The Use of Data in Planning for Operations: State-of-the-Practice Review

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FOREWORD

Planning for operations provides the foundation for proactively operating the transportation system. It is a joint effort between planners and operators to improve transportation system performance, with a focus on the integration of management and operations strategies into planning activities. The Federal Highway Administration (FHWA) promotes the use of a performance-based approach for the integration of operations into the transportation planning and investment decisionmaking processes at metropolitan and State levels. Access to comprehensive, high-quality data on the operation of the transportation system is vital to fully applying this approach.

This report reviews the state-of-the-practice among metropolitan planning organizations in using data to support planning for operations activities. Planners and operators can use this report to generate ideas to advance their efforts to use data to plan for operations. This review was conducted at the outset of an FHWA project to develop a prototype framework for sharing planning and operations data between State and local transportation agencies from multiple sources within a region. The results of the review were used to inform the development of the framework.

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Research and Development

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16. Abstract

The purpose of this state-of-the-practice review is to identify the current use of data by metropolitan planning organizations to perform planning for operations activities. This information will be used to develop the virtual data access framework and to help establish requirements for the data that should be accessible by planning agencies via the framework. In addition to data availability and use, this review also looks at the barriers to the use of data so that the project team can design the framework to help address some of these barriers to increase use of the resulting framework. This report was developed in conjunction with another state-of-the-practice review on data access, sharing, and integration.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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CHAPTER 1. INTRODUCTION

SUMMARY OF OVERARCHING PROJECT

In 2012, the Federal Highway Administration (FHWA) initiated a 3-year project entitled "Virtual Data Access (VDA) Framework" to develop a prototype framework for sharing planning and operations data between State and local transportation agencies from multiple sources within a region. The framework will bring together many types of transportation data to give planners and operators a multifaceted view of transportation performance both over time and by location. The purpose of the VDA Framework is to improve the breadth of available data and reduce the barriers to the use of that data so that transportation agencies across a region can advance their decisionmaking and performance reporting capabilities in the area of operations. Through greater access to data collected in a region, metropolitan planning organizations (MPOs) and State transportation departments will be better equipped to conduct performance management and performance-based planning and programming as emphasized in the Moving Ahead for Progress in the 21st Century Act (MAP-21).

FHWA's project focused on using the VDA Framework to support planning for operations, including the use of data from the framework as input to planning for operations analysis and simulation tools. Planning for operations is a joint effort between planners and operators to integrate management and operations (M&O) strategies into the transportation planning process for the purpose of improving regional transportation system efficiency, reliability, and options.[1] In addition, the data will be used to support reporting operational performance measures.

The prototype framework will undergo a proof-of-concept test in the Kansas City region, where transportation operating and planning agencies have a high level of collaboration, a need for easily accessible integrated transportation operations data, and the capability to use that data for planning for operations. The framework is being developed in coordination with the proof-of-concept partners, the Mid-America Regional Council and Kansas City Scout, as well as other stakeholders from across the United States. To support the proof-of-concept test, the FHWA project team is developing a Performance Measurement and Analysis Tool (PMAT) that demonstrates one of the many options for using the integrated data from the VDA Framework. The PMAT will access public and private sources of data through the VDA Framework and calculate performance measures according to user-specified parameters. The performance measures will be displayed on a map of the region as well as through the use of data tables and charts. The PMAT will be a map-based web application that allows users to view travel time reliability, delay, and traffic volume throughput on arterials and freeways and extract calculated performance data in the form geographic information system (GIS) shape files. In addition, users will be able to export the data to Network EXplorer for Traffic Analysis (NeXTA), an analysis, modeling, and simulation (AMS) data hub that was developed by FHWA to support the exchange of data among multiple resolutions of AMS tools. The data exported from PMAT will support the analysis for operations strategies in a dynamic traffic assignment (DTA) modeling tool as part of NeXTA.

The VDA Framework and PMAT are being developed using primarily open source software and will be available to other regions to leverage. The results of the proof-of-concept test will be documented and shared as part of technology transfer webinars near the end of the project.

OBJECTIVES OF THE STATE-OF-THE-PRACTICE REVIEW

The purpose of this state-of-the-practice review was to identify current use of data by MPOs to perform planning for operations activities. This information will be used to develop the VDA framework and to help establish requirements for the data that should be accessible by planning agencies via the framework. In addition to data availability and use, this review also looks at the barriers to the use of data so that the project team can design the framework to help address some of these barriers to increase use of the resulting framework.

RELATIONSHIP TO DATA SHARING STATE-OF-THE-PRACTICE REVIEW

This report was developed in conjunction with another state-of-the-practice review on data access, sharing, and integration. The data access, sharing, and integration review focuses on current data sharing and integration practices among State and local agencies, such as data environments, technical integration formats, and business rules for integration and sharing. It supports the project by establishing a foundation of previous experiences that can be used in defining how the data integration and sharing elements of the framework are designed, whereas the planning for operations review will be used to determine the data that should be input to the framework to support common or emerging planning for operations practices.

ORGANIZATION OF STATE-OF-THE-PRACTICE REPORT

This report covers information from national literature and research in the first several chapters and then provides detailed information for eight metropolitan areas in case studies in the last half of the document. The first chapter of this report helps acquaint the readers with the purpose of the project and this report. Chapters two through four cover three key components of a performance-based approach to planning for operations that require data: monitoring system performance and tracking objectives, evaluating M&O strategies in the planning process, and assessing the impact of M&O strategies post-implementation. These three chapters contain information from national-level research and publications. Chapter five summarizes the barriers and challenges that have been identified through conversations with planning for operations practitioners and literature reviews. The last chapter contains case studies of eight MPOs and their use of data in the three key data-driven components of planning for operations: monitoring, analysis for planning, and post-implementation evaluation.

CHAPTER 2. USE OF DATA IN MONITORING TRANSPORTATION OPERATIONAL PERFORMANCE AND TRACKING PERFORMANCE OBJECTIVES

DATA NEEDS FOR MONITORING PERFORMANCE—PERSPECTIVE FROM NATIONAL LITERATURE

Monitoring the operational performance of elements of the transportation system is becoming more prevalent, particularly in large metropolitan areas on freeways. Transportation agencies in major metropolitan areas often have large amounts of archived or real-time data collected through road sensors and their central control systems, although there are significant limitations to the use of this data for performance monitoring.(2) Typically, the sensors cover a limited portion of the freeway network, and the failure rate for in-pavement and roadside traffic sensors is high (e.g., 35 percent for the California Freeway PeMS loop detectors). In addition, arterial roads are either not covered by these sensors or the data collected is not useful for travel-time analysis.(2)

The recent emergence of probe data is creating more opportunities for transportation operating agencies and MPOs to monitor and analyze travel times according to elements of the network and routes and to aggregate origin-destination (O-D) travel times geographically. In 2013, FHWA made a national set of average travel time probe data freely available to States and MPOs to use for their performance management activities. This data set is referred to as the National Performance Management Research Data Set. There are also several commercial probe data systems available based on cell phone location, Global Positioning System (GPS)-equipped vehicles (usually fleets), and cell phones or other personal devices with GPS systems.(2) Prior to the release of the National Performance Management Research Data Set, data from these systems were typically only available for purchase through the private sector. Instead of purchasing this data, one of the MPOs interviewed for this state-of-the-practice review found it much more cost effective to deploy its own sensors.

As outlined in *SHRP2 L05 Incorporating Reliability in the Transportation Planning Process – Technical Guidance*, data used to monitor current travel time reliability conditions and examine past reliability trends by planning and operating agency departments include the following:(3)

- Automated spot traffic data (e.g., loop, acoustic, radar traffic detectors) including volume, speed, occupancy and other data[.]
- Travel time data (probe data)[.]
- Incident logs[.]
- Crash data[.]
- Operational data (e.g., logs of messages displayed on variable message signs, 511 calls or alerts)[.]
- Weather data.

On the national level, the Texas Transportation Institute (TTI) produces the *Urban Congestion Report* for FHWA on a quarterly basis to disseminate congestion and reliability trends for the United States as a whole and for cities with freeways instrumented with traffic sensors.(4) The report provides results for three primary operations performance measures: congested hours, travel time index, and planning time index. Table 1 contains the definitions of these key performance measures and the input data for the measures.

Table 1. FHWA urban congestion report performance measures and input data.(4)

Performance Measure	Definition	Input Data
Congested hours	The average length of time each day that roads in a particular city are congested.	• Five-min section-level speeds and vehicle-miles traveled (VMT).
Travel time index	The extra time spent in traffic during peak traffic times as compared to light traffic times. In mathematical terms, it is the peak travel time divided by the free-flow travel time. If using speed in calculations, it is the free-flow traffic speed divided by the peak traffic speed. Both calculations will yield identical travel time index values.	• Average free-flow speeds for each section during off-peak times. • Five-min section-level speeds and VMT for peak traffic periods (6–9 a.m., 4–7 p.m.).
Planning time index	The extra time cushion needed during peak traffic periods to prevent being late. In mathematical terms, it is the near-worst case travel time (95th percentile) divided by the free-flow travel time. If using speeds in calculations, it is the free-flow traffic speed divided by the near-worst case traffic speed (5th percentile).	• Average free-flow speeds for each section during off-peak times. • Five-min section-level speeds and VMT for peak traffic periods (6–9 a.m., 4–7 p.m.).

The National Transportation Operations Coalition developed a set of 12 key operations performance measures in 2005, and in 2007, those measures were pilot tested and refined for National Cooperative Highway Research Project 20-7, *Guide to Benchmarking Operations Performance Measures*.(5) The report was developed by the University of Maryland in 2008 and documents the pilot testing and review by State transportation departments, cities, and MPOs and the resulting set of performance measures. The refined set of operations performance measures include the following:(5)

- Customer satisfaction.
- Extent of congestion—spatial.
- Extent of congestion—temporal.
- Incident duration (i.e., the time elapsed from the notification of an incident until all evidence of the incident has been removed from the incident scene).

- Recurring delay vehicle.
- Speed.
- Throughput.
- Travel time.
- Travel time—reliability.
- Travel time—trip.

The pilot test sites also tested data collection and compilation procedures, and the report contains a pertinent table showing the data collection method, basic data obtained from the data collection method, and the performance measure that the data collection supported. The table from this report is presented in figure 1.

Contrast of Data Collection Methods

						Performance Measures Supported								
Method	Sub-Method	Base Measurements	Typical Sampling Parameters	Free-way Use	Arterial Use	Speed	Travel Time	TT - Reliability	Recurring Delay	Non-Recurring Delay	Extent of Congestion	Throughput	Costs	Primary Deployment Issues
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
	Oval 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		
Float-ing car	GPS instru-mented	Travel time	8-10 runs per year, per corridor	✓	✓	x	x		x		x		Budget $300 to $500 per mile	Minimum sampling parameters
Ve-hicle Probe	Toll-tag transpon-der	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 minute	✓	?	x	x	x	x	x	x		$50-$1000/ mile/year	Data latency and sampling density
	Cell phone probes		1-10 minute	✓	?	x	x	x	x	x	x		$500-$1000/ mile/year	Accuracy, privacy, and business model sustainability

Figure 1. Chart. Data collection methods to support operations performance measures.[(5)]

The data needed to support key traffic incident management (TIM) performance measures—including roadway clearance time, incident clearance time, and secondary crashes, as well as the data needed to support TIM modeling and analysis as defined in the 2012 FHWA report, *Analysis, Modeling, and Simulation for Traffic Incident Management Applications*—is listed as follows:(6)

- Incident type (crash, disabled vehicle, fire, debris, abandoned vehicle).
- Incident collision type (fixed object, overturn, vehicle/side, vehicle/head-on, vehicle/rear-end).
- Incident "timeline" data (time stamps for start of incident, detection, verification, on-scene arrival, lane/shoulder open, all clear).
- Incident severity (KABCO injury scale).
- Incident location (route, travel direction, milepost or GPS coordinates).
- Incident blockage.
    - Cross section feature affected (lane, partial lane, right shoulder, left shoulder, median, off maintained way)[.]
    - Lane type (through/general purpose, through/high-occupancy vehicle (HOV), auxiliary, on-ramp, off-ramp)[.]
    - Begin/end time.
- Number of involved vehicles.

CHAPTER 3. EVALUATING M&O STRATEGIES IN PLANNING

M&O STRATEGIES CURRENTLY EVALUATED

In general, it is not yet common practice among MPOs to quantitatively evaluate and forecast the potential impacts of M&O strategies on transportation system performance, safety, and other measures. The majority of cases that were examined for this review did not forecast impacts of M&O strategies as part of the planning process. The examples of M&O strategy evaluation were primarily performed as part of a Federal initiative, such as an integrated corridor management (ICM) AMS study or an FHWA AMS data integration project. A notable exception was the Bay Area Metropolitan Transportation Council (MTC), which used an activity-based model to evaluate express lanes, congestion pricing, intelligent transportation systems (ITS) improvements, HOV and bus rapid transit, and contraflow lanes. In addition, MTC was involved in the evaluation of signal optimization, freeway service patrols, and transit and travel demand management (TDM) improvements.

Through an FHWA AMS data integration project, the Portland, OR, MPO (Metro) evaluated ITS improvements, signal systems, ramp meters, and transit and truck priority along a corridor.(7) The San Diego Association of Governments (SANDAG) is continuing to use the modeling approach from the ICM AMS work to evaluate proposed operations improvements on other corridors.

OVERVIEW OF DATA NEEDS FOR ANALYSIS TOOLS AND METHODS

Many different tools and methods are available to support the quantitative analysis of M&O strategies in planning and programming, and most of the MPOs interviewed for this state-of-the-practice review reported that they were initiating or advancing their use of tools for evaluating M&O strategies to support planning and investment decisions.

Using the categories established in FHWA's *Applying Analysis Tools in Planning for Operations* brochure, the following tools can be used for analyzing M&O strategies:(8)

- Sketch planning and prioritization tools.
- Travel demand models.
- Analytical and deterministic tools (*Highway Capacity Manual* (HCM) based).
- Simulation models including microscopic, mesoscopic, and macroscopic models.
- Traffic signal optimization tools.

In addition, archived operations data can be used to analyze M&O strategies. More advanced analysis methods are being studied and integrated into operations modeling and analysis, including the following:

- DTA.
- Multiscenario methods.
- Multiresolution modeling.

Currently, only multiresolution or multiscenario analysis methods have the capability to analyze all of the M&O strategies commonly recognized.[9] The M&O strategies that may be analyzed by a specific tool or methodology are shown in figure 2 from the 2012 FHWA *Operations Benefit/Cost Analysis Desk Reference*, which provides additional information on each of the tools listed in the figure.[9]

Tool/Methodology	Travel Demand Management	Public Transit Systems	Arterial Traffic Management	CVO	HOT Lanes	Freeway Management Systems	Incident Management Systems	Regional Multimodal Traveler Info	Work Zone Management
BCA.net			●			●			
Cal-B/C		○	●		●	●	●	●	
COMMUTER Model	●								
EMFITS			●			●	●	●	○
FITSEval			●			●	●	●	
HERS-ST (Preprocessor)			●			●	○		
IDAS	●	○	●	●	●	●	●	●	●
IMPACTS	○		○		○				
Multiresolution/ Multiscenario Methods	●	●	●	●	●	●	●	●	●
NET_BC									
SCRITS			●		●	●	●	●	
STEAM			●			●	●	●	
TOPS-BC	○	○	●	○	●	●	●	●	●
TRIMMS	●	●							

● Addresses most elements of strategy ○ Addresses some elements of strategy

Figure 2. Chart. Capability of analysis tools/methodologies to address M&O strategies.[9]

The FHWA Operations Benefit/Cost Analysis Desk Reference and the Strategic Highway Research Program 2 (SHRP2)—L05 *Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes: Technical Reference* both contain the same three broad categories of analysis tools and methods: sketch planning methods, post-processing methods, and simulation (or multiresolution and multiscenario) methods.[9,3] The SHRP2—L05 report also contains a fourth category, monitoring and management tools and methods, which is not included in this discussion because those tools and methods primarily focus on assessing past conditions. Sketch planning methods have fairly limited data requirements, whereas post-processing methods require more specific data, and simulation (or multiresolution and multiscenario) methods have more comprehensive data requirements.

The SHRP2—L05 report, *Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes: Technical Reference*, provides a summary of the input data needed for each major type of analysis tool or method.(3) The descriptions of the general needs are followed by examples that illustrate the specific use of data for analyzing M&O strategies as part of the planning, programming, or project development phase prior to implementation of the strategies.

Sketch Planning Methods: Input Data

Most sketch-planning methods can be used when only limited data is available. They require segment free-flow speed and distance at the most basic level. Average travel time is input as the next step, and the travel time can be obtained through measuring it in the field, extracting it from a model, or estimating it based on segment volume and capacity.(3)

Postprocessing Methods: Input Data

The input data needed for model postprocessing methods includes link-level data available from most regional travel demand models or simulation models. These data include basic facility capacities, basic geometric data, and loaded roadway volumes that may represent peak hour, peak period, or daily analysis. Information on the probability of various weather conditions (e.g., number of days or year of rain) and road work is needed for assigning weights to scenarios if multiscenario approaches are used.(3)

Simulation or Multiresolution and Multiscenario Methods: Input Data

At a minimum, simulation or multiresolution and multiscenario methods require a regional travel demand model as well as the data needed to develop and calibrate a simulation model. The data required for a simulation model generally include detailed roadway geometry, traffic signal timing, and discrete data on travel speeds and volumes. A condition occurrence distribution for a multiscenario analysis would require archived data on demand, incidents, and weather as well as the distribution of the likelihood of each scenario.(3)

DATA NEEDS AND USE IN AMS OF SPECIFIC M&O METHODS OR STRATEGIES

There are a few national transportation publications that have recently been issued or drafted that address AMS techniques for more specific M&O strategies or transportation management methods, including FHWA's *Analysis, Modeling, and Simulation for Traffic Incident Management Application*; the U.S. Department of Transportation's (USDOT) *Traffic Analysis Toolbox Volume XIII: Integrated Corridor Management Analysis, Modeling, and Simulation Guide*; USDOT ITS Joint Program Office's *Use of Mobile Data for Weather-Responsive Traffic Management Models*; and FHWA's *Assessing the Effectiveness of Transportation Management Plan (TMP) Strategies*. (See references 6, 10, 11, and 12.) The following sections provide information on the data needs for analyzing the potential impacts of TIM strategies and ICM.

Data Needs in AMS of TIM

The FHWA report *Analysis, Modeling, and Simulation for Traffic Incident Management Application* provides pertinent information regarding data needs for evaluating TIM strategies using several types of models: sketch planning models, deterministic (HCM-type macroscopic) models, mesoscopic simulation models, and microscopic simulation models, as shown in figure 3.(6) Again, the sketch planning models have fairly low data requirements, whereas the mesoscopic and microscopic models are much more data intensive. One of the primary improvements in TIM AMS applications recommended by the authors is the need for a data dictionary and guidelines to ensure consistent data collection and archiving of TIM data to enable comparisons and data integration across agencies.(6)

Model Type	Network	Demands	TIM	Calibration
Sketch Planning Models	Minimal. Generally deals with regional VMT and VHT.	Minimal. Generally regional VMT.	General categories of TIM strategies. No specific implementation details.	Not applicable.
Deterministic (HCM Type Macroscopic) Models	Link and intersection-specific lane geometry, speed limits, controls (signal timing).	Link and intersection-specific hourly demands by vehicle type (usually just peak hour).	Incident types (number of lanes locked, specific links affected, and average duration). Strategies to be tested and expected effects on average lane blockage durations.	Not generally done.
Mesoscopic Simulation Models	Same as deterministic HCM.	OD tables by hour of day for peak periods.	Same as for deterministic HCM.	Observed flows and link speeds.
Microscopic Simulation Models	Same as HCM plus signal detector locations, signal controller settings, turn pocket lengths.	Same as mesoscopic or link and intersection-specific demands by vehicle type.	Incident start/end times, longitudinal location within link. Expected effect of strategies on specific incident duration.	Observed flows and link speeds.

Figure 3. Chart. Data needs for each model type to analyze TIM strategies.(6)

Data Needs and Use in AMS of ICM

Recently, USDOT developed an AMS methodology for use in evaluating and forecasting the impact of ICM on several key integrated corridor performance measures: delay, travel time reliability, and throughput. This methodology has been demonstrated by three ICM sites in the United States: San Diego, CA; Dallas, TX; and Minneapolis, MN. ICM integrates transportation management techniques across facilities and modes along a corridor to balance demand, coordinate management strategies, reduce congestion, and improve the overall operational performance of the corridor. The methodology required to assess the effects of ICM is significantly more complex than traditional transportation investments. The assessment of ICM typically includes freeways and arterials as well as multiple modes and potentially road or parking pricing strategies. In addition, the impacts of ICM need to be evaluated in several operations scenarios, including incidents, weather, special events, and other non-recurring events that disrupt normal travel conditions. The ICM AMS methodology is flexible and requires significant tailoring to meet the needs of individual corridors. The methodology integrates up to three classes of modeling tools (microscopic, mesoscopic, and macroscopic) as well a mode shift model and a transit travel time estimation model, interfaces between the tools, and a performance measurement or benefit-cost module.[10]

The ICM AMS methodology has substantial requirements for data that is high-quality, reliable, and collected continuously for at least 6 to 12 mo. The data should be collected from all sources during the same time period. Archived data sources are generally preferred over manually collected data, and data collected during different operational conditions allow greater opportunity to model the impacts of ICM during different operational scenarios. Long-term archived data enables congestion patterns over many days to be analyzed.[10]

USDOT's *Traffic Analysis Toolbox Volume XIII: Integrated Corridor Management Analysis, Modeling, and Simulation Guide* contains an extensive list of sample data requirements for conducting AMS for ICM, as seen in figure 4.[10]

Network	Travel Demand	Traffic Control	Transit	ITS Elements
• Link distances • Free-flow speeds • Geometrics-freeways ○ # Travel lanes ○ Presence of shoulders ○ # HOV lanes (if any) ○ Operation of HOV lanes ○ Accel/Dec lanes ○ Grade ○ Curvature ○ Parking ○ Ramps • Geometrics-arterials ○ Number of lanes ○ Lane usage ○ Length of turn pockets ○ Grade ○ Turning restrictions • Parking ○ Parking facilities – Location – Capacity ○ Park-and-ride lots – Location – Capacity	• Link volume • Traffic composition • On- and off-ramp volumes • Turning movement counts • Vehicle trip tables • Person trip tables • Transit ridership	• Freeways ○ Ramp metering – Type (local, system-wide) – Detectors – Metering rates – Algorithms (adaptive metering) ○ Mainline control – Metering – Lane use signals – Variable speed limits • Arterials ○ Signal system description – Controller type – Phasing – Detector type and placement – Signal settings – Signal timing plans ○ Transit signal priority system – Control logic – Detection – Settings ○ Emergency preemption system – Control logic – Detection – Settings	• Transit routes ○ Transit stops – Location – Geometrics – Dwell times ○ Transit schedules – Schedule adherence data – Transfer locations • Transit speeds • Transit fares • Payment mechanisms • Paratransit • Demand-responsive • Rideshare programs	• Surveillance system ○ Detector type ○ Detector spacing ○ CCTV • Information dissemination ○ CMS ○ HAR ○ Other (e.g., 511) ○ In-vehicle systems • Incident management ○ Incident detection ○ CAD system ○ Response and clearance ○ Incident data logs • Tolling system ○ Type ○ Pricing mechanisms • TMC ○ Control software/ functions ○ Communications ○ Data archival dissemination • Transit/fleet management system ○ AVL ○ Communications ○ Traveler information bus stops

Notes:

- These data must be provided for all links in the corridor study area.
- These data must be provided for a consistent analysis time period, including the same data from all facilities in the corridor area.
- To facilitate the assessment of variability in traffic volumes and speeds, data must be provide for multiple days of the week and months of the year for all facilities in the study corridor.

Figure 4. Chart. Sample data requirements for AMS for ICM.[(10)]

Dallas Area Rapid Transit (DART) and U.S. 75 Dallas ICM Team conducted an AMS assessment of the effects of several ICM strategies on the performance of the U.S. 75 corridor as documented in a 2010 report from USDOT.[(13)] The U.S. 75 corridor in Dallas is a critical, regional corridor in which freeway and arterial expansion is not possible. As outlined in "Integrated Corridor Management," the corridor includes the following:[(14)]

- Continuous frontage roads[.]
- HOV lanes on U.S. 75 and IH-635[.]
- Dallas North Tollway[.]
- 167 Miles of Arterials[.]
- DART Bus network including express service[.]
- DART Light Rail (Red and Blue Lines)[.]

The AMS approach used for U.S. 75 included using the North Central Texas Council of Governments' TransCAD travel demand model, a mesoscopic simulation model (DIRECT), a time of departure choice element, and an analysis of mode shift and transit. The ICM strategies that were assessed for the U.S. 75 corridor include the following:(13)

- "Comparative travel time information (pretrip and en-route)[.]
- Incident signal retiming plans for arterials[.]
- Incident signal retiming plans for frontage roads[.]
- Light-Rail Transit (LRT) smart parking system[.]
- Red Line capacity increase[.]
- LRT station parking expansion (private parking)[.]
- LRT station parking expansion (valet parking)[.]"

Several data elements were used as input or for calibration and validation of the various modeling components used in the assessment. The North Central Texas Council of Governments' travel demand model provided the primary source of vehicular trip tables and networks that were used as input to DIRECT. The DART on-board survey provided the data to estimate the transit O-D trip table also used as input to DIRECT.

The following data were used for the validation and calibration of the model:(13)

- "Traffic flows at individual links, as well as on screenlines across the arterial, freeway, and transit components of the ICM Corridor[.]

- Travel times along critical segments of the ICM Corridor freeway and arterial components[.]

- O-D surveys, identifying travel patterns along the freeway and arterial components of the ICM Corridor[.]"

Queue observations were made along critical segments of the ICM Corridor freeway and arterial components. An extensive AMS method was also applied to the I-394 corridor in Minneapolis an east-west commuter route that connects the Minneapolis Central Business District to the western suburbs. This assessment focused on the impacts of the following ICM strategies:(15)

- "Earlier Dissemination of Traveler Information[.]
- Comparative Travel Times[.]
- Parking Availability at Park-and-Ride Lots[.]

- Incident Signal Retiming Plans[.]
- Predefined Freeway Closure Points[.]
- HOT Lanes Open to All[.]
- Transit Signal Priority."

The AMS for the corridor relied on a combination of the region's travel demand model in TP+, travel demand forecasting software package, and a mesoscopic simulation model, DynusT, developed by the University of Arizona. DynasT includes a mode shift model. As with the Dallas pilot, the Twin Cities regional travel demand model developed in TP+ was used to extract networks and trip tables for the analysis for the corridor. Additional data entered into the model included signal timing plans and intersection lane geometry configuration. The traffic flow model was calibrated using the speed-density relationship in the field data, and the O-D tables were calibrated using link count data. Detector data were also used to develop time-dependent O-D tables. Collected travel time validated the calibrated model. Automated passenger count and route ridership data were used to create the transit O-D tables.(15)

The following data were used for model validation:

- Traffic counts.
- Travel times collected by probe vehicles.
- Link volumes and speeds.
- Speed space-time contours and volumes from field sensors (for incident scenario validation).

In San Diego, the ICM AMS was performed on the I-15 corridor, which is a primary artery for the movement of commuters and goods from northern San Diego County to downtown. It is an 8- to 10-lane freeway with two reversible managed (high-occupancy toll (HOT)) lanes. The AMS tested several ICM strategies, including the following:(16)

- "Pre-Trip Traveler Information[.]
- En-Route Traveler Information[.]
- Freeway Ramp Metering[.]
- Signal Coordination on Arterials with Freeway Ramp Metering[.]
- Physical Bus Priority[.]
- Congestion Pricing on Managed Lanes."

The AMS approach used by the San Diego team consisted of a TransCAD-based regional travel demand model and a TransModeler-based corridor microsimulation model. As input to the microsimulation model, the roadway network, and an a.m. peak period, O-D trip table for the I-15 corridor study area was extracted from the regional travel demand model. The microsimulation model was calibrated using a three-step strategy to calibrate on capacity, route choice, and system performance. The California Department of Transportation (Caltrans) Performance Measurement System (PeMS) database provided much of the data for the calibration and validation, including speed data. As outlined in *Annex 3. ICM AMS Results for* *the I-15 Corridor*, the set of data used to calibrate and validate the microsimulation model included the following:[16]

- Traffic flows at individual links along the I-15 corridor[.]
- Speed profiles along critical segments of the corridor[.]
- Queue observations along critical segments of the corridor freeway and arterial components.

ASSESSING IMPACT OF IMPLEMENTED M&O STRATEGIES

Overview

This section addresses another key component of a performance-based approach to planning for operations that requires data: assessing the impact of M&O strategies post-implementation. This review did not systematically identify the data needed to evaluate each M&O strategy post-implementation but instead identified examples during conversations with MPOs.

There are several more examples of M&O strategies that were evaluated post-implementation than were found for evaluation during planning. Traffic signal coordination or retiming projects were frequently mentioned by MPOs as an M&O strategy that is evaluated for improvements via the collection of travel time data. Other examples include a cost-benefit analysis of the Houston, TX, area TIM program and the use of traffic count data to conduct before-and-after studies of implemented M&O strategies by the Southwestern Pennsylvania Commission (SPC). In addition, the Houston TranStar partnership (including Houston-Galveston Area Council (H-GAC)) conducts public surveys to assess the use and impacts of the TranStar traveler information Web site.

CHAPTER 4. BARRIERS TO USE OF DATA IN PLANNING FOR OPERATIONS

During conversations with MPOs regarding this review, many of the same issues were reported regarding barriers or challenges to using data in planning for operations. They typically fell into the broad categories of transportation system coverage, data quality, data format or resolution, and costs in terms of funding and staff time.

There were typically very limited data on arterial performance and gaps of coverage on freeways. One MPO reported having difficulty obtaining transit data from the 10 transit operators in the region. Some regions obtained private sector, third-party data for coverage on arterials, but one region mentioned concerns that it may not represent the typical traveler. Other regions conducted special travel time runs on arterials but collected data manually. This typically does not allow for the modeling of M&O strategies during different operational conditions (e.g., weather, incidents, and special events).

Issues with data quality were also mentioned as a barrier, including loop detector and tube failures. MPOs reported having to spend considerable effort in postprocessing data before being able to use it in models or performance measures. Specifically, MPOs mentioned probe travel time data and traffic count data as requiring significant processing. In addition, the temporal resolution of data that the MPOs received was often not fine enough for their models, specifically the newer models. The MPOs needed data in 15-min increments or less but were receiving data in 24- or 1-h increments.

The cost of obtaining system performance data was also a key barrier to use of data in planning for operations. For example, in Houston, the toll-tag readers collecting freeway performance data were too expensive to deploy across the entire network. The region is looking to move to Bluetooth®, but the communications necessary to link the devices across such a large region are costly. Purchasing data from commercial vendors was also reported as expensive.

In addition, MPOs cited the time required to integrate data from multiple operating agencies across the region to create a more comprehensive view of the region's performance as a challenge. This is one of the main challenges that this VDA framework aims to address in this project.

Chapter 6 includes eight case studies that provide a closer view of the efforts to use data for planning for operations in fairly advanced regions across the United States.

CHAPTER 5. CASE STUDIES

REGIONAL TRANSPORTATION COMMISSION (RTC) OF SOUTHERN NEVADA (LAS VEGAS)

RTC of Southern Nevada, which serves as the MPO and transit authority for Southern Nevada, collects a wide variety of transportation operations data from freeways, arterials, and transit facilities for use in planning and operations activities. RTC records transit boardings, ridership, and operational efficiency but does not maintain regular route-specific transit travel patterns. The Freeway and Arterial System of Transportation (FAST) is a regional ITS organization administered by RTC and funded by RTC and the Nevada Department of Transportation (NDOT). FAST aggregates large quantities of data for both planning as well as distribution to travelers. Using side-fire radar, inductive loops, closed-circuit televisions (CCTVs) and video image detection, FAST collects the following data elements:

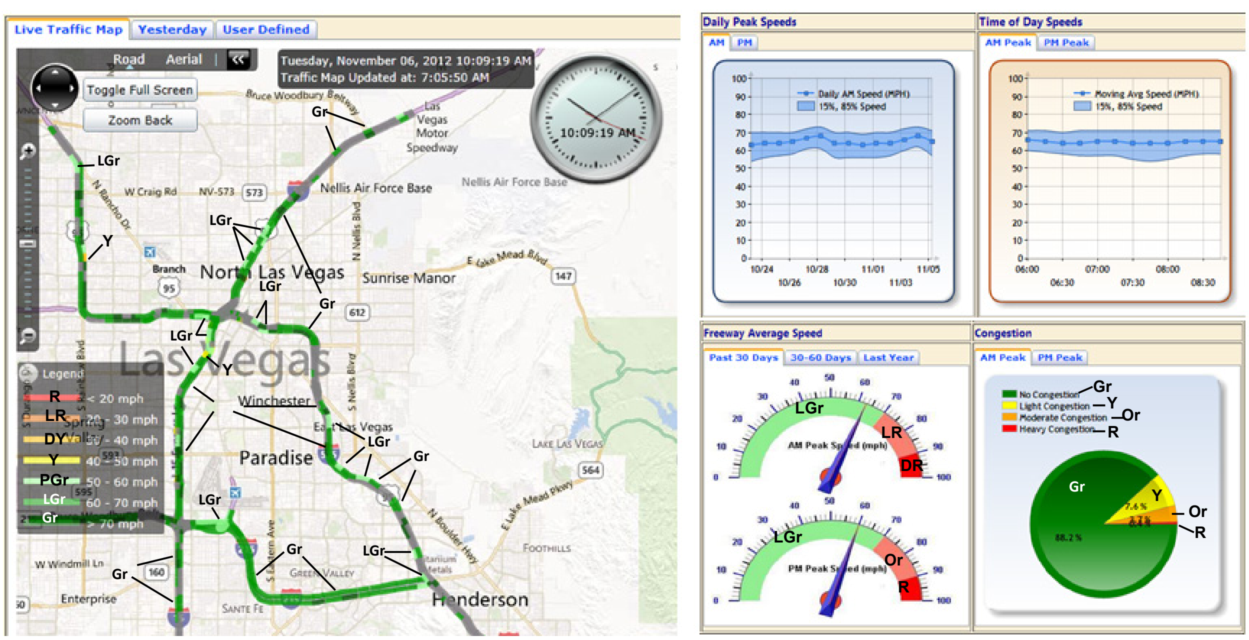
- Average annual daily traffic (AADT).
- Average travel time.
- Average travel speed.
- VMT.
- Incidents and delays.
- Vehicle classification.
- Volume and occupancy.

Use of Data in Monitoring Transportation Operational Performance and Tracking Performance Objectives

RTC currently uses the data collected by FAST to generate a graphic that depicts relative congestion (as volume-to-capacity ratio) to automatically identify the most congested corridors to define systems/networks of interest, which is depicted as step 3 in the congestion management process (CMP) framework in figure 5.(17) Although FAST has no formal process to identify corridors for operations investment, relying instead on operators observations, the next Long Range Transportation Plan and Transportation Improvement Plan updates will incorporate congestion reliability data in investment decisions. Furthermore, FAST has begun tracking performance using performance-based goals and targets and recently completed its first benefit-cost analysis of operations and mobility projects.

Figure 5. Flowchart. The eight-step CMP framework used by RTC.(17)

FAST collects travel time, speed, VMT, incident, delay, classification, volume, and occupancy data, which are streamed to the Nevada FAST Web site, where an interactive dashboard displays live and archived conditions for use by travelers, as shown in figure 6.(18)



©RTC.

Figure 6. Screen capture. Nevada FAST Web site's interactive dashboard.(18)

Evaluating M&O Strategies in Planning

To supplement the volume-to-capacity ratio, RTC plans to incorporate analytical tools such as travel forecast models, signal optimization tools, and simulation models to quantify and validate the benefits of the proposed projects.

The CMP prioritizes improvements that address congestion at a list of sites that have been determined to be in need of improvement based on the following four components of congestion:[(19)]

- **Intensity**—Based on both volume to capacity ratio for freeways, interstates, and ramp links as well as percent reduction in speed for arterial and collector links.
- **Duration**—The number of hours in which congestion exceeds the intensity threshold.
- **Extent**—The number of persons or vehicles affected by congestion, calculated based on car/truck volumes and estimated occupancy rate.
- **Reliability**—Based on crash rates and non-crash-related incidents, obtained from the Freeway Service Patrol operated by NDOT.

Current evaluation of strategies in planning does not include quantitative considerations of collected data but rather a qualitative hierarchy to prioritize demand reduction and mode shifts over highway capacity expansion.

Assessing Implemented M&O Strategies

In the *2011–2014 Transportation Improvement Report*, RTC recommends periodic assessment of implemented strategies but has not yet completed these evaluations. RTC has enlisted contractors to conduct several before-and-after studies to examine the effectiveness of transit, arterial, and parking projects. Many of these projects are still being implemented, and data collection has not yet concluded.[(20,21)]

H-GAC (HOUSTON)

H-GAC houses the MPO for an eight-county region surrounding Houston and serves more than 6 million people across 7,800 mi^2.[(22)] H-GAC has access to various sources of real-time and archived operations data and is updating its CMP to incorporate this data to support better long-term planning activities.

H-GAC is advancing in its use of operational performance data available in the region. It has access to fairly extensive freeway data collected and used in real-time by TranStar, a multi-agency coalition and traffic management center (TMC) focused on the management and operation of the region's transportation system. The region has a network of toll-tag readers that collect speed and travel time data on freeways and toll roads. The Texas Department of Transportation (TxDOT) is in the process of replacing the toll-tag readers on its freeways with Bluetooth® readers because they provide comparable data collection capabilities at a significantly lower cost.

H-GAC also has access to freeway incident management information from TxDOT's Regional Incident Management System (RIMS). RIMS is the central database where data for the majority of freeway incidents within Houston and surrounding areas are recorded. The information gathered by TxDOT on incidents includes incident detection, verification, response time, and clearance time.

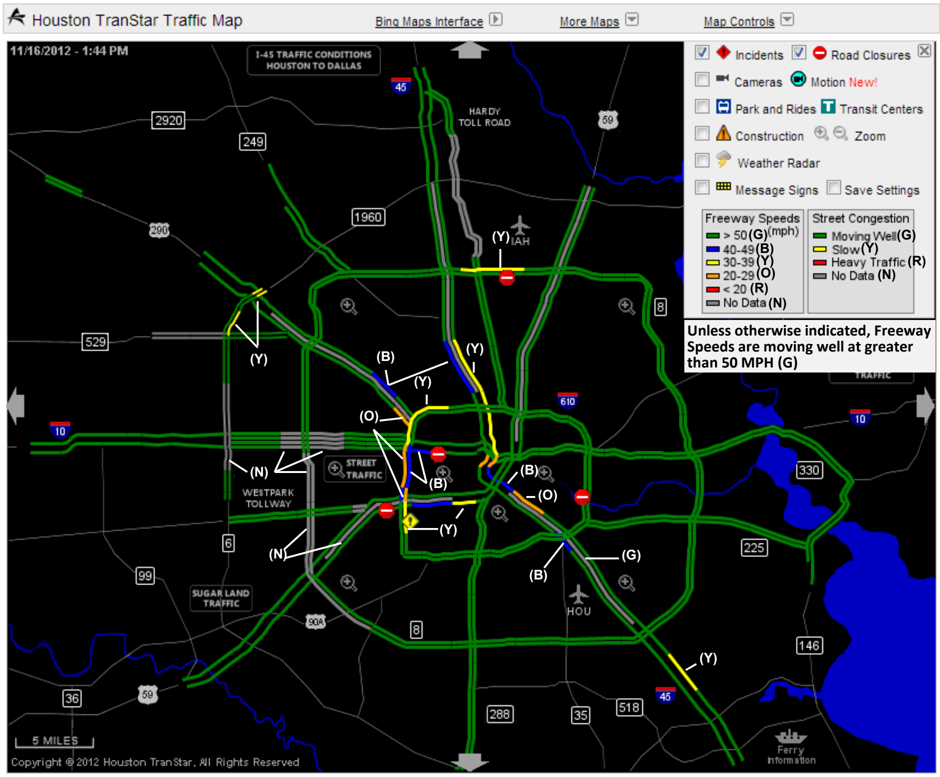
Like most MPOs, H-GAC has faced more challenges in measuring arterial performance than freeway performance. H-GAC purchased 2009 travel time and speed data from a private, third-party data provider to help assess system performance. H-GAC has been working with TTI to conflate the third-party data with H-GAC's modeling network, which would assist in validation of travel speed for the model. This model will allow for a before-and-after review of how specific projects may have affected travel times and speeds.

Efforts in the region have been underway to implement Bluetooth® technology to provide continual real-time traffic data on its roadway network not just to capture and use traffic information but also to control the quality of the data. Houston has implemented Bluetooth® readers on a 60-mi^2 test section on its arterial system to capture arterial speeds and has been approved for funding through H-GAC to fund deployment of additional Bluetooth® readers across the remainder of its arterial network. Several other communities have also implemented Bluetooth® readers on arterials in the region but not to the extent of the City of Houston's proposed network. Once fully operational, H-GAC and the city will be able to capture real-time traffic conditions on arterials. In addition, the information from the system will benefit real-time operations by helping operators identify system slowdowns, determine causes, and dispatch resources to address the problem.

H-GAC has access to traffic count data primarily from TxDOT, which usually collects 5-year saturation counts with tubes. TxDOT is the primary count source for H-GAC's travel demand model, and the data ares provided to H-GAC at no cost. However, a location's count is only registered for a single 24-h period, and any construction, incident, or counter malfunction will not result in a second attempt to collect a count. It would be cost-prohibitive for the region to conduct a continual, comprehensive count program with a road network as extensive as the Houston-Galveston area, which has more than 50,000 network links.

Use of Data in Monitoring Transportation Operational Performance and Tracking Performance Objectives

Much of the travel time data collected on the performance of the transportation system are used for real-time management and operation of the system by TranStar at the TMC and for providing traveler information on the public Web site. TTI collects the toll-tag reader and Bluetooth® data from passing vehicles and calculates the freeway speeds and travel times. The results are fed into a color-coded speed map (figure 7) that displays system performance. This map is used for real-time monitoring and incident management at the Houston TranStar control room and for public dissemination on the Houston TranStar Web site.(23)



©Houston TranStar.

Figure 7. Screen capture. Houston TranStar color-coded traffic map.[23]

These data are archived and, to a lesser extent, used for monitoring performance measures and objectives. H-GAC is reviewing options for conducting performance reporting using these datasets. Houston TranStar produces an annual report that documents measures of annual average incident clearance time, changes in measured congestion, and traveler use of information.

Evaluating M&O Strategies in Planning

The use of data in evaluating M&O strategies in the planning process has been limited thus far. In early 2012, H-GAC made its first attempt to quantitatively evaluate some of its ITS project submissions to the Transportation Improvement Program (TIP) through IDAS. H-GAC worked to evaluate several ITS components in IDAS, including traffic signal system improvements, CCTVs, and dynamic message board installations, among others, but had difficulty with the process and initially obtained some questionable results.

The modeling group at H-GAC has used the data from TranStar (i.e., toll-tag readers and other detectors) to validate the speed data in its freeway models and has used arterial data from a third-party vendor to validate its arterial models.

Assessing Implemented M&O Strategies

H-GAC will be looking at private third-party data to identify before-and-after impacts of project implementations. While some pertinent information may be gathered from this exercise, results could be affected by variables that may not be project-related. For example, the economic downturn and recovery from 2009–2012 may influence both safety and mobility metrics. H-GAC is planning for better post-implementation evaluation as part of its current CMP modifications.

H-GAC recently used a contractor to perform a benefit-cost analysis of the region's incident management program investments, and the results showed a high benefit-cost ratio. H-GAC intends to use these results to inform decisionmakers in the region about investments in TIM.

The incident management data housed in TxDOT's RIMS is used to monitor the effectiveness of incident management activities on the system. Those data are reviewed on a monthly basis to analyze incident management activities on the freeways. Current efforts to enhance incident management activities in the region involve increased use of this database to monitor performance and provide information to partners and policymakers.

The Houston TranStar partnership conducts surveys on and tracks usage of the TranStar traveler information Web site. Surveys show that the Web site has a high benefit to the public, with approximately half a million viewers each month. Understanding travelers' use of information enables TranStar to tailor its programs more effectively.

H-GAC has worked with operations data to learn about how the timing of evacuation decisions affects traffic patterns. Evacuations are difficult to model because destinations are often unknown and may change en route. In addition, other factors can play into an evacuation, such as the impact Hurricane Katrina had on Hurricane Rita's evacuation over a month later. Archived operations data was used to identify issues related to the both the Hurricane Rita and Hurricane Ike evacuations. They detected a dual wave of evacuation traffic that could be better addressed with additional coordination between evacuation announcements and employer early dismissals.

Data Barriers

H-GAC has encountered several barriers when trying to use data for planning for operations. Travel time and speed data are predominantly generated by toll-tag readers, which are too expensive to implement throughout their region of about 8,000 mi^2. Regional operators, including TxDOT and various communities, are investigating or implementing Bluetooth® readers to capture travel data, which are much more affordable. In the meantime, H-GAC is using third-party data to look at system performance, but the data are proprietary, and there are concerns that it may not accurately depict normal traffic. Furthermore, traffic count data provided by 5-year saturation counts conducted by TxDOT are not accurate enough for operations and planning activities.

BAY AREA MTC (SAN FRANCISCO)

MTC is the transportation planning, coordinating, and financing agency for the nine-county San Francisco Bay Area. It has extensive experience in the evaluation of management and operation strategies in planning. At the long-range planning level, MTC has evaluated M&O strategies such as arterial signal coordination, ramp metering, congestion pricing, and express lanes using the region's travel demand model and other post-processing methods. Since 2007, MTC's Freeway Performance Initiative (FPI) has been involved with the development of corridor studies that will be used to develop a roadmap for the selection of the best projects and operational strategies in the region based on performance and cost-effectiveness. With respect to performance monitoring, MTC has been evaluating the potential to use the Caltrans PeMS to support their state-of-the-system reporting.(24) In addition, MTC supported the development of the Traffic Operations System Equipment Management System (TEMS), a central database for inventory and status information for the San Francisco Bay Area ITS and traffic operations devices operated and maintained by Caltrans. The following sections describe these examples with a focus on the data used for these efforts.

Use of Data in Monitoring Transportation Operational Performance and Tracking Performance Objectives

MTC has multiple sources of transportation performance data for monitoring the operational performance of the area's highways. These sources include the following:

- PeMS.
- MTC 511 system.
- Caltrans Highway Congestion Monitoring Program (HICOMP).
- Caltrans Traffic Accident Surveillance and Analysis System (TASAS).
- Private sector data.

PeMS is an Internet-based data archive system that collects historical and real-time traffic data in California to compute freeway performance measures. It collects traffic data from freeway detectors such as counts and occupancies and can automatically compute speeds, VMT, vehicle hours traveled (VHT), delay, travel time index, and productivity for every detector location every 5 min. PeMS also aggregates several of the performance measures in time and space. Figure 8 presents a screenshot of the PeMS online system. Users can retrieve data using the standard query forms within the system.(25)

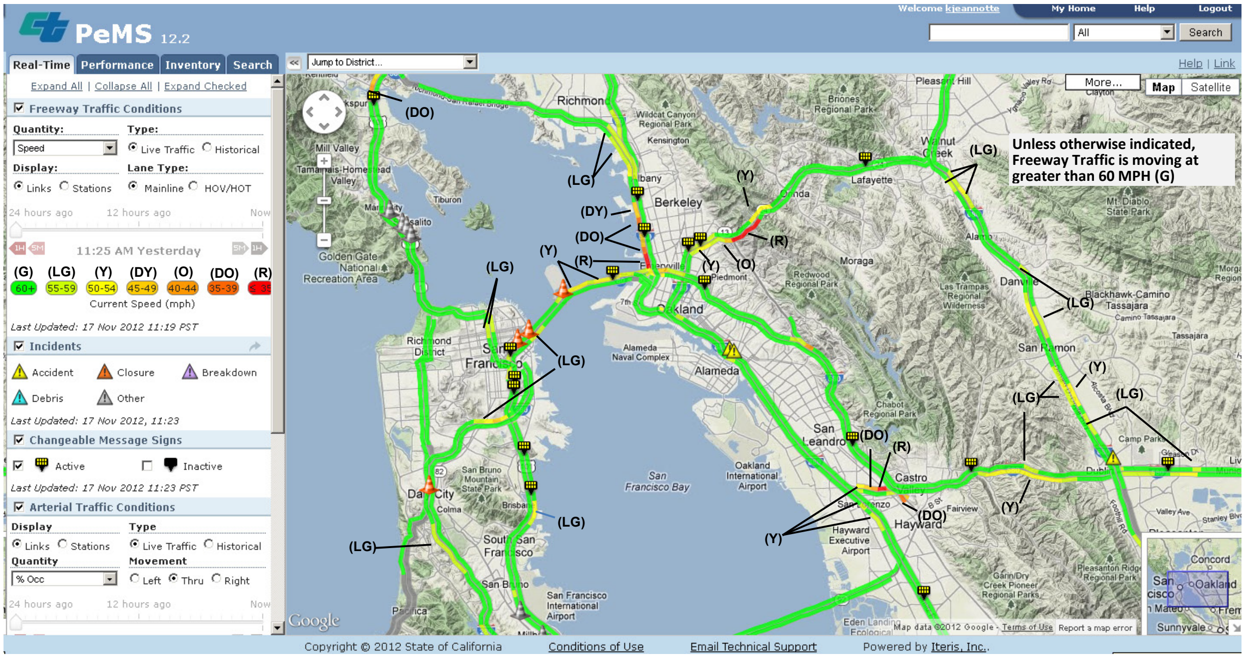


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Figure 8. Screen capture. PeMS online system.[25]

The MTC 511 system (figure 9) is a one-stop source for traffic, transit, ridesharing, and parking and bicycling data for the nine-county San Francisco Bay Area.[26] The traffic section ingests real-time traffic speed and travel time information on highways and major arterials from a private sector data provider. This information is checked against several quality filters that help ensure the data are as accurate as possible before it is used by the 511 system to provide traveler information to Bay Area travelers. In addition, Traveler Information Center operators input into the 511 Traffic/Transit Reporting and Management System information on incidents, planned closures, and event data coming from several external data sources, including Caltrans, the California Highway Patrol, and the media. The 511 system then provides travel time and incident information for user-selected routes based on real-time and historical information. The system reports both typical travel time and current travel time as well as roadway incidents and closures to aid travelers in determining whether they should consider route, departure time, or mode changes. The transit section of 511 provides information about routes, schedules, real-time departures, and transit trip planning. Users can obtain complete information, including maps for a multimodal trip spanning multiple agencies. The rideshare section of 511 provides users with the ability to save time and money by accessing information on traditional, dynamic, and casual ridesharing. The bicycling section of the 511 system provides information about bike maps and biking infrastructure as well as bike sharing facilities. The parking section of 511 provides static and real-time data (when available) about parking at train stations, park-and-ride lots, and public and private parking lots and garages.

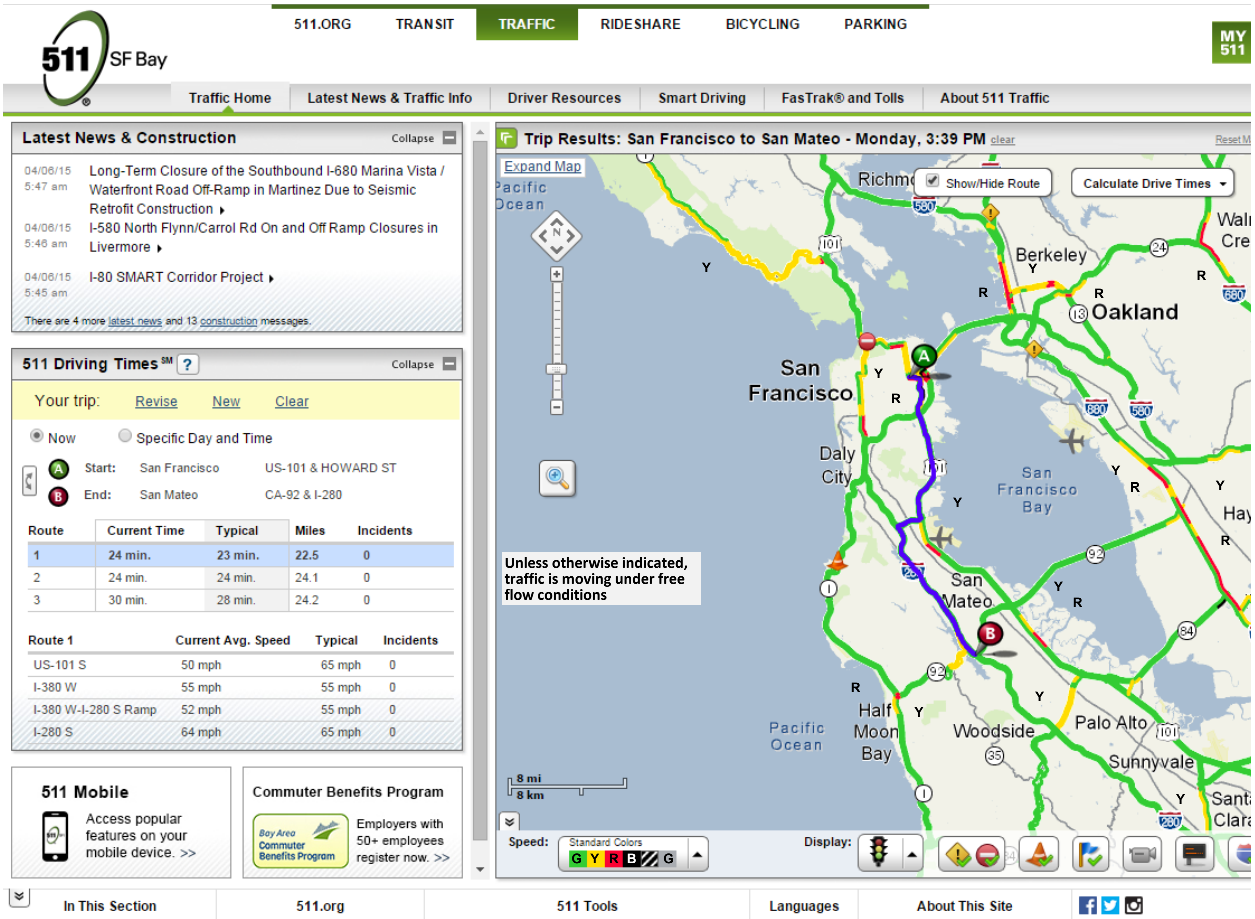

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Figure 9. Screen capture. MTC 511 system.[26]

The HICOMP report has been produced by Caltrans since 1987. The HICOMP report is produced annually and contains a compilation of measured congestion data reflecting conditions on urban freeways in California. Over several years, MTC produced a state-of-the-system report and shared this data with Caltrans for the HICOMP report. The data was collected by driving specially equipped vehicles along congested freeway segments during peak travel periods. Caltrans also performs floating car runs at least twice per year on freeway segments with HOV lanes. The HICOMP report includes maps illustrating the congested locations, the duration of congestion, and the hours of delay for each congested segment.

TASAS is a traffic records system containing an accident database linked to a highway database. The highway database contains description elements of highway segments, intersections and ramps, access control, traffic volumes, and other data. TASAS contains specific data for accidents on State highways.

MTC purchases private sector speed data collected over a large geographical area for most roadways on a regional scale. The private sector data provider aggregates traffic from GPS-enabled vehicles, mobile devices, traditional road sensors, and many other sources.

Evaluating M&O Strategies in Planning

Regional Transportation Plan

MTC and the Association of Bay Area Governments adopted Plan Bay Area in 2013. Plan Bay Area integrates a new sustainable communities strategy element into the Regional Transportation Plan, resulting in an integrated transportation, land use, and housing plan targeted to reduce greenhouse gas emissions for cars and light-duty trucks.(27) MTC relied on a performance-based approach, focusing on measurable outcomes to help understand how potential transportation investments could advance the region's goals. Regionally significant transportation projects and scenarios were evaluated based on their level of support for adopted targets and based on their cost-effectiveness (benefit-cost assessment). The adopted performance targets for Plan Bay Area predominantly focused on the sustainability goals of the region. Unlike previous regional transportation plans, for the first time the majority of the performance targets dealt with issues beyond the scope of traditional transportation planning, incorporating issues such as public health impacts, the potential for greenfield growth, and economic development.

Travel Model One, the region's activity-based travel demand model, was leveraged to evaluate the performance of both projects and scenarios. For all non-committed projects (i.e., projects either lacking full funding or environmental clearance), two assessments were performed to determine their usefulness and efficiency in achieving the plan's objectives. First, each transportation project was qualitatively evaluated based on its level of support for the adopted targets. Projects could receive an overall targets score ranging from +10 (strongly supporting all targets) to -10 (strongly adversely affecting all targets). Second, all major capacity-increasing transportation projects with costs exceeding $50 million and/or with regional impacts were evaluated using a quantitative model-based benefit-cost analysis. This process went beyond the adopted performance targets to consider as many quantifiable benefits as possible, seeking to determine which projects are most cost-effective in providing benefits to users and society.(28)

The qualitative criteria for each of the 10 performance targets included the following:

- Climate protection (carbon dioxide (CO_2) reduction).
- Adequate housing.
- Healthy and safe communities (particulate matter).
- Healthy and safe communities (collisions).
- Healthy and safe communities (active transportation).
- Open space and agricultural preservation.
- Equitable access.
- Economic vitality.
- Transportation system effectiveness (non-auto mode share/VMT).
- Transportation system effectiveness (maintenance).

All projects were assessed using Travel Model One, creating a level playing field across all of the region's analyzed projects. A no-build model run was conducted to determine the baseline future year conditions (e.g., total regional travel time, tons of airborne emissions, non-recurring delay, collisions, etc.). After changing the baseline conditions to represent project-related improvements, the model was then run again to analyze with-project future year conditions.

Table 2 lists the project benefits and costs that were quantified and monetized in the project-level benefit-cost assessment. Benefits were based on year 2035 travel model output for a typical weekday and, therefore, had to be multiplied by an annualization factor to determine the annual benefits. Capital costs were annualized based on the expected useful life of the corresponding transportation asset type and then combined with a net annual operating and maintenance cost.

Table 2. Benefits and costs quantified in the project-level benefit-cost assessment.[28]

Project Benefits	Project Costs

• Travel time reduction:
  ○ Auto: free-flow travel time, recurring delay, non-recurring delay
  ○ Truck: free-flow travel time, recurring delay, non-recurring delay
  ○ Transit: in-vehicle travel time, out-of-vehicle travel time
• Travel cost savings:
  ○ Auto operating costs
  ○ Auto ownership costs
  ○ Parking costs
• Emissions reduction:
  ○ CO_2
  ○ Particulate matter less than 2.5 µm in diameter
  ○ Reactive organic gases
  ○ Nitrogen oxides
• Collision reduction:
  ○ Fatalities
  ○ Injuries
  ○ Property damage
• Health cost savings due to active transportation
• Noise reduction
	• Capital costs
	• Net operating and maintenance costs

By combining the targets assessment and benefit-cost assessment, MTC staff were able to inform policymakers about the merits and limitations of projects. The results of the project-level performance assessment, including some operations and management strategies, are summarized in figure 10 and figure 11.[28] Each bubble chart shows the benefit-cost ratio (on the vertical axis) and the targets score (on the horizontal axis).

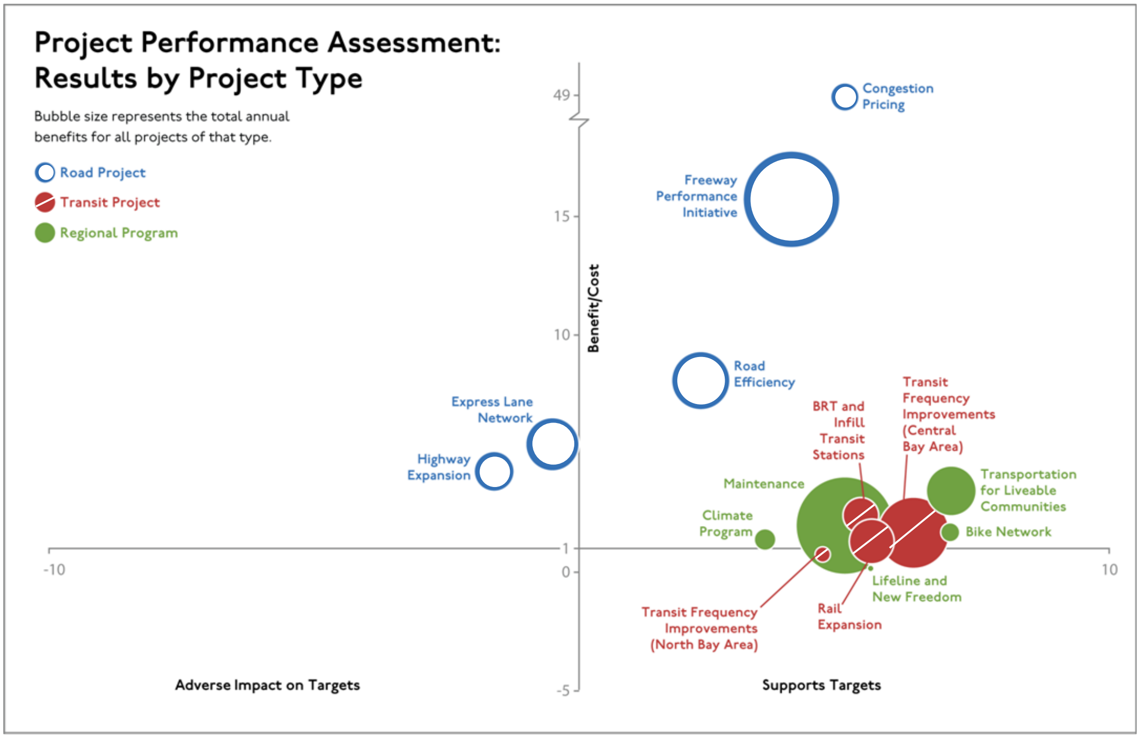

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Figure 10. Diagram. Project performance bubble chart by project type.[28]

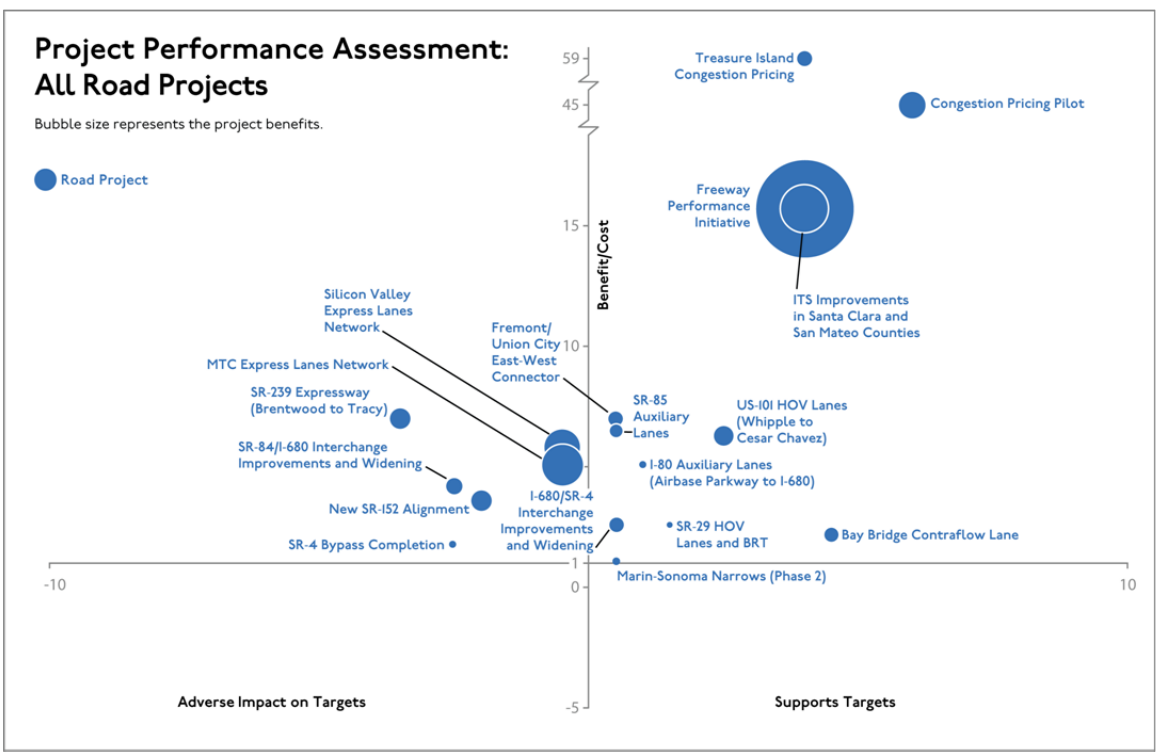

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Figure 11. Diagram. Project performance bubble chart: all road projects.[28]

The following themes emerged from the assessment related to M&O strategies:

- Utilization of ITS technologies and implementation of congestion pricing programs were very cost-effective and also supported many of the plan's targets, in contrast to highway expansion projects.

- Express lanes are moderately cost-effective due to the high capital costs, but they adversely impact the Plan Bay Area targets by increasing capacity for automobiles.

FPI

Because of limited opportunities for highway expansion, MTC initiated the FPI to try to maximize the capacity of the existing roadways through the use of M&O strategies based on performance and cost effectiveness. Several corridors were analyzed as part of the FPI program, each including a quantitative assessment of existing freeway conditions and development and assessment of short-term and long-term congestion relief strategies and projects. The results from these FPI corridor studies have been incorporated into Caltrans' Corridor System Management Plans (CSMPs). The California Transportation Commission requires that all corridors with a project funded through the Corridor Mobility Improvement Account have a CSMP that is developed with regional and local partners. The CSMP recommends how the congestion reduction gains from the Corridor Mobility Improvement Account projects will be maintained with supporting system management strategies.

Existing Conditions Analysis: The goal of the existing conditions analysis was to perform a comprehensive assessment of the existing traffic performance in a corridor, including the following:

- **Mobility**—How well the corridor moves people and freight.

- **Reliability**—The relative predictability of the public's travel time.

- **Safety**—The safety characteristics in the corridor, including crashes (i.e., fatality, injury, and property damage).

- **Other**—Other measures of interest such as productivity, VHT, person hours traveled, transit, and park-and-ride capacity.

New and archived data were used for assessing the traffic performance in the existing conditions analyses on the FPI corridors to varying extents, including data from the following:

- PeMS.
- MTC 511 system.
- HICOMP.
- TASAS.
- New and historical probe vehicle runs, vehicle occupancy surveys, and traffic counts.

Figure 12 through figure 14 present some of the performance measures generated for the FPI existing conditions analysis using archived traffic data.[29]

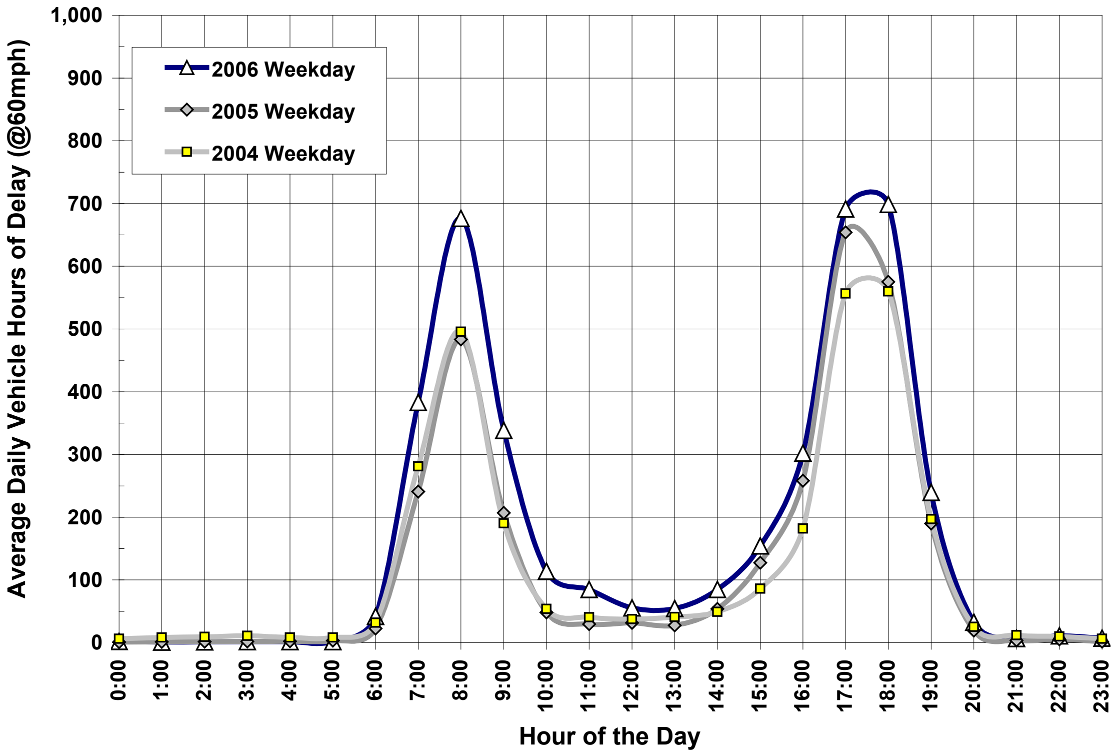

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Figure 12. Line graph. Mobility: average weekday hourly delay.[29]

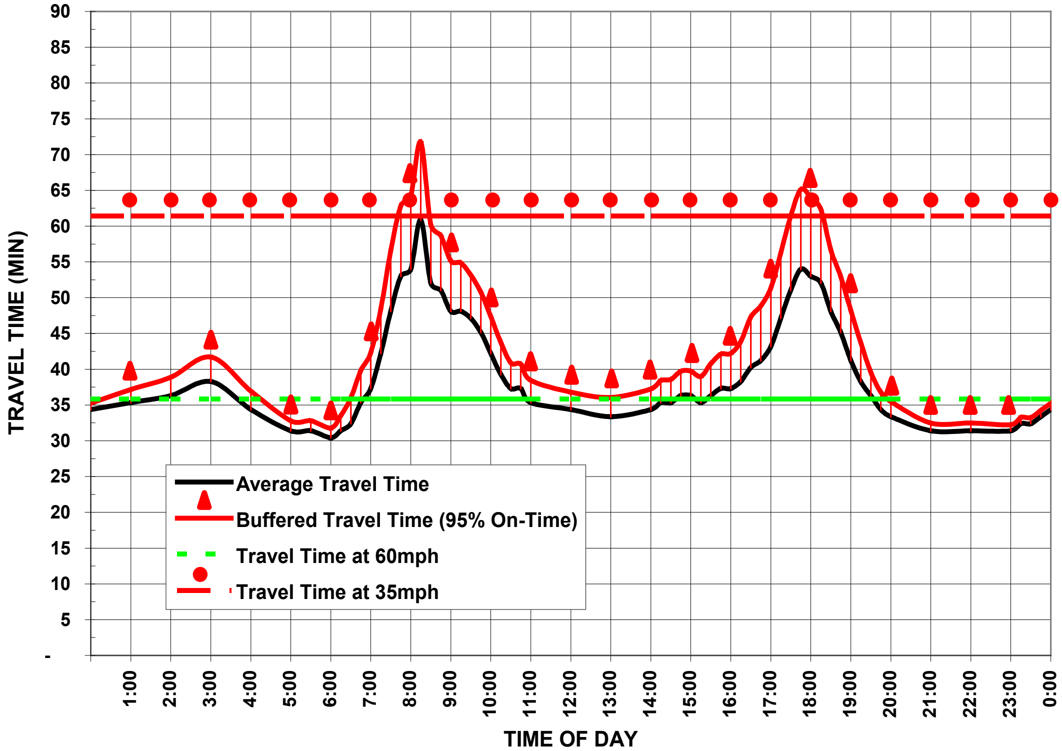

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Figure 13. Line graph. Reliability—buffer index.[29]

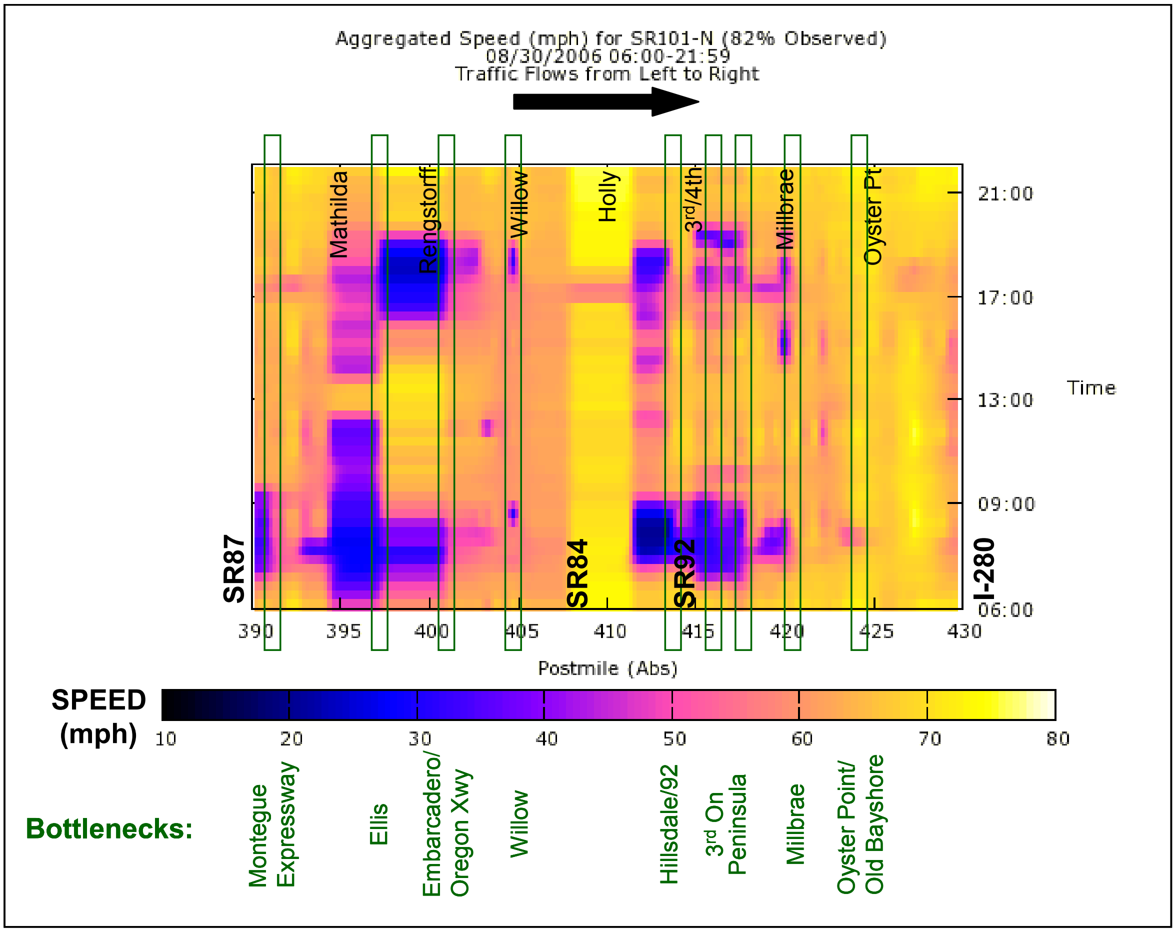

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Figure 14. Illustration. Heat map of bottleneck locations and extents.[29]

Analysis of Strategies: FPI corridor studies have involved several types of analysis tools, including sketch planning tools (e.g., IDAS, California Life-Cycle Benefit/Cost Analysis Model, postprocessing), travel demand modeling, macrosimulation, and microsimulation (e.g., Paramics). Models were validated using speeds, queue lengths, and travel times identified during the existing conditions analysis and traffic count data from PeMS or other sources. Prior to identifying potential strategies for the corridor, the cause(s) of the existing congestion were assessed. This aids in developing strategies that will actually address the congestion problems. The performance measures generated and the project prioritization methods used as part of the analysis varied but generally included VHT, VMT, speed, travel time, total delay, miles of congestion, reliability, and benefit-cost. As an example, recommended strategies for the I-580 East FPI corridor in Alameda County, CA, studies included the following:

- ITS improvements.
- Corridor-wide ramp metering.
- Signal optimization.
- Augmented freeway service patrol.
- Accelerated planned auxiliary lane and ramp improvements.

- Extended and enhanced HOV/HOT operations.
- Major interchange improvements.
- Additional transit and TDM improvements.[30]

TEMS

Cost-effective management of transportation infrastructure is a critical challenge facing transportation agencies, particularly for traffic control devices, ITS, and operations equipment, which are now relied upon heavily for real-time traffic and incident management. Compounding this challenge for MTC as the entity responsible for traveler information and the freeway service patrol is Caltrans' responsibility for deploying, operating, and maintaining the majority of the ITS equipment and systems. As such, MTC and Caltrans District 4 initiated the development of TEMS, a central database and equipment management system for San Francisco Bay Area ITS and traffic operations devices. TEMS consolidated the several existing traffic operations system databases and spreadsheets and ensures the following:

- An accessible, Web-based, robust software that provides a repository for ITS and traffic operations devices information.

- A practical way to manage ITS and traffic operations inventory, status, and maintenance information, including a uniform, consistent standard for characterizing equipment.

- Reliable and accurate ITS, traffic operations, and transportation management center information.

It includes a database and mapping of inventory and status information for the ITS and traffic operations equipment deployed and planned, including changeable message signs, ramp meters, mainline meters, detector stations, CCTV, extinguishable message signs, highway advisory radio, control cabinets, and associated communications. Figure 15 presents a sample screen from TEMS.[31]

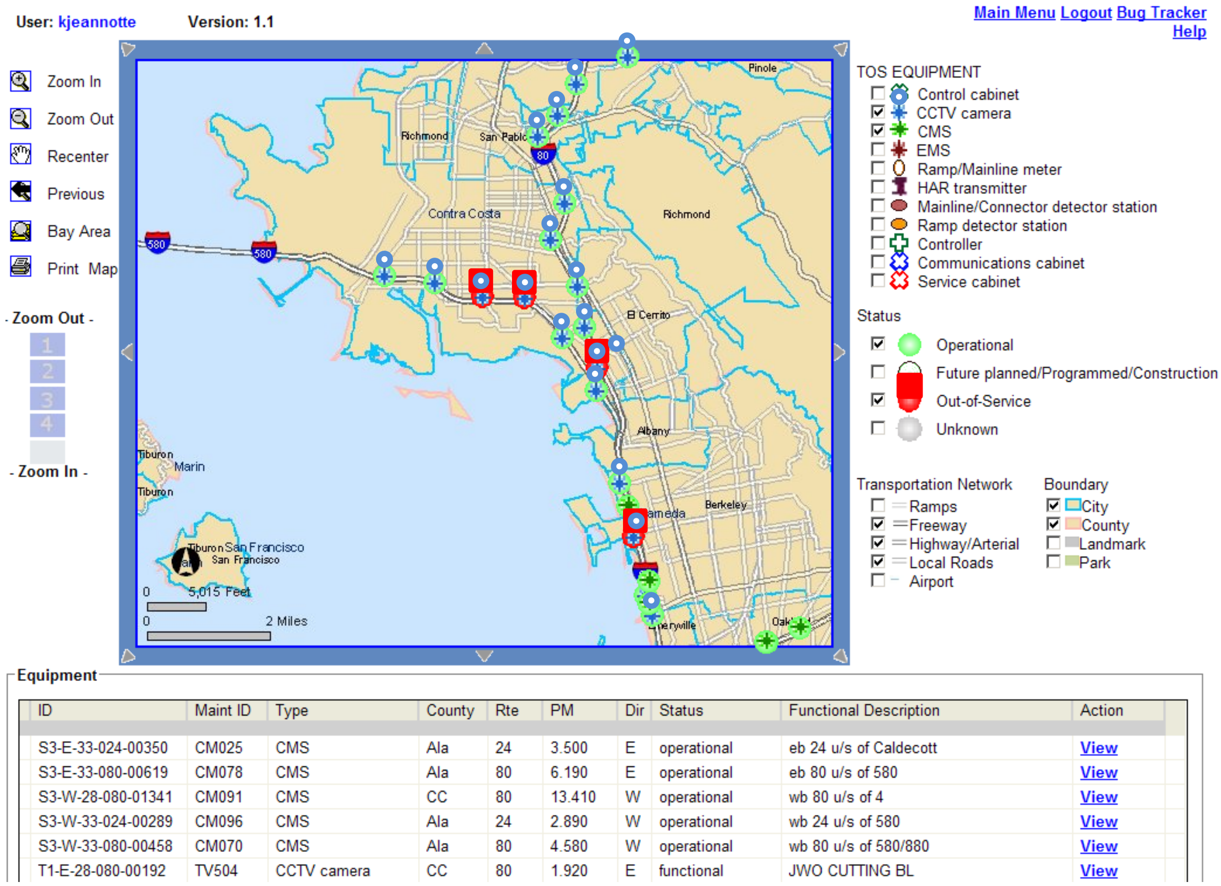

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Figure 15. Screen capture. TEMS.[(31)]

Data Barriers

Some data barriers and gaps include the following:

- Need to improve detector coverage to minimize detection gaps.
- Need to enhance detector maintenance to improve detector health and confidence in the data.
- Insufficient availability of data and performance information on arterial facilities and freeway ramps. They are exploring the use of private sector provider data to address this need, as well as ways to eliminate the detector gaps on the freeway.

MTC is committed to advancing the use of real-time and archived data for a variety of planning for operations activities. One example is that since 2012, it has switched to using a private sector data provider as the primary source for regional congestion monitoring instead of using the floating car method because it is costly and usually only a few days' worth of data are obtained. MTC has also been promoting enhancements to PeMS that would improve the system's usability, data extraction capabilities, and ability to analyze and quantify non-recurrent congestion as well as expand the system to include arterial and ramp data.

SPC (PITTSBURGH)

SPC is the MPO for the greater Pittsburgh 10-county area. Its regional operations planning efforts were originally based on the Pennsylvania Department of Transportation (PennDOT) Transportation System Operations Plan and are integrated into the regional long-range transportation plan. SPC's 2011 Regional Operations Plan identified the following seven priority areas:

- Traffic signal operations.
- Incident and emergency management.
- Traveler information.
- Operational teamwork.
- Intermodal connectivity.
- Freeway and arterial operations.
- Freight management.

SPC has traditionally collected most of its own traffic data for use in planning for operations, including 6,600 traffic counts in a 10-year period from roadways throughout the region.[(32)] SPC also collects travel time, speed, and delay data by conducting travel time runs along regional corridors every 3 years and uses GPS receivers and on-board diagnostic tools to inform investment decisions and support CMP.

SPC collects its own park-and-ride utilization data as well as most of its traffic counts. The organization also receives additional traffic count data and incident data from PennDOT.

In recent years, SPC has moved away from the traditional floating car method of data collection and has integrated new sources of data such as private third-party vehicle probe data, which is made available through PennDOT and through the use of Bluetooth® detection devices. These Bluetooth® devices are used in temporary installations much like traffic counters, but their function is to gather travel time and speed data rather than traffic volume data.

Use of Data in Monitoring Transportation Operational Performance and Tracking Performance Objectives

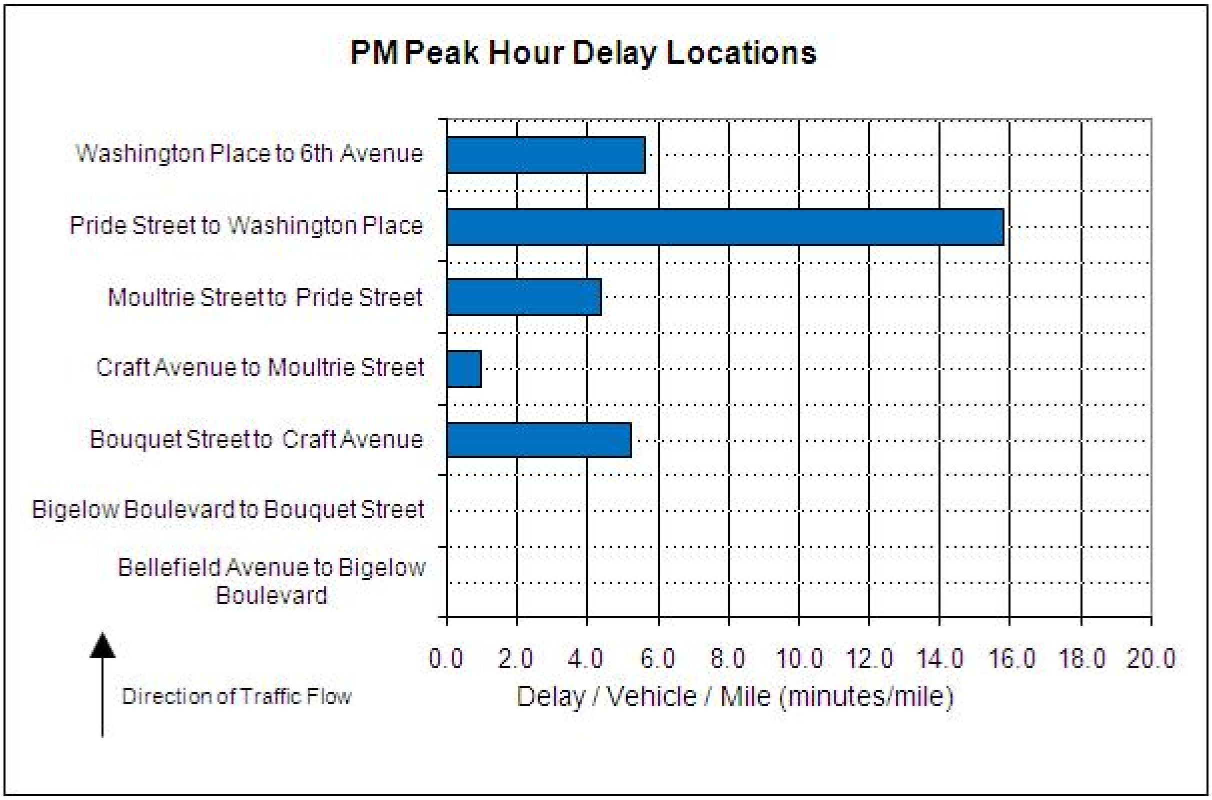
SPC's corridor travel time run data were aggregated by corridor and evaluated based on forecasted congestion levels for a.m. and p.m. peak periods. Comparing observed speeds with the posted speed limit, SPC reported performance measures, including delay per vehicle and per vehicle mile, as well as total delay and total delay per mile.

Collected data are used to customize the 25 congestion management strategies in the SPC toolbox for targeted corridors to address both recurring and non-recurring congestion.[(33)]

Rather than setting specific thresholds for acceptable levels of congestion or explicit targets, SPC aggregates regional rankings of congested corridors that are addressed in the Regional

Operations Plan, developed in conjunction with PennDOT.[34] These regional rankings are depicted in various graphics to show relative performance in accordance with the specified metrics.

Figure 16 depicts delay data for various corridors, enabling SPC to identify congested segments and to select targeted operational improvements for congestion mitigation.[35]

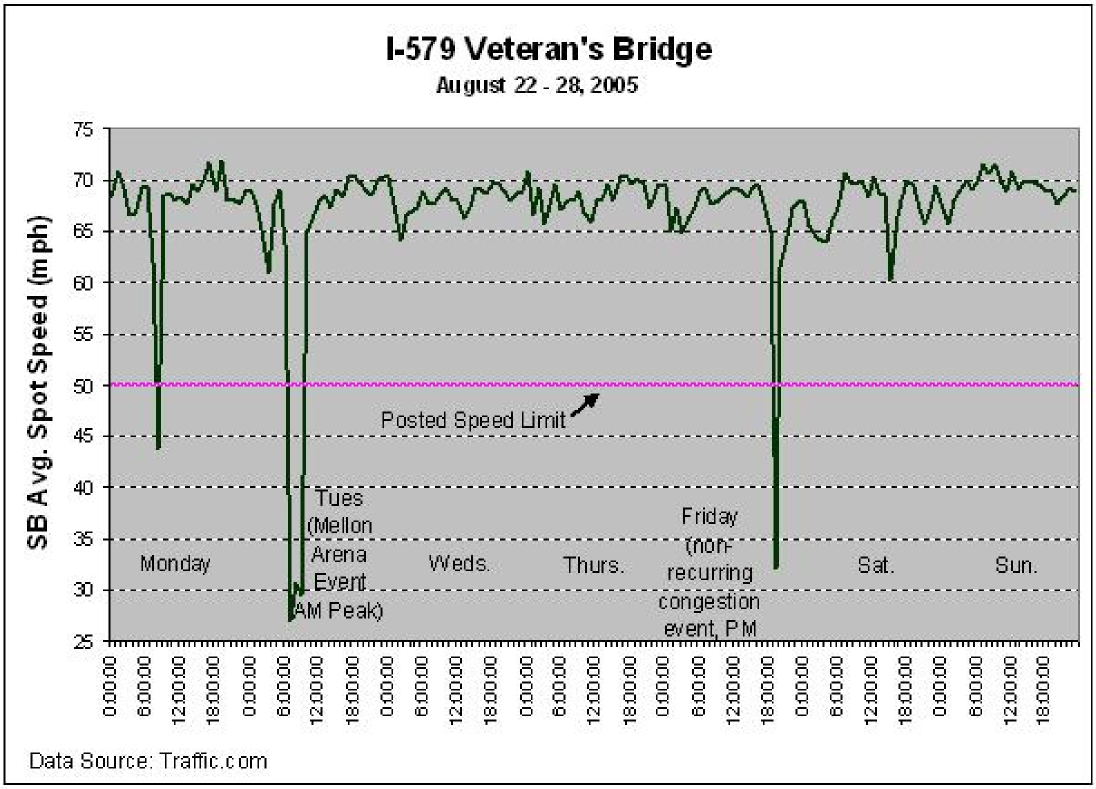


©SPC.

Figure 16. Bar graph. Comparison of corridor segments by delay per vehicle per mile.[35]

Figure 17 illustrates the variability in speeds caused by incidents as a measure of non-recurring congestion.[35] This graph identify patterns and problem regions and can help inform regional strategies for incident management, special event planning, and work zone management without actively measuring non-recurring congestion.

SPC has begun to update its CMP analysis methodologies and data products in order to use new technologies and new sources of data. A comprehensive update of the CMP Web site is underway and will incorporate freeway and expressway reliability performance measures that account for non-recurring congestion.



©SPC.

Figure 17. Line graph. Variability in speed caused by incidents as a measure of nonrecurring congestion.

Evaluating M&O Strategies in Planning

SPC recognizes that a stronger connection is needed between the CMP and project selection to encourage the implementation of M&O strategies. Engaging outside partners has been a major challenge to strengthening connection.

The commission uses 10 years of traffic counts and real-time information to improve traffic flows and reduce transit travel times through adaptive traffic signalization strategies.(34) It also uses microsimulation and visualization modeling software to facilitate detailed traffic analysis for proposed projects and to generate animated model results for demonstrations to policymakers and other relevant stakeholders.

Assessing Implemented M&O Strategies

SPC's Traffic Operations and Safety Committee focuses at least once a year on evaluating implemented strategies from the Regional Operations Plan initiatives. It also compares M&O strategies with capital improvement projects to assess cost effectiveness and overall performance improvement of the system.(34)

SPC has used traffic count data from loop detectors to conduct before-and-after studies of implemented M&O strategies to evaluate performance, such as the regional traffic signal program, but not all projects have enough money in the budget for these assessments. The organization, in conjunction with its planning partners, also plans to assess a recently completed ramp management study to determine its applicability for other sites.[34]

Data Barriers

SPC has documented a lack of available transit operations data from 10 regional transit agencies as a barrier to using data for the CMP, but it is currently developing a regional transit smartcard program that may enable better collection and coordination of data in the future. The commission is also looking to improve its measures of non-recurring congestion through a partnership with the new TMC to increase data sharing and develop additional performance measures to support the CMP, such as incident clearance time.[34]

SANDAG (SAN DIEGO)

SANDAG is the MPO for San Diego County, serving as the regional decisionmaking body for 18 cities and county government within its jurisdiction.[36] SANDAG compiles traffic count data for significant roadways and all Caltrans routes in the San Diego region, which are collected annually and maintained by the 18 jurisdictions, Caltrans, and the county. SANDAG published this information online from 2006 to 2010 to provide average weekday traffic counts, which are two-way, 24-h volumes.[37] SANDAG is in the process of acquiring arterial data from a private sector data vendor.

SANDAG also uses Caltrans' PeMS to access data. PeMS is a real-time archive data management system for transportation data in California. It collects raw detector data in real time, stores and processes these data, and provides a number of Web pages that provide analysis of the performance of the freeway system.

The following information is available in PeMS (plots, tabular, and/or mapped):

- An inventory of the freeways and detectors that are in the geographical segment.
- Inventory of routes, corridors, managed facilities, field elements, arterials, transit agencies, and freeway service patrol beats.
- Performance measures (actual and predicted), including VMT, VHT, delay, lost productivity (congested lane mile hours), travel times, Q (the average speed of a vehicle, calculated by dividing VMT byVHT), travel time index, congestion pie, bottlenecks, AADT, mobile 6 modeling (measured VMT versus the measured speed), level of service (LOS), etc.
- Detector health.
- Lane closures.
- California Highway Patrol incidents.
- Photolog images.

SANDAG uses the PeMS tool for visualization of the data, as well as GIS mapping applications available to visualize the traffic information compiled from Caltrans sensors. SANDAG generally uses the PeMS tool for planning activities such as post-analysis, planning analysis, identification of bottlenecks, and identification of critical areas of travel time savings. Through the I-15 ICM project, SANDAG worked with Caltrans to develop a PeMS module entitled Corridor-PEMS that allows many of the planning and operations activities conducted with PeMS to be done using real-time data.(38) SANDAG has developed a smart decision support system as part of the ICM project that will look at real-time model performance, operational data, and historical offline model data to develop, recommend, and implement corridor-level response plans in real time. For example, the decision support system will allow the coordination and use of freeway ramp meters with arterial signals to manage congestion levels during an incident based on real-time and archived operational data.

SANDAG also developed the initial prototype PeMS module, entitled Arterial PeMS, to extend PeMS capabilities and functionalities beyond the State Highway System to collect arterial data and report performance.

Use of Data in Monitoring Transportation Operational Performance and Tracking Performance Objectives

SANDAG produces an annual *State of the Commute* report for the public on the usage and performance of freeways, transit facilities, and local roads. The report provides regional travel trends, traveler delay data, and key statistics for several travel corridors in the region. The reports also include before-and-after analysis for recently deployed projects. Data used for the *State of the Commute* reports include freeway and arterial data from PeMS and transit data from area transit providers.(39) The 2013 *State of the Commute* report introduced arterial corridors to the report.

SANDAG monitors regional bottlenecks on an ongoing basis using Caltrans' PeMS bottleneck algorithm, which allows SANDAG to identify major bottlenecks. Recent expansions of the detector network for PeMS were developed specifically for the San Diego region to incorporate real-time transit and arterial data. SANDAG uses transit travel time and ridership data to track improvement toward general target objectives.

Evaluating M&O Strategies in Planning

SANDAG currently uses archived operations data to validate its models. The organization plans to expand the data used to develop its models to include pedestrian and bicycle data to support and advance pedestrian and bicycle modal improvements through the Active Transportation Grant Program and the Regional Bicycle Plan.(40,41) Along with the County of San Diego and a local college, SANDAG developed a bike counter program to begin capturing bike data. Current efforts using this system have focused on establishing initial baseline data collection efforts and developing a long-term strategic plan for incorporating bicycle data in future *State of the Commute* reports to support ongoing bicycle data collection efforts.

SANDAG is making the transition to an activity-based model, including an active transportation component, and plans to use archived operations data to baseline the new model. SANDAG is also looking to advance a performance-based management approach to corridor management based on real-time and historic data.

As part of the I-15 ICM initiative, SANDAG led the AMS for various ICM strategies for the corridor. The AMS approach used by the San Diego team consisted of extracting a subarea of the macro regional travel demand model for use in a corridor-level micro-simulation model.

In cooperation with Caltrans, SANDAG has used a similar analysis, simulation, and modeling approach to develop CSMPs for other major corridors, including I-805, to identify, evaluate, and plan corridor-based system management strategies.[42]

Assessing Implemented M&O Strategies

SANDAG has not historically performed evaluations of implemented operations projects and strategies but has begun to aggregate data from the newly constructed express lanes on the I-15 corridor and will be using that data to compare FasTrak (an electronic toll collection system in California) users to normal traffic. SANDAG will use these data to monitor the performance of the 20-mi express lanes system and determine operational improvement strategies to best maximize overall corridor mobility and operational efficiencies that can be considered over time. SANDAG provides before-and-after study results for a few significant roadway infrastructure and transit improvements in the region as part of each annual *State of the Commute* report.

Data Barriers

The greatest challenge SANDAG has with data in planning for operations is arterial collection where there is not yet sufficient infrastructure, although new equipment is being added to supplement the data from PeMS. Currently, SANDAG only has access to enough freeway travel data to provide consistent and complete performance reporting.

SANDAG also has had challenges in obtaining data in small enough time increments to validate its models. It also has occasional issues with roadway sensor failures when conducting travel time analyses.

PORTLAND METRO

Metro is the MPO for the three-county area surrounding Portland, OR. Metro's 2014 Regional Transportation Plan continues the performance-based, outcomes-driven planning approach established with its 2035 Regional Transportation Plan, adopted in 2010.[43] Metro recently implemented its first round of performance-based planning with a call for projects for the TIP.

Metro has access to primarily freeway operations data sources but is working on implementing a plan for data collection on arterials and determining how this data can be used for planning. Metro has developed a strong partnership with Portland State University through which they are working on new methods for collecting, analyzing, and archiving transportation system performance data in the Portal system, an archived data user service for the Portland-Vancouver metropolitan region. Through Portland State University's Portal, Metro has access to traffic counts, speed, occupancy, incident, weather, transit, and freight data. The traffic data are collected by loop detectors across the freeway. Metro has also obtained travel time data from a private third-party data provider.

Use of Data in Monitoring Transportation Operational Performance and Tracking Performance Objectives

During the 2035 Regional Transportation Plan development, Metro and its partners established several performance targets, shown in figure 18, to monitor and report out during each plan update.(44) As a key element of its CMP, Metro began a monitoring program to assess the performance of 24 mobility corridors every 2 years and use that information to inform incremental land use and transportation project implementation decisions. Metro developed a *Mobility Corridor Atlas* to serve as a baseline that includes land use and performance data for regional measures such as travel time, safety, and bike and pedestrian network completion.(45) This publication will be updated in 2015. Metro uses data from Portal to track performance measure targets that are part of the regional transportation plan.

Economy	• Safety • Congestion - by 2035 reduce VHD/person by 10% compared to 2010 • Freight reliability
Environment	• Basic infrastructure • Clean air - by 2035 ensure zero % population exposure to at-risk levels of transportation-related air pollution • Travel
Equity	• Affordability - by 2035, reduce the share of households in the region spending 50% of income on housing and transportation compared to 2000. • Congestion - by 2035 reduce VHD/person by 10% compared to 2010 • Access to daily needs

©Portland Metro.

Figure 18. Chart. Policy-level performance targets.(44)

Evaluating M&O Strategies in Planning

As part of the process for developing its TIP, Metro provides a *Data Resource Guide* that contains updated performance data on several measures implemented along Metro's 24 mobility corridors along with its request for projects. The applicants are advised to use this data in completing their project applications and are encouraged to move those performance indicators in a positive direction through their projects. The *Data Resource Guide* includes performance information on regional travel options, transit, safety, roadways, and active transportation.(46)

Metro has also developed a *Regional Transportation System Management and Operations (TSMO) Plan* to maximize the benefits of new investments and to facilitate data collection and analysis for use in planning—for example, through installation of automated vehicle locators to provide transit data and the use of media access control address-reading technology to provide traffic data.[47] Congestion data on the system are used to help determine which projects will be funded using the funds allocated specifically for TSMO. Metro relies on before-and-after data to establish projected impacts from the proposed TSMO projects.

The data used to validate Metro's transportation models include traffic count data collected by local jurisdictions in the region along cuts or screenlines to verify auto assignments. Metro also uses an online archive of freeway count data, and the Oregon Department of Transportation recently purchased private third-party data for comparing travel times and speeds. The purchased data cover a large number of arterials, but they are fleet-based and limited to whatever facilities those vehicles are traveling on.

Metro is also moving from experimentation to broader use with a DTA model. The organization's DTA model is still fairly new and is in a transition period from development to application.

Metro participated in an FHWA demonstration project on the use of a data integration hub to easily transfer model and limited field data between AMS tools. The demonstration focused on NW 185th Avenue in the Portland area and helped evaluate ITS in the corridor, including ramp metering, adaptive signal control, and transit/truck priority. The data sources for the demonstration included field-measured 24-h link volumes and speeds, peak period turning movement counts, signal timing data, regional travel demand model data, and Bluetooth® travel time data.[7]

Assessing Implemented M&O Strategies

Metro is not currently assessing implemented M&O strategies, but the latest version of the Regional Transportation Plan notes that they will be evaluated in the near term.

Data Barriers

Loop detectors have only been deployed on the region's limited-access freeways, which restrict the amount of data available on the system, and the data must be supplemented with simulated data from model output for the rest of the system. Evaluation of strategies as part of the larger planning process depends on the expansion of data capture along the rest of the freeway and arterial system. Metro is now working with private third-party data and using it to update its performance measures.

Assimilating data from a wide variety of sources can be challenging; for example, private third-party travel time has to be heavily postprocessed before it can be used. Also, the resolution of the volume data Metro receives from local jurisdictions is not sufficient for the needs of newer modeling tools: tube count data are aggregated into hourly figures, whereas 5-, 10-, or 15-min intervals are more appropriate. There are also significant postprocessing needs for the count data.

In working with the DTA model, Metro has found that it had to spend a great deal of time to get Synchro® data into its network. Metro also wants better methods of visually depicting data to demonstrate trends and analyze problems.

WILMINGTON AREA PLANNING COUNCIL (WILMAPCO)

WILMAPCO is the MPO for Cecil County, MD, and New Castle County, DE. It collects or acquires data from its planning partners to use for monitoring transportation system performance as part of its CMP and to illustrate congestion visually through maps that highlight areas of improved or degraded performance. The area is moving forward in expanding its data collection efforts. The area is moving forward in expanding its data collection efforts, including the installation of many Bluetooth® devices covering freeways and arterials in 2015. These devices are provided and managed by the Delaware Department of Transportation (DelDOT) TMC.

DelDOT is the primary source of the archived data for WILMAPCO. Along the expressway, there are radar traffic detectors about every 0.5 mi collecting speed and volume data. The University of Delaware Center for Transportation provides WILMAPCO with freeway and arterial data that it collects through annual GPS travel time runs. The region also collects traffic count data from a variety of sources, which it uses for level of service analysis. In addition, WILMAPCO has access to transit usage data from the Delaware Authority for Regional Transit, including park and ride utilization data, ridership, and monthly seating capacity. Soon, WILMAPCO will have Bluetooth® travel time data along the arterials from the DelDOT TMC. WILMAPCO supplements archived data from DelDOT with arterial travel time data from a private third-party data provider. WILMAPCO intends to collect more data in-house to reduce cost.

Use of Data in Monitoring Transportation Operational Performance and Tracking Performance Objectives

WILMAPCO uses arterial travel time data to focus on improving the flow of traffic through coordinated signal timing. The data are used to analyze volume-based level of service to identify congested intersections and target regions for improvement. Two other performance measures are monitored using the data, including travel speed versus free-flow speed and the number of crashes along a corridor. The performance measures are visually depicted (as in figure 19 and figure 20) and tracked over time to identify areas in need of improvement.[48]

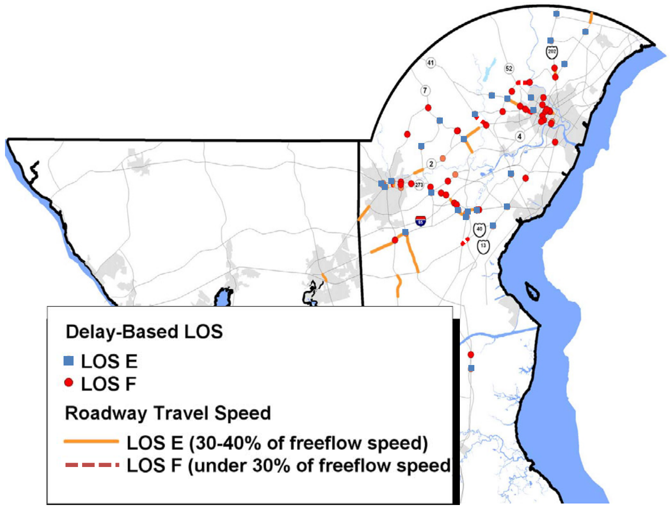


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Figure 19. Map. The a.m. peak intersection level of service and travel speed.(48)

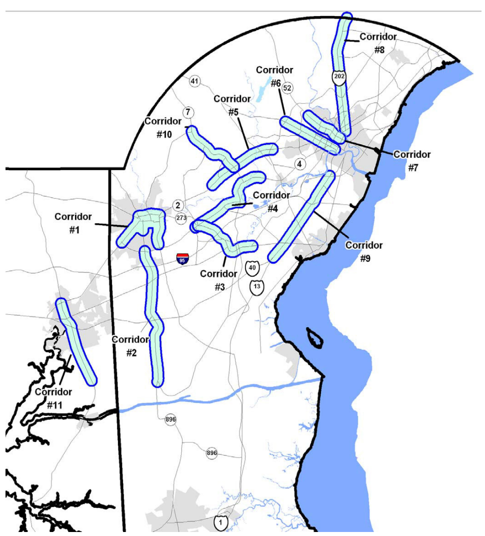

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Figure 20. Map. Identified congested corridors.(48)

Evaluating M&O Strategies in Planning

In 2012, WILMAPCO began including in its congestion management system report an Intersection Operational Analysis section that examines the performance of signalized intersections and prioritizes congested intersections that can be alleviated by adjusted signal timing methods such as traffic responsive signalization (TRS) and those that require capital improvements to increase performance.(49) WILMAPCO's 2014 version of the Intersection Operations Analysis section has expanded beyond signal timing adjustments to include the following:

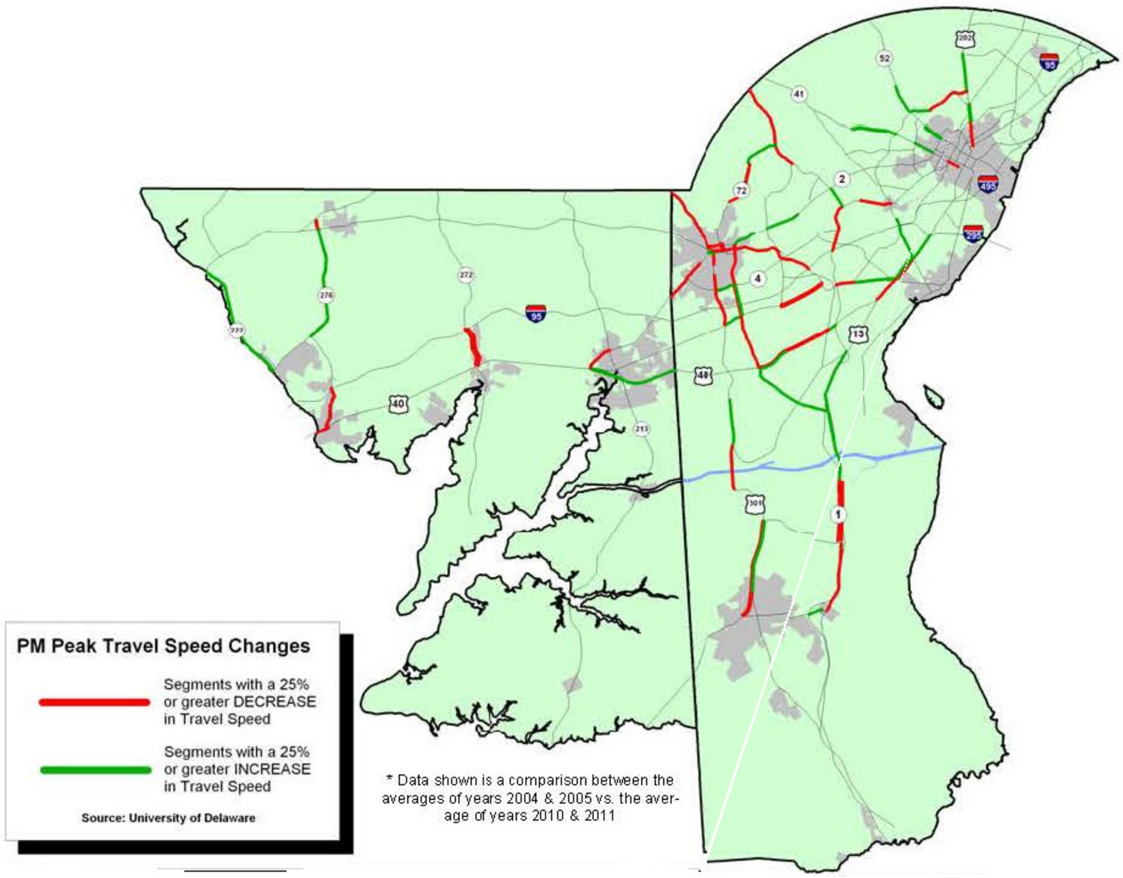
- Regional delay/capacity analysis for signalized intersections in the arterial network.

- Identification of intersections that can no longer function efficiently due to limited capacity.
- Prioritization of intersections in need of capital improvements, minor adjustments, or only signal timing improvements.
- Status update on capital improvements and implementation of TRS to demonstrate progress to decisionmakers and the public.[(49)]

Beyond this effort, WILMAPCO's strategy evaluation is more qualitatively focused, favoring those strategies that eliminate trips, create a mode shift, and effect operational efficiency over capital improvements. WILMAPCO found that the outputs of cost-benefit analyses were not useful for informing decisionmakers, and WILMAPCO no longer conducts the analyses.

Assessing Implemented M&O Strategies

WILMAPCO's congestion management system does not yet include conducting assessments of individually implemented M&O strategies, but it is working with State transportation departments on coordinating the data necessary for the analysis. Regional performance improvements and degradations can be seen from its system monitoring section (figure 21), which can be used to inform future decisions. In the assessment of individual strategies, WILMAPCO has experienced difficulty isolating the effects of a particular strategy in conjunction with local development, where business closures and signal retiming activities impact system performance but are not regularly reported to the agency.



©WILMAPCO.

Figure 21. Map. The p.m. peak travel speed changes, 2004–2011.[48]

Data Barriers

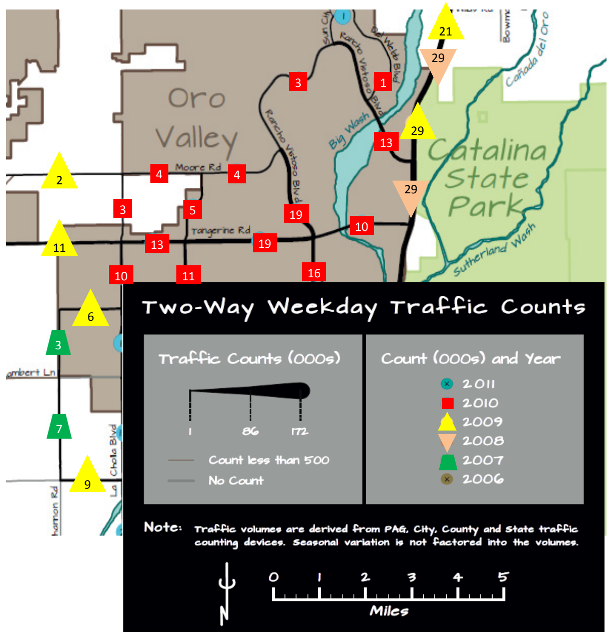
WILMAPCO's barriers include a lack of funding and resources to collect before-and-after data necessary for the assessment of individual strategies.

PIMA ASSOCIATION OF GOVERNMENTS (PAG) (TUCSON)

PAG collects much of its own data, supplemented by data from member jurisdictions and contractors. Collecting and compiling data on system performance is part of PAG's work program. PAG aggregates all traffic volume counts on arterials and collectors in the region and collects turning movement data. It receives performance data on freeways and other State roadways from the Arizona Department of Transportation (ADOT).

Use of Data in Monitoring Transportation Operational Performance and Tracking Performance Objectives

Travel time, speed, and intersection delay are used to generate a travel time index and the annual delay per traveler to measure system performance as well as traffic counts to track volume-to-capacity ratios, which are depicted graphically to show relative congestion throughout the region (figure 22).[(50)]



©PAG.

Figure 22. Map. PAG relative congestion.[(50)]

PAG has set several system performance objectives and performance measures as part of the CMP monitoring process in its current regional transportation plan, and the organization has begun monitoring those objectives as part of its 2045 Regional Transportation Plan development process. PAG will continue to evaluate the relevance of its CMP objectives as it implements revisions to the CMP and assesses the requirements associated with performance measure reporting required as part of MAP-21 legislation. PAG is working with the University of Arizona to launch a travel time collection effort using Bluetooth® technology.

Evaluating M&O Strategies in Planning

M&O strategies are generally prioritized based on objectives, goals, and resources that have been agreed upon by consensus among member jurisdictions and supplemented by user input, such as survey input from participants in the rideshare program.

The PAG region uses a Synchro® model for 600 signals, and this model is used to evaluate signal timing projects. In conjunction with the University of Arizona, PAG has begun to develop a mesoscopic model that will have the potential to evaluate more M&O strategies. To prove the concept, researchers and PAG staff have tested the new model on a bus rapid transit evaluation that involves the regional travel demand model, the mesoscopic model, and the microscopic model (Vissim).

Recently, Tucson and Portland participated in an FHWA demonstration project on the use of a system to integrate data between AMS tools as well as limited field data. In addition to demonstrating aspects of the AMS system, the test in Tucson focused on the following two objectives for the I-10 corridor and its interchanges:

- Identify future capacity requirements for the I-10 corridor.
- Evaluate optimal construction sequencing for the corridor and its interchanges.

The data sources for the test in Tucson are defined in table 3, which is taken from the FHWA AMS integration project report. The AMS test used a DTA and VISSIM model.

Table 3. Data sources for AMS integration test in Tucson.[(7)]

Source Data Type	AMS Tool	Source
Regional travel demand model	TransCAD	PAG
24-h segment counts, intersection turning movement counts, I-10 mainline speed data		Collected by quality counts for ADOT
Regional Synchro® models	Synchro®	PAG

Blank cell = Not applicable.

Assessing Implemented M&O Strategies

Due to limited staff and funding, most performance evaluation is conducted using Synchro® analysis rather than post-implementation studies. However, PAG has evaluated selected corridor timing projects through a comparison of before-and-after volume and speed data.

Data Barriers

Performance measures established in the CMP report were focused on low-cost options because of funding limitations. PAG would like to conduct more before-and-after studies but lacks the staff required to cover all activities.

REFERENCES

1. Federal Highway Administration (2015). "Planning for Operations Homepage." (Web site) Washington, DC. Accessed online: December 3, 2015. (http://www.plan4operations.dot.gov/)

2. Mahassani, H.S., Kim, J., Chen, Y., Stogios, Y., Brijmohan, A., and Vovsha, P. (2014). *SHRP2 L04: Incorporating Reliability Performance Measures in Operations and Planning Modeling Tools*, SHRP 2 Report S2-L04-RR-1, Transportation Research Board, Washington, DC. (http://www.trb.org/Main/Blurbs/170716.aspx)

3. Vandervalk, A., Louch, H., Guerre, J., and Margiotta, R. (2014). *Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes – Technical Reference*, SHRP 2 Report S2-L05-RR-3, Transportation Research Board, Washington, DC. (http://www.trb.org/Main/Blurbs/168856.aspx)

4. Federal Highway Administration (publication date unknown). "The Urban Congestion Report (UCR): Documentation and Definitions" (Web site) Washington, DC. Accessed online: December 3, 2015. (http://www.ops.fhwa.dot.gov/perf_measurement/ucr/documentation.htm.)

5. Tarnoff, P.J., Young, S. E., Crunkleton, J., and Nezamuddin N. (2008). *Guide to Benchmarking Operations Performance Measures*, Preliminary Draft Final Report for the Transportation Research Board of the National Academies. (http://www.catt.umd.edu/research/benchmarking)

6. Margiotta, R., Dowling, R., and Paracha, J. (2012). *Analysis, Modeling, and Simulation for Traffic Incident Management Applications*, Report No. FHWA-HOP-12-045, Federal Highway Administration, Washington, DC. (http://www.ops.fhwa.dot.gov/publications/fhwahop12045/index.htm)

7. Nevers, B. L., Nguyen, K. M., Quayle, S. M., Zhou, X. and Taylor, J. (2013). *The Effective Integration of Analysis, Modeling, and Simulation Tools*, Report No. FHWA-HRT-13-036, Federal Highway Administration, McLean, VA. (http://www.fhwa.dot.gov/publications/research/operations/13036/index.cfm)

8. Jeannotte, K., Sallman, D., Margiotta, R. and Howard, M. (2009). *Applying Analysis Tools in Planning for Operations,* Report no. *FHWA-HOP-10-001*, Federal Highway Administration, Washington, DC. (http://www.ops.fhwa.dot.gov/publications/fhwahop10001/index.htm)

9. Sallman, D., Flanigan, E., Jeannotte, K., Hedden, C., and Morallos, D. (2012). *Operations Benefit/Cost Analysis Desk Reference*, Report No. FHWA-HOP-12-028, Federal Highway Administration, Washington, DC. (http://www.ops.fhwa.dot.gov/publications/fhwahop12028/index.htm)

10. Alexiadis, V. and Sallman, D. (2012). *Traffic Analysis Toolbox Volume XIII: Integrated Corridor Management Analysis, Modeling, and Simulation Guide*, Report No. FHWA-JPO-12-074, U.S. Department of Transportation's Research and Innovative Technology Administration, Washington, DC. (http://ntl.bts.gov/lib/50000/50600/50615/30B00211.pdf)

11. Mahmassani, H., Mudge, R., Hou, T., and Kim, J. (2013). *Use of Mobile Data for Weather Responsive Traffic Management Models*, Report No. FHWA-JPO-13-003, United States Department of Transportation, Research and Innovative Technology Administration, Federal Highway Administration, Washington, DC. (http://ntl.bts.gov/lib/47000/47300/47329/FHWA-JPO-13-003-Final_Pkg_V1.pdf)

12. Scriba, T., Chandler, B., Kehoe, N., Beasley, K., O' Donnell, C., Luttrell, T., and Perry, E. (2012). *Assessing the Effectiveness of Transportation Management Plan (TMP) Strategies: Feasibility, Usefulness, and Possible Approaches*, Report No. FHWA-HOP-12-043, Federal Highway Administration, Washington, DC. (http://www.ops.fhwa.dot.gov/wz/resources/publications/fhwahop12043/fhwahop12043.pdf)

13. U.S. DOT, RITA, *Integrated Corridor Management Analysis, Modeling, and Simulation Results for the U.S. 75 Corridor in Dallas, Texas*, September 2010, unpublished.

14. USDOT, Research and Innovative Technology Administration (2010). "Integrated Corridor Management," United States Department of Transportation, Washington, DC. Workshop Presentation.

15. Alexiadis, V. and Armstrong, A. (2010). *Integrated Corridor Management Modeling Results Report: Dallas, Minneapolis, and San Diego*, Report No. FHWA-JPO-12_037, USDOT, Research and Innovative Technology Administration, Washington, DC. (http://ntl.bts.gov/lib/54000/54300/54346/ICM_Modeling_Results_Report__FHWA-JPO-12-037_.pdf)

16. USDOT, *Annex 3. ICM AMS Results for the I-15 Corridor in San Diego, California*, September 2010, unpublished.

17. Regional Transportation Commission of Southern Nevada (2009). *2013-2035 Regional Transportation Plan*, *Appendix 6: Congestion Management and Project Selection Process,* Regional Transportation Commission of Southern Nevada, Las Vegas, NV. Accessed online: December 3, 2015. (www.rtcsnv.com/planning-engineering/transportation-planning/2013-2035-regional-transportation-plan-update)

18. Regional Transportation Commission of Southern Nevada (2015). "FAST Dashboard" (Web site), Las Vegas, NV. Accessed online: December 3, 2015. http://bugatti.nvfast.org/Default.aspx.

19. ICF Consulting (2006). *Congestion Management Process Innovations: A Menu of Options*, New York State Association of Metropolitan Planning Organizations, New York, NY. Accessed online: December 7, 2015. (http://www.incog.org/Transportation/congestionandtraffic/CMS_FINAL_REPORT.pdf)

20. Muthukumar, V. and Dangeti, M. (2011). *Before and After Studies for RTC Transit*, Regional Transportation Commission of Southern Nevada, Las Vegas, NV. Accessed online: December 7, 2015. (http://www.rtcsnv.com/mpo/plansstudies/Docs/UPWP_report_4.0.pdf)

21. Kimley-Horn and Associates, Inc. (2011). *Before and After Studies for RTC Transit – Boulder Highway Before Study*, Regional Transportation Commission of Southern Nevada, Las Vegas, NV. Accessed online: December 7, 2015. (http://www.rtcsnv.com/mpo/plansstudies/Docs/2011-06-30%20BEFORE%20REPORT%20-%20Boulder%20Highway%20v7(No%20UNLV%20Data).pdf)

22. Houston-Galveston Area Council (2014). "Houston-Galveston Area Council Homepage" (Web site), Houston, TX. Accessed online: December 3, 2015. (http://www.h-gac.com/home/default.aspx)

23. Houston TranStar (2015). "Real-Time Traffic Map" (Web site), Houston, TX. Accessed online: December 3, 2015. (http://traffic.houstontranstar.org/layers/)

24. Metropolitan Planning Commission (2014). "State of the System: Measuring Bay Area Transportation Performance" (Web site), Oakland, CA. Accessed online: December 3, 2015. (http://www.mtc.ca.gov/library/state_of_the_system/)

25. California Department of Transportation (2014). "Performance Measurement System (PeMS)" (Web site), CA. Accessed online: December 3, 2015. (http://pems.dot.ca.gov/)

26. Bay Area Metropolitan Transportation Commission (2015). "511 System" (Web site). Accessed on December 3, 2015. (http://www.511.org)

27. Association of Bay Area Governments and the Metropolitan Transportation Commission (2013). *Plan Bay Area*, Oakland, CA. Accessed on December 3, 2015. (http://www.mtc.ca.gov/planning/plan_bay_area/)

28. Association of Bay Area Governments and Metropolitan Transportation Commission (2013). *Plan Bay Area - Strategy for a Sustainable Region - Final Performance Assessment Report*, Oakland, CA. Accessed online: December 7, 2015. (http://planbayarea.org/pdf/final_supplemental_reports/FINAL_PBA_Performance_Assessment_Report.pdf)

29. Cambridge Systematics and System Metrics Group (2008). *San Mateo/Santa Clara 101 Corridor – Existing Conditions Analysis*, Metropolitan Transportation Commission, Oakland, CA.

30. Caltrans District 4 (2010). *Interstate 580 East - Corridor System Management System*, Oakland, CA. Accessed online: December 4, 2015. (http://dot.ca.gov/hq/tpp/corridor-mobility/CSMPs/d4_CSMPs/i580/580E_CSMP_Summary.pdf)

31. Caltrans, Metropolitan Transportation Commission, and California Highway Patrol, Traffic Operations System Equipment Management System (TEMS). Accessed TEMS 2012.

32. Southwestern Pennsylvania Commission (2014). "Data Services Home" (Web site), Pittsburg, PA. Accessed online: December 4, 2015. (http://www.spcregion.org/data_store.shtml#traffic)

33. Southwestern Pennsylvania Commission (2011). *2040 Transportation and Development Plan for Southwestern Pennsylvania*, *Section 4. The Transportation Plan,* Southwestern Pennsylvania Commission, Pittsburg, PA. Accessed online: December 7, 2015. (http://www.spcregion.org/pdf/lrp2040/2040%20Plan_4_Transportation%20Plan.pdf)

34. Southwestern Pennsylvania Commission (2011). *2011 Regional Operations Plan*, Southwestern Pennsylvania Commission, Pittsburg, PA. Accessed online: December 7, 2015. (http://www.spcregion.org/pdf/rop11/2011_ROP_FINAL_070611.pdf)

35. Southwestern Pennsylvania Commission (2015). *Congestion Management Corridors: Allegheny County: Corridor 125: 5th Ave/Forbes Ave*, Southwestern Pennsylvania Commission, Pittsburg, PA. Accessed December 7, 2015. (http://www.spcregion.org/trans_cong_corr125.shtml)

36. San Diego Association of Governments (2004). *Regional Comprehensive Plan for the San Diego Region*, San Diego Association of Governments, San Diego, CA. Accessed online: December 7, 2015. (http://www.sandag.org/?projectid=1&fuseaction=projects.detail)

37. San Diego Association of Governments (2015). "Transportation" (Web site) San Diego Association of Governments, San Diego, CA. Accessed online: December 4, 2015. (http://www.sandag.org/index.asp?subclassid=78&fuseaction=home.subclasshome)

38. San Diego Association of Governments (2013). "I-15 Integrated Corridor Management" (Web site), San Diego Association of Governments, San Diego, CA. Accessed online: December 4, 2015. (http://www.sandag.org/index.asp?projectid=429&fuseaction=projects.detail)

39. San Diego Association of Governments (2013). *State of the Commute 2013,* San Diego Association of Governments, San Diego, CA. Later reports available at: http://www.sandag.org/index.asp?projectid=257&fuseaction=projects.detail.

40. San Diego Association of Governments (2012). "TransNet Active Transportation Grant Program: Cycle 2" (Web site), San Diego Association of Governments, San Diego, CA. Accessed online: December 4, 2015. (http://www.sandag.org/index.asp?classid=13&subclassid=98&projectid=418&fuseaction=projects.detail)

41. San Diego Association of Governments (2014). *Riding to 2050, The San Diego Regional Bicycle Plan*, San Diego Association of Governments, San Diego, CA. Accessed online: December 7, 2015. (http://www.sandag.org/index.asp?projectid=353&fuseaction=projects.detail)

42. System Metrics Group, Inc. (2010). *Corridor System Management Plan (CSMP) San Diego County I-805, Final Report*, San Diego Association of Governments, San Diego, CA. Accessed online: December 7, 2015. (http://www.dot.ca.gov/dist11/departments/planning/pdfs/corridor/2010_CSMP_Final_Report.pdf)

43. Metro (2014). *2014 Regional Transportation Plan*, Metro, Portland, OR. Accessed online: December 7, 2015. (http://www.oregonmetro.gov/regional-transportation-plan)

44. Metro (2010). *2035 Regional Transportation Plan*, Metro, Portland, OR. Accessed online: December 7, 2015. (http://www.oregonmetro.gov/regional-transportation-plan)

45. Metro (2010). "Mobility Corridor Atlas" (Web site), Metro, Portland, OR. Accessed on December 4, 2015. (http://www.oregonmetro.gov/mobility-corridors-atlas)

46. Metro (2014). *2015 – 2018 Metropolitan Transportation Improvement Program,* Metro, Portland, OR. Accessed online: December 7, 2015. (http://www.oregonmetro.gov/metropolitan-transportation-improvement-program)

47. Metro (2010). *Regional Transportation System Management and Operations Plan,* Metro, Portland, OR. Accessed online: December 7, 2015. (http://www.oregonmetro.gov/regional-transportation-system-management-and-operations-plan)

48. Wilmington Area Planning Council (2012). *2012 Congestion Management System Summary*, Wilmington Area Planning Council, Wilmington, DE. Accessed online: December 4, 2015. (http://www.wilmapco.org/RTP2040/appendix/AppendixK.pdf)

49. Wilmington Area Planning Council (2015). "Congestion Management System website" (Web site), Wilmington Area Planning Council, Wilmington, DE. Accessed online: December 4, 2015. (http://www.wilmapco.org/cms/)

50. Pima Association of Governments (2015). “2012 Traffic Volumes in Metropolitan Tucson and Eastern Pima County” (Web site), Pima Association of Governments, Pima, AZ. Accessed online: December 4, 2015. (https://www.pagnet.org/RegionalData/TravelDataandForecasting/AnnualTrafficCountProgram/tabid/108/Default.aspx)

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