congested
			Travel time reliability index		% travel heavily congested
			% travel meeting LOS standards		Hours heavily congested
			% miles meeting LOS standards		
	Aviation	Passengers	Departure reliability	Highway adequacy (LOS)	Demand to capacity ratios
				% population within 30min drive time	
	Rail	Passengers		% population < X time or distance	
	Seaport	Passengers		Highway adequacy (LOS)	
	Transit	Ridership	Average headway		
		Passenger miles			
	Pedestrian		Level of Service (LOS)	Sidewalk coverage	
	Bicycle		Level of Service (LOS)	Bike lane/shoulder coverage	
Freight	Highway	Combination truck tonnage	Combination truck average travel speed		Vehicles per lane mile
		Combination truck ton miles traveled	Combination truck delay		% miles severely congested
		Combination truck miles traveled	Travel time reliability index		Combination truck Incoming/outgoing tonnage
		Truck miles traveled			
	Aviation	Tonnage		Highway adequacy (LOS)	
	Rail	Tonnage		Highway adequacy (LOS)	
				Quality rail access	
	Seaport	Tonnage		Highway adequacy (LOS)	
		Truck equivalent units			

Source: FDOT Modal Office Coordination Task Team, November 2012

2.2.2.2 California Department of Transportation

The California DOT developed a framework for performance measures based on the following criteria:

- The use of existing data sources to confirm existing activities in California's regional transportation planning organizations, wherever possible;
- The measures must be easy to use and simple to understand; and
- The measures should be measurable across all modes to the greatest extent possible.

Key highway/operational performance measures in the California DOT program include mobility and reliability which are measured using average delay per vehicle and percent variation of travel time respectively.

- Average delay per vehicle – it is used as a mobility performance measure and is derived from the difference between free-flow travel times, based on posted speeds, and the estimated travel times, based on measured or modeled speed estimates during the analysis period.
- Percent variation of travel time – Reliability is defined as the variability in transportation services between the expected and actual travel time. The percent variation, standard deviation of travel times divided by the average travel time, is used to estimate this variability. Application of this reliability measure in the cities of San Francisco and Los Angeles, and Orange and San Diego counties indicates that this variability measure may not be correlated with delays and that it depends on a number of factors, including the distance between interchanges, roadway geometries, and other factors.

2.2.2.3 Washington State Department of Transportation

Since 1988, the Washington State DOT has been collecting, analyzing, and reporting on congestion to help the public and officials better understand how congestion is evolving and what mitigation strategies are effective for improving commutes. Over the years, WSDOT has adapted and expanded its congestion reporting to include mobility and congestion relief programs in all of its strategic and performance-based reporting. WSDOT publishes quarterly and annual updates on mobility titles Gray Notebook and Annual Congestion Report respectively.

The Annual Congestion Report provides detailed analysis on where and how much congestion occurs, and whether it has grown on state highways. The report focuses on the most traveled commute routes in the urban areas, and where data are available around the state. WSDOT and University of Washington experts use a two-year span to more accurately identify changes and trends seen on the state highway system that may be missed looking at a one-year comparison.

WSDOT produces the following statewide congestion performance measures:

- Total Statewide Delay
- Per Person Delay
- Percentage of the State Highway System Delayed and Congested
- Vehicle Miles Traveled

WSDOT produces the following additional congestion performance measures for its major urban areas:

- 95% Reliable Travel Times
- Percentage of days when speeds were less than 36 mph
- HOV Lane reliability standard

- HOV Lane travel times

2.2.3 MPOs/Local Government Practices

2.2.3.1 Chicago Metropolitan Agency for Planning

Chicago Metropolitan Agency for Planning (CMAP)'s Congestion Management Process (CMP) provides an ongoing, systematic method of managing congestion that provides information about both system performance and potential alternatives for solving congestion-related problems. CMAP's use and continual development of a regional CMP will help advance the quality of life and mobility goals described in the comprehensive regional plan. In order to be effective, the CMP incorporates extensive monitoring of the transportation network through the use of performance measures such as the following:

- Freeway Congestion Scans
- Travel Time Index
- 95th percentile Travel Time
- Planning Time Index
- Congested Hours

2.2.3.2 MetroPlan Orlando

Each year, MetroPlan Orlando collects data from federal, state, and local sources to evaluate trends impacting the region's transportation system. Results are presented in *Tracking the Trends: A Transportation System Indicator Report* for the Orlando Metropolitan Area. The purpose of this report is to identify and evaluate transportation system trends occurring over the past several years in the Orlando Metropolitan Area. The report contains information on such transportation modes as private automobiles, transit, aviation, rail, bicycling and walking. The highway performance measures employed include:

- Vehicle Miles Traveled
- State and Local Road Mileage
- Traffic Counts

2.2.3.3 Georgia Regional Transportation Authority

Georgia Regional Transportation Authority (GRTA) publishes an annual Transportation MAP Report which sets performance measures for tracking the performance of the transportation system in Metropolitan Atlanta. Measures are organized in six general categories – Mobility, Transit Accessibility, Air Quality, Safety, Customer Satisfaction, and Transportation System Performance. These categories broadly align with the four statewide transportation goals – supporting economic growth and competitiveness, ensuring safety and security, maximizing the value of transportation assets, and minimizing impact on the environment. The performance measures are:

- Freeway Travel Time Index

- Freeway Planning Time Index
- Freeway Buffer Time Index
- Daily Vehicle Miles Traveled per person or driver
- Pavement Condition Rating
- Transit Passenger Miles Traveled, and
- Annual Transit Passenger Boardings

2.2.3.4 North Florida Transportation Planning Organization

The North Florida Transportation Planning Organization (TPO) is the independent regional transportation planning agency for Duval, Clay, Nassau and St. Johns counties. The TPO's Congestion Management System identifies congested state roadway segments and corridors, and ways to reduce or minimize congestion that do not involve building more lanes or adding new roads. This list is updated on a five-year cycle with data collection, planning studies, improvement projects and monitoring in the interim.

Three types of measurements are used to identify congested roadways:

- Roadway Length
- Volume to Capacity Ratio
- Vehicle Miles Traveled

Recently the TPO approved Blue Toad technology to be deployed throughout the region and once deployed it will provide real time travel data. Two hundred sixty (260) sensors will be deployed virtually covering the entire region. The merits of this technology include the ability to collect real time data, to integrate with dynamic message signs, and the opportunity to produce an annual congestion report.

2.2.4 Travel Time Reliability

Traditionally, agencies have concentrated on mitigating recurring congestion by comparing demand and capacity during the peak periods and by removing those bottlenecks. However, congestion is often due to other sources, such as crashes, work zones, and adverse weather conditions. Therefore, new approaches and performance measures are needed to mitigate congestion considering those non-recurring events.

One of the key principles that the FHWA has promoted is that the measures used to track congestion should be based on the travel time experienced by users of the highway system. While the transportation profession has used many other types of measures to track congestion (such as level of service), travel time is a more direct measure of how congestion affects users. Travel time is understood by a wide variety of audiences – both technical and non-technical – as a way to describe the performance of the highway system.

Travel time reliability allows agencies to evaluate the performance of a facility beyond just the peak hour, and to consider operations over a longer period of time considering non-recurring events. Travel time reliability is defined as how much travel times vary over the course of time. Travel time reliability is significant to many transportation system users, whether they are vehicle drivers, transit riders, or freight shippers. Personal and business travelers value reliability because it allows them to make better use of their own time. Shippers and freight carriers require predictable travel times to remain competitive. Reliability is a valuable service that can be provided on privately-financed or privately operated highways. Because reliability is so important for transportation system users, travel time reliability should be considered as a key performance measure.

2.2.4.1 FHWA Measures of Travel Time Reliability

Through its research, FHWA recommends the use of four measures – 90th or 95th percentile travel time, buffer index, planning time index, and frequency that congestion exceeds some expected threshold. Because reliability is defined by how travel times vary over time, it is useful to develop frequency distributions to see how much variability exists. Calculating the average travel time and the size of the "buffer" – the extra time needed by travelers to ensure a high rate of on-time arrival – helps to develop the reliability measures. They are all based on the same underlying distribution of travel times, but describe reliability in slightly different ways:

- 90th or 95th percentile travel time
- Planning Time Index – How much larger the buffer is than the "ideal" or "free flow" travel time (the ratio of the 95th percentile to the ideal). For example, a planning time index of 1.60 means that, for a 15-minute trip in light traffic, the total time that should be planned for the trip is 24 minutes.
- Buffer Index – It represents the extra buffer time (or time cushion) that most travelers add to their average travel time when planning trips to ensure on-time arrival. For example, a buffer index of 40 percent means that, for a 20-minute average travel time, a traveler should budget an additional 8 minutes to ensure on-time arrival most of the time.
- Frequency that congestion exceeds some expected threshold – This is typically expressed as the percent of days or time that travel times exceed X minutes or travel speeds fall below Y mph. The frequency of congestion measure is relatively easy to compute if continuous traffic data is available, and it is typically reported for weekdays during peak traffic periods.

2.2.4.2 FDOT and Travel Time Reliability

FDOT (2000) developed and documented the Florida Reliability Method in which they defined reliability on a highway segment as the percent of travel that takes no longer than the expected travel time plus a certain acceptable additional time. They define three major components of reliability: travel time, expected travel time, and acceptable additional time.

- Travel time – the time it takes a typical commuter to move from the beginning to the end of a corridor.

- Expected travel time – the median travel time across the corridor during the time period being analyzed.
- Acceptable additional time – the amount of additional time, beyond the expected travel time, that a commuter would find acceptable during a commute.

Mathematically, the acceptable travel time can be estimated as follows:

$$Accecptable\ Travel\ Time = \alpha + \Delta$$

α is median travel time

Δ is acceptable additional time, expressed as a percentage of median travel time

The percent of reliable travel time is calculated as the percent of travel on a corridor that takes no longer than this acceptable travel time. This definition defines failure clearly and quantitatively, however it relies on the median travel time, which may change over time as a function of demand. Thus this definition does not allow the tracking of reliability over time for a given facility.

Lily Elefteriadou and Xiao Cui (2005) summarized several definitions of reliability, presented some preliminary data analysis findings related to travel time and discussed the advantages and disadvantages of various definitions. Based on their findings, they summarized that two different performance measures related to reliability could be developed:

- A performance measure which would be appropriate for use by an agency to monitor the performance of various facilities; and
- A performance measure appropriate to be ultimately provided to travelers for estimating travel times between a given origin and a given destination.

FDOT's research projects on travel time reliability since 2005 (FDOT Contracts BD545-48, BD545-70, BD545-75, BDK77 977-02 and BDK 77 931-04) developed tools for predicting travel time reliability for freeways to assist in the project prioritization and selection process. The latest research effort (FDOT Contract BDK77 977-10, March 2012) made improvements to the freeway travel time reliability method, developed a new arterial travel time reliability method and proposed a framework for considering travel time reliability in a multimodal context. Improvements in the freeway travel time reliability method include two performance measures – Travel Time Index and Planning Time Index. Arterial travel time estimation models were developed using the simulation program CORSIM.

2.2.5 Summary of Contemporary Practices

The research conducted in the field of traffic congestion and bottlenecks helped in the development of various mobility performance measures. FHWA, Texas Transportation Institute and others have developed national performance reports to analyze national mobility. State DOTs, MPOs and local governments have adopted some of the performance measures depending on their local and regional needs. **Table 2-2** summarizes how the parameters are defined among the various procedures.

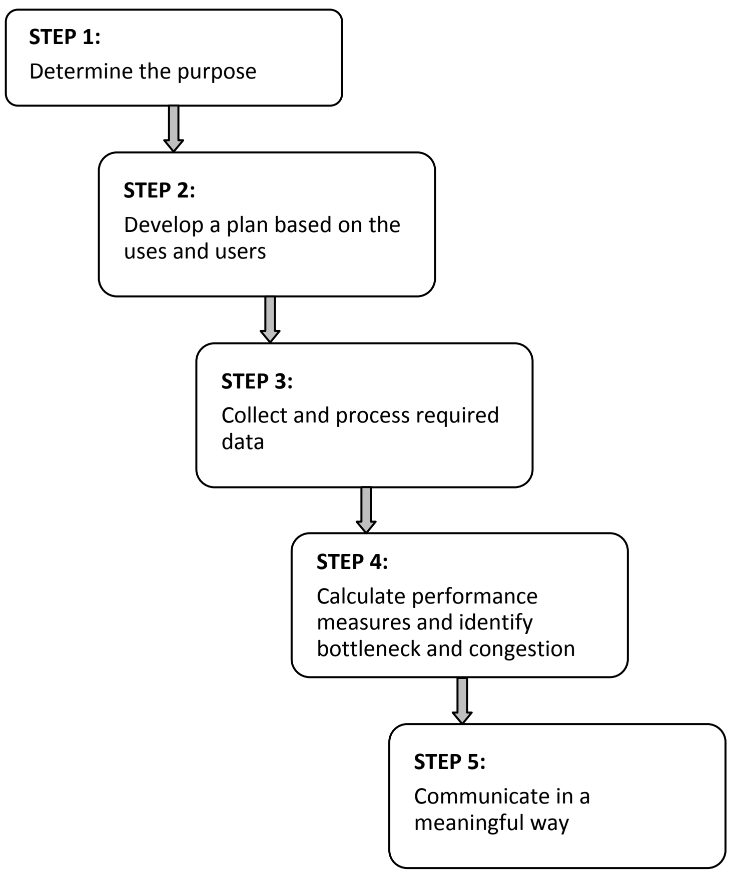
Table 2-2 Comparison of parameters between various procedures

Parameter	FHWA	Texas Transportation Institute	INRIX	FDOT Reliability Model
Peak Period	6 – 9 am; 4 – 7 pm	6 – 10 am; 3 – 7 pm	6 – 10 am; 3 – 7 pm	4 – 7 pm
Free-Flow Speed	85th percentile speed during weekday off peak (9 am – 4 pm and 7 – 10 pm) and weekend (6 am – 10 pm)	85th percentile speed during overnight hours (10 pm – 5 am)	85th percentile speed during overnight hours (10 pm – 5 am)	Posted speed limit plus 5 mph
Congested Conditions	Speed less than 45 mph	Based on Travel Time Index	Speed less than 50% of free-flow speed	Speed less than 10 mph of free-flow speed

2.3 Bottleneck Identification Methodology

Historically, the most common measures of congestion used by agencies were volume-to-capacity ratio, vehicle hours of delay and mean speed. Recent research efforts including those by FDOT identify the importance of using travel time and reliability as measures of congestion. FHWA provides a methodical approach for agencies considering adoption of reliability measures. This methodology was used as the basis and adapted to identify the bottlenecks and congestion on Florida's SIS network. This section describes this process in further detail. **Figure 2-2** presents the flowchart describing the approach that can be used to identify the bottlenecks and congestion.

Figure 2-2 Methodology to Identify Bottleneck and Congestion



STEP 1: Determine the purpose

During the project kick-off meeting, it was identified that the primary purpose of identifying bottlenecks would be for planning purposes. The bottlenecks should be identified using maps on a statewide or district level to accommodate multiple audiences. The resulting product should be easy to understand and interesting to read.

STEP 2: Develop a plan based on the uses and users

After identifying the intended uses and users, a plan that outlines various elements related to collecting data, calculating measures, and reporting results is developed. The plan is developed based on the following sets of parameters:

- Auto mode along the general purpose lanes and high-occupancy-vehicle (HOV) lanes will be considered.
- Bottlenecks will be identified based on weekday travel patterns along the SIS network. For the purpose of bottleneck identification, weekday is considered as Monday through Friday.
- Vehicle probe data from INRIX will be used for obtaining the travel times along the SIS network.
- Travel time reliability measures will be used for identifying bottlenecks.
- Quarterly trends of travel time reliability measures will be prepared.

STEP 3: Collect and process required data

Vehicle probe data provided by INRIX will be used for identifying the bottlenecks.

STEP 4: Calculate performance measures and identify bottlenecks

The parameters required to calculate the performance measures and identify the bottleneck are listed below:

- **90th percentile travel time** – Compute the 90th percentile travel time during weekdays (6 am to 7 pm) for each quarter of the year.
- **Free-flow travel time** – Compute the free-flow travel speed as the 85th percentile speed for all days of year during overnight period (10 pm to 5 am). The free-flow travel time can be computed from the free-flow travel speed.

  Concern has been expressed in literature as well as by the FDOT staff whether the 85th percentile speeds represents the free-flow conditions on arterials and freeways consistently. Traffic on the arterial streets behave very differently from traffic on the freeways since many other outside elements, in addition to traffic levels, control how the traffic flows. These other factors include such items as signal timing plans, signal density, driveway density, and access management features such as raised medians. During overnight hours when fewer vehicles are on the roadway, arterial streets may have different free flow speeds than during daylight hours when different signal timing plans are used. Progression along a corridor may be enhanced by additional green time during peak operating conditions, which changes the free flow speeds for the street.

  The results from the INRIX data have been analyzed for SIS arterials and it was observed that the 85th percentile speed for arterials is consistent with the free-flow speed on these roadways. As such, 85th percentile speed has been defined as the free-flow speed for arterials as well as freeways.

- **Planning time index** – Compute the planning time index during weekdays (6 am to 7 pm) for each quarter of the year. This is calculated by dividing 90th percentile travel time by the free-flow travel time. If the planning time index is less than 1.00, round the index value up to 1.00.

- **Frequency of congestion** – Compute the percent of time during the weekdays (6 am to 7 pm) when travel speeds are 75 percent of the free-flow travel speed. This measure is computed for each section of the network for each quarter of the year.

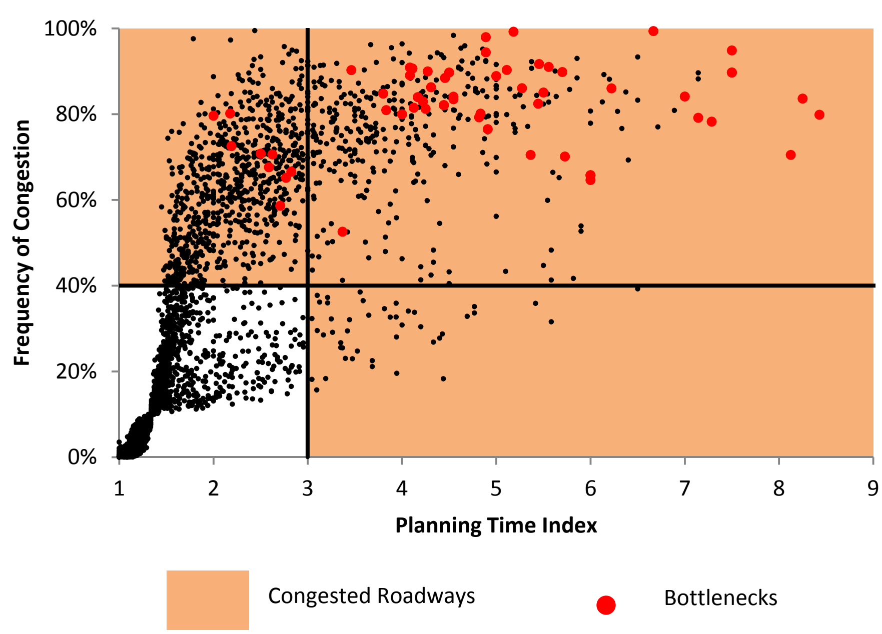
- **Congested Roadways** – The portions of the roadway network with planning time index greater than 3.0 (for freeways) and 2.0 (for arterials) or frequency of congestion greater than 40 percent are identified as congested roadways.

  If the frequency of congestion on a TMC segment is greater than 40 percent, it indicates that the speeds on that segment are less than 45 mph (for freeways with 60 mph speed limit) and 30 mph (for arterials with 45 mph speed limit) for a minimum of 5 hours during the day. This would identify roadway segments that have slower speeds at a minimum during the morning and evening peak periods. As such, the frequency of congestion greater than 40 percent was considered as a criterion for identifying congested roadways.

  The higher the planning time index, the higher the time travelers need to plan for reaching their destinations on time. As explained earlier, traffic on the arterial streets behave very differently from traffic on the freeways. As such, different thresholds for planning time index were selected for freeways and arterials for identifying congested roadways.

- **Bottlenecks** – The portion of the congested roadway network which has the highest combination of planning time index and frequency of congestion is identified as a bottleneck.

Figure 2-3 Illustration of Congested Roadways and Bottlenecks



STEP 5: Communicate in a meaningful way

Once performance measures have been calculated and bottlenecks are identified, the results are be displayed in easy-to-understand tables and graphics that meet the needs of your users and uses as identified in Step 1.

2.4 Details of INRIX Data Processing

FDOT purchased vehicle probe date from INRIX along Florida's roadways at five minute intervals from July 2010 to June 2011. This section provides details on INRIX data processing for determining the traffic bottlenecks on Florida's SIS.

Step 1: Initial Processing

The data obtained from INRIX was for the whole state of Florida. This data was processed to extract the vehicle probe data for SIS facilities only. The following three steps were performed before conducting detailed analysis.

- The original raw file from INRIX for the whole state of Florida contained 711,351,697 vehicle probe data records. Data for the SIS facilities only was identified and extracted from the statewide data which resulted in 293,372,069 vehicle probe data for further processing.
- The original vehicle probe data from INRIX was provided in Coordinated Universal Time (UTC) standard. These universal times were converted to Florida local time including the adjustment for the daylight savings time.
- Next, the data was formatted to a format convenient for conducting analysis using Oracle.

Step 2: Calculate Performance Measures

In order to calculate the performance measures, the following parameters were defined:

- Valid weekday – is defined as any weekday excluding holidays (listed below)
- Daytime – is defined as the time from 6 am to 7 pm
- Overnight hours – is defined as the time from 10 pm to 5 am
- Holidays – the following days are considered as holidays: Independence Day (07/05/10), Labor Day (09/06/10), Columbus Day (10/11/10), Veterans Day (11/11/10), Thanksgiving Day (11/25/10), Thanksgiving Friday (11/26/10), Christmas Day (12/24/10), New Year's Day (12/31/10), Martin Luther King, Jr. Day (01/17/11), Washington's Birthday (02/21/11), Memorial Day (05/30/11).

The processed data obtained from step 1 was analyzed using Oracle software and the following measures were calculated.

- Number of Observations [COUNT_OBSERVATIONS] – this measures the number of data records for each TMC segment for the whole year.

- Daytime 10^{th} Percentile Speed [SPD_PCTILE_10_DAYTIME] – this measures the 10^{th} percentile speed for valid weekdays during daytime for each TMC segment for the whole year. This is also equivalent to the 90^{th} percentile travel time.

- Free-flow Speed [FF_SPD] – this measures the 85^{th} percentile speed for all 365 days during overnight hours for each segment.

- Daytime Planning Time Index [PTI_DAYTIME] – this measure is calculated for each TMC segment for the whole year using the following formula. If the calculated PTI_DAYTIME value is less than 1.0, then the index value is rounded up to 1.0.

  - PTI_DAYTIME = $\frac{FF\_SPD}{SPD\_PCTILE\_10\_DAYTIME}$

- Frequency of Congestion [FREQ_CONG] – this measures the percent of time that the travel speeds are less than 75 percent of the free-flow speed. This measure is calculated for valid weekdays during daytime hours.

Step 3: Statistical Validation of Performance Measures

Since the vehicle probe data was obtained from INRIX for every five minute interval, ideally there would be a speed recorded every 5 minutes on each traffic segment. The maximum theoretical count, if there were 1 record for each 5 minute time period, would be 105,120. However, the number of records for a given TMC segment in the data varied widely. The number of records for each TMC ranged from as small as 7 records to as high as 101,722 records for the whole year.

Since the INRIX data included a large sampling of the vehicle speeds on Florida's SIS, a statistical validation of the calculated performance measures is essential. The margin of error is a statistic expressing the amount of random sampling error in a survey's results. With large margin of error, it is anticipated that the confidence in the survey's results is less. Margin of error occurs whenever a population is incompletely sampled.

For the INRIX vehicle probe data, margin of error for two performance measures – free-flow speed and daytime 10^{th} percentile speed – are calculated. The TMC segments for which the margin of error is greater than 10 percent are not accounted for in the estimation of traffic bottlenecks. As a result, 211 TMC segments out of 6,293 SIS TMC segments did not meet the statistical validation.

2.5 Conclusion

This technical memorandum summarized the research efforts in the field of traffic congestion and bottlenecks and presented the various mobility performance measures used by agencies to quantify congestion. Using this information, a methodology to identify bottlenecks and congestion on Florida's Strategic Intermodal System (SIS) network is recommended.

The next steps include applying the recommended methodology and identify the bottlenecks along SIS network using INRIX vehicle probe data. The bottlenecks identified along the SIS network using the methodology presented in this technical memorandum are summarized in a brochure and submitted separately.

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