On-Call Simulation Modeling Training

Model Development, Calibration and Review

presented to Caltrans

presented by Cambridge Systematics, Inc.





October 1, 2018

Today's Agenda

- Background and objectives
- Model Development Review
- Model Validation Datasets
- Changing FHWA Guidance on Calibration
- Calibration Process Review
- Model Review Process



Project Background and Objectives

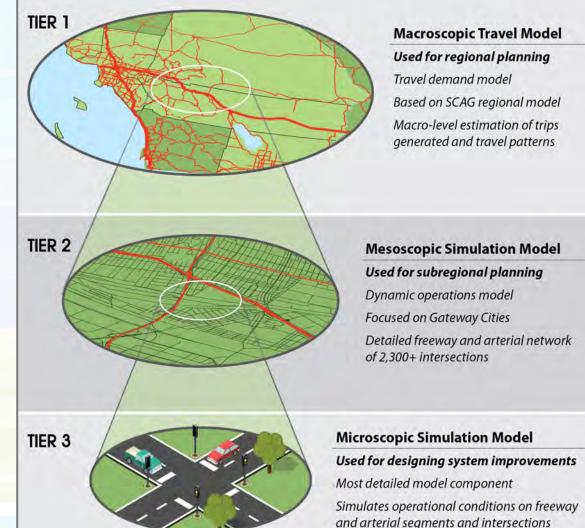
- Senate Bill (SB) 375 (Sustainable Community), SB 743 (CEQA Reform), and SB 391 (California Transportation Plan) require a more robust quantitative and analytic evaluation to describe the relative performance of transportation policies, strategies, and programs.
- SB 1, now in force, created the Solutions for Congested Corridors Program. Caltrans will be collaborating with regional partners to identify and develop fixes for these corridors, which cannot be analyzed using static methods alone.
- On-call traffic simulation training will enable Caltrans to meet the mandate of these bills by educating Caltrans staff about how to perform complex analyses of our facilities for critical planning, operations, and capital improvement projects using the latest generation of traffic analysis tools.

Webinar Four-part Series

- Webinar 1 Transportation Analysis and Simulation Overview Delivered in January 2018
- Webinar 2 Scoping a Simulation Project Delivered in June 2018
- Webinar 3 How to Develop, Calibrate & Review Models Today
- Webinar 4 How to Interpret and Communicate Model Results and How to Produce Output for Environmental Studies from Simulation Models – Documentation of calibration assumptions and results; documentation of overall analysis results; with and without project; tables, charts, graphics and maps summaries of performance measures. Key output from simulation models, key needs for environmental studies (volumes, delays, speeds, queueing, travel time, VMT, etc.), how to use and interpret simulation model output for environmental studies. Delivery date tentative January 2019.

Macro, Meso and Micro Simulation Modeling

- Macro Long range traffic forecasts, regional patterns and mode shift
 - » Usually Demand Modeling
 - » Rarely Simulation
- Meso Traveler information, HOT lanes, congestion pricing, regional diversion
- Micro Detailed analysis of physical improvements and traffic control strategies, congested conditions



Analysis Resolutions



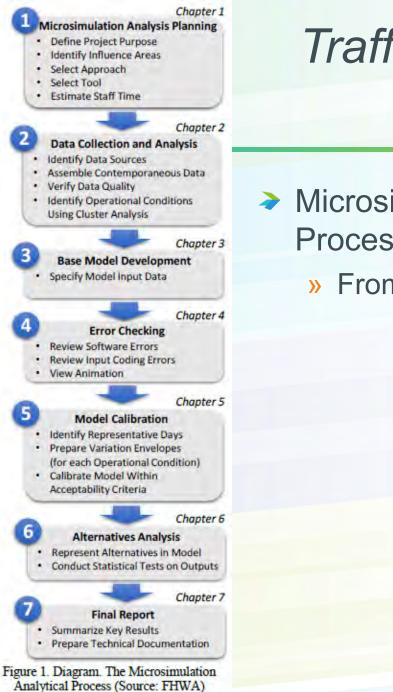
What is Calibration?

Calibration is the adjustment of model parameters to improve the model's ability to reproduce time-dynamic system performance observed under specific operational conditions.

What is Validation?

Process where the analyst checks the overall modelpredicted traffic performance for a street/road system against field measurements of traffic performance, such as traffic volumes, travel times, average speeds, and average delays.

MODEL DEVELOPMENT



Traffic Analysis Tools: Volume III Microsimulation

- Microsimulation Model Development Process
 - » From forthcoming update version

Geometry

- » Network connectivity
- » Section/Link parameters
- » Turn/Connector parameters
 - Reduced speeds
 - U-turn prohibitions

Signal Controls

- » Physical movements coded for each phase
- » Proper coding of timing and phase settings
- » Fixed vs Actuation
- » Actuation settings properly coded?
- » Coordination?

Stop Controls

» Driver reactions

Basics Actuated	Detectors					
Recall: No 🔻						
Minimum Green:	10.00 sec 🔶	Max-Out:	55.00 sec 🔶	Passage Time:	4.80 sec	-
Permissive Period From:	0.00 sec 🖨	Permissive Period To:	50.00 sec 🖨	Force-Off:	60.00 sec	-
Variable Initial						
Maximum Initial Green	: 15.00 sec 🗧	Seconds per Actuation: 2	.50 sec 🜲	Hold		
Gap Reduction						
Minimum Gap: 3.00 s	ec 🔹 Tim	e Before Reduce: 1.70 se	c 🖨 Tin	ne to Reduce: 3	30.00 sec	•

Demands

- » Zones / Centroids / Parking Lots
- » Review OD preparation and adjustment process
- » Traffic Demands
 - Static Routes
 - OD Matrices
 - Vehicle Types
 - Scaling Factors
- Warm-up time
- Cool-down time

- ITS Elements
- Existing Traffic Management Strategies
- Transit

Pre-Calibration Error Checking

- Test via diagnostic runs
 - » Low volume simulations
- Are vehicle movements realistic?
- Are signals functioning correctly?
- Are vehicles routed logically?

MODEL VALIDATION DATASETS

Traditional Types of Data

Physical Geometry

- Rectified aerial photography
- Base GIS
 mapping files

Traffic Control

- Signs
- Signal control timing plans
- Ramp Meter Controls

Travel Demand

- Traffic counts
- Vehicle classification counts
- Transit
 Schedules

Operational Data

- Speeds
- Travel times
- Congestion
- Queuing measurements
- Other field
 observations

Using PeMS Data – Downloading Data

- PeMS Data Clearinghouse provides a single access point for downloading PeMS data sets.
- Flow and Speed
 - » 5-minute data
 - » AM, PM peak period or 24 hours
 - » Week or Weekday (Tuesday, Wednesday, Thursday), no holidays
 - » Month or Year
- Health of Detectors
 - » Use flow and speed, only if it observed data is good.

Туре	District	1.0.2.2.1		
Station	5-Minute	Submit		
D7 201	3 Station 5-Minute		Data Summary	
	FMAMJJASO		 This dataset contains the standard PeMS ro data. The algorithms used to process raw o described in the System Help. 	
16			Months with data are indicated by a gray re rectangle to view a listing of files available	
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Field Sp Name Timestamp Station District Freeway #	ecification Comment The date and time of the beginning of the summary interval. For example, a time do contain measurements collected between 08:00:00 and 08:04:59. Note that secon values are always 0 for five-minute aggregations. The format is NH/DD/YW Hr24:NH:55 Unique station identifier: Use this value to coss-reference with Metadata files. District # Freeway #	Units f i i i	File Name d07_toxt_station_5min_2018_01_01_bt.gz d07_toxt_station_5min_2018_01_02_bt.st.gz d07_toxt_station_5min_2018_01_04_bt.gz d07_toxt_station_5min_2018_01_05_bt.gz d07_toxt_station_5min_2018_01_05_bt.gz d07_toxt_station_5min_2018_01_05_bt.gz d07_toxt_station_5min_2018_01_05_bt.gz d07_toxt_station_5min_2018_01_05_bt.gz d07_toxt_station_5min_2018_01_07_bt.dz d07_toxt_station_5min_2018_01_01_bt.dz	29,746,960 30,407,709 30,085,444 29,034,393 30,545,474 30,031,755 28,880,544 30,235,207
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Lane Type A string indicating the type of lane. Possible values (and their meaning are: . CD (Coll/Dist) CH (Conventional Highway) FF (Fwy-Fwy connector)

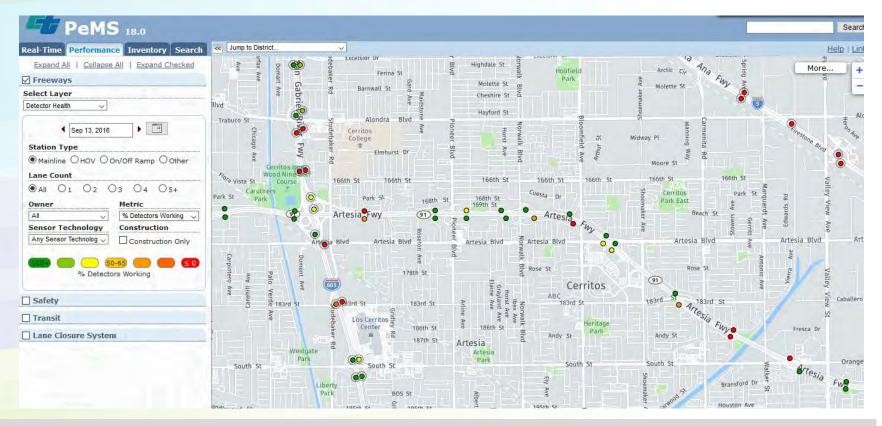
· FR (Off Ramp) HV (HOV) ML (Mainline) OR (On Ramp) Segment length covered by the station In

Total number of samples received for all Percentage of individual lane points at this

es

File Name	Bytes	
d07_text_station_5min_2018_01_01.txt.gz	29,746,960	
d07_text_station_5min_2018_01_02.txt.gz	30,407.709	
d07_text_station_Smin_2018_01_03.txt.gz	30,085,444	
d07_text_station_5min_2018_01_04.txt.gz	29,034,393	
d07_text_station_5min_2018_01_05.txt.gz	30,545,474	
d07_text_station_5min_2018_01_06.txt.gz	30,031,755	
d07_text_station_5min_2018_01_07.txt.gz	28,880,544	
d07_text_station_5min_2018_01_08.txt.gz	30,235,207	
d07_text_station_5min_2018_01_09.txt.gz	29,396,188	
d07_text_station_5min_2018_01_10.txt.gz	30,540,067	
d07_text_station_5min_2018_01_11.txt.gz	30,779,357	
d07_text_station_Smin_2018_01_12.txt.gz	30,776,595	
d07_text_station_5min_2018_01_13.txt.gz	30,194,909	
d07_text_station_Smin_2018_01_14.txt.gz	29,612,702	
d07_text_station_5min_2018_01_15.txt.gz	30,337,947	
d07_text_station_5min_2018_01_16.txt.gz	30,560,173	
d07_text_station_5min_2018_01_17.txt.gz	30,519,709	
d07_text_station_5min_2018_01_18.txt.gz	30,637,635	
d07_text_station_5min_2018_01_19.txt.gz	30,579,904	
d07_text_station_5min_2018_01_20.txt.gz	30,007,286	
d07_text_station_5min_2018_01_21.txt.gz	28,598,486	
d07_text_station_5min_2018_01_22.txt.gz	29,598,423	
d07_text_station_5min_2018_01_23.txt.gz	29,486,038	
d07_text_station_5min_2018_01_24.txt.gz	29,348,853	

PeMS Detector Health



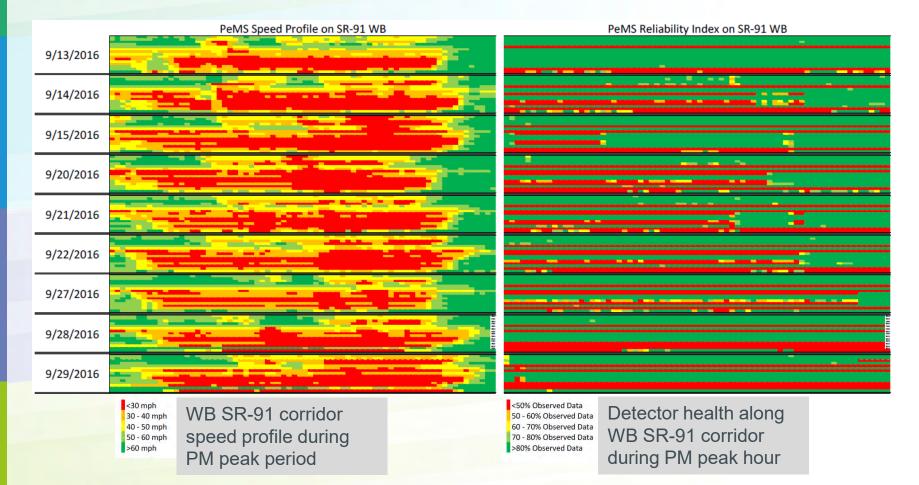
http://pems.dot.ca.gov/?dnode=search&content=cnt_search&view=p#33.87487,-118.08187,15

Using PeMS Data – Analyzing Data

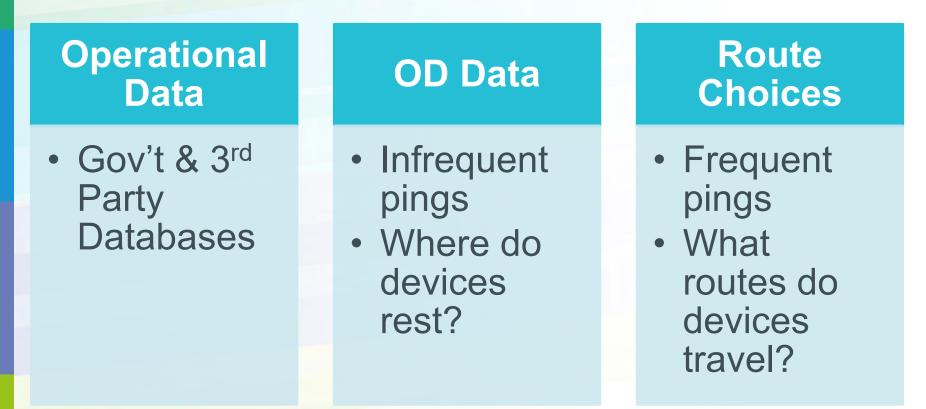
Once data is selected for the region and time of interest, heat maps can be developed to visualize speeds, congestion, flows, and quality of data for a specific time period.

												Но	ur														Arroyo
Name	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23			Grande
BROADWAY HWY 135 101 SB VDS MLSB	67	67	67	67	67	67	67	66	66	65	65	65	65	65	64	63	63	62	64	67	67	67	67	67	/		-
OAK PARK BLVD 101 NB VDS MLSB SB	66	66	66	66	66	66	65	63	62	63	63	63	63	63	63	63	60	57	61	62	64	65	66	66			
SHELL BEACH RD 101 NB VDS MLSB S	65	65	65	65	65	65	65	65	64	64	64	63	63	63	62	59	56	56	61	64	64	65	65	65	1		Price St
SPYGLASS DR 101 SB VDS MLSB SB	69	69	69	69	69	69	68	67	67	66	65	65	64	64	61	51	38	35	55	66	67	67	68	68			Price St
AVILA BEACH DR 101 NB VDS MLSB S	70	70	70	69	70	70	70	70	70	69	69	67	67	67	65	59	44	38	60	69	69	69	70	70			Pismo Beach
SAN LUIS BAY DR 101 SB VDS MLSB	69	69	69	69	69	69	68	67	67	66	65	65	64	64	63	61	59	58	64	67	67	68	68	69			
SO HIGUERA ST EXIT 101 NB VDS ML	67	67	67	67	67	67	67	67	66	65	64	64	63	63	62	58	54	55	64	66	66	67	67	67			Avila
SO HIGUERA ST ON RAMP ST 101 NB	67	67	66	66	67	67	67	67	67	66	65	65	64	64	63	59	53	56	64	67	66	66	67	67		1	Beach
LOS OSOS VALLEY RD 101 SB VDS ML	69	69	69	69	69	68	67	67	_67	67	66	66	66	65	64	61	55	60	65	67	67	67	68	68			Dr
PRADO RD CMS 101 NB VDS MLSB SB	67	66	66	66	66	67	67	66	65	65	65	64	63	62	61	59	55	58	65	67	67	67	67	67			
PRADO RD 101 NB VDS MLSB SB	67	66	66	66	66	67	67	67	66	66	66	65	64	63	63	59	55	57	66	67	67	67	67	67			
MADONNA RD 101 SB VDS MLSB SB	69	69	69	69	69	68	67	67	66	66	66	65	64	64	63	61	59	61	66	67	67	67	68	68			Los Osos
MARSH ST 101 SB VDS MLSB SB	69	69	69	69	69	68	67	66	65	65	64	64	63	63	62	61	61	61	65	67	67	68	68	68			Valley Rd
BROAD ST 101 SB VDS MLSB SB	69	70	70	70	69	69	68	66	65	64	64	63	63	63	62	60	60	60	64	66	67	68	69	69		1000	
TORO ST 101 NB VDS MLSB SB	66	66	66	66	67	67	67	65	65	66	66	65	65	65	65	63	63	63	66	67	67	67	67	67			Con
GRAND AVE IN SLO AT 101 SB VDS M	69	69	68	69	68	69	67	65	65	66	67	67	66	66	65	65	66	66	67	68	68	68	68	69			San
MONTEREY ST 101 NB VDS MLSB SB	66	65	65	65	66	66	66	65	65	66	66	66	66	66	65	65	66	66	67	67	66	66	66	66			Luis
FOX HOLLOW RD 101 NB VDS MLSB SB	67	66	66	66	67	67	66	65	65	65	65	65	65	64	64	64	64	64	66	67	67	67	67	67			Obispo

Speeds and Reliability Index Comparison



Emerging Types of Data – Connected Devices and Location Based Services



Transportation Databases - Federal

Database	Description	Extents
FHWA Highway Performance Monitoring System (HPMS)	Data on the extent, condition, performance, use and operating characteristics of the nation's highways. Also captures characteristics of some arterial and collector functional systems.	Nationwide
FHWA National Bridge Inventory (NBI)	Condition data on more than 600,000 bridges located on Interstate Highways, U.S. highways, State and county roads, and publicly-accessible bridges on Federal lands.	Nationwide
FHWA National Household Travel Survey (NHTS) Add-On	Supplementary survey data purchased by State DOTs, MPOs, and COGs for their local areas.	Survey Partners (also known as Add-Ons) exist nationwide
U.S. Department of Homeland Security Weigh-in-Motion (WIM) Stations	WIM devices record axle weights and gross vehicle weights as vehicles drive over a measurement site.	Nationwide
National Performance Management Research Data Set (NPMRDS)	Historical traffic information using anonymous, real- time aggregated GPS probe data from a wide array of commercial vehicle fleets, connected cars and mobile apps.	Nationwide (for National Highway System)

Transportation Databases State and Regional

Database	Description	Extents
Caltrans Performance Measurement System (PeMS)	Real-time and historical traffic data collected from nearly 40,000 individual freeway detectors.	All major metropolitan areas in California
Location-Based Services Data	Set of mobile phone location based services data used to glean insights into linked trips and tours, robust demographics, and travel purpose.	Southern California
Arterial Performance Measurement Tool (APMT)	Establishes baseline performance conditions for selected subregional arterial corridors, such as travel demand, productivity, mobility and reliability.	Specific to Los Angeles County
Caltrans Automated Pavement Condition Survey (APCS)	Condition data collected at highway speeds using specialized vehicles with inertial profilers, transverse laser system, and high resolution cameras for all lanes of the entire State Highway for compliance reporting for MAP-21.	Within the State of California

Transportation Databases State and Regional

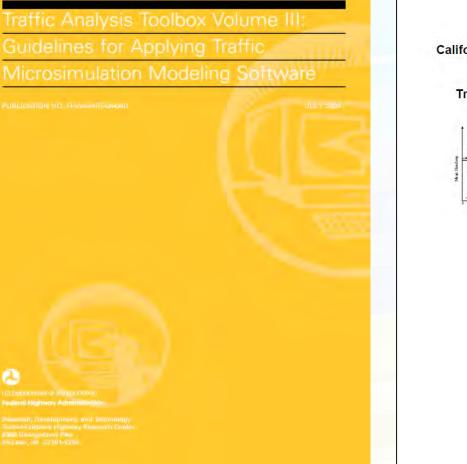
Database	Description	Extents		
Statewide Integrated Traffic Records System (SWITRS)	Data gathered from collision scenes by California Highway Patrol staff and members of its Allied Agencies.	Within the State of California		
California Vehicle Inventory and Use Survey (CA-VIUS)	State-level vehicle inventory survey that has collected information about commercial vehicle operations from establishments that operate trucks on California's roadways.	Mostly geared towards trucks that operate in California		
Caltrans Traffic Counts	Individual Caltrans Districts have calculated the volumes hourly, daily, and monthly to derive an annual average daily traffic count.	Within the State of California		
Truck Activity Monitoring System (TAMS)	Uses inductive loop signature technology to obtain high resolution truck data at Inductive Loop Detector sites and Weigh-in-Motion sites.	Various locations across California		

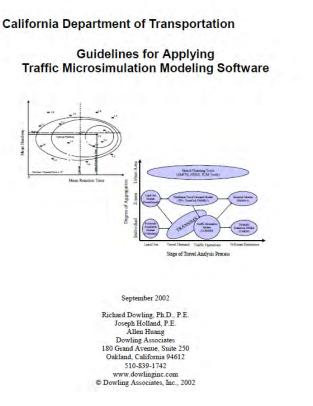
Transportation Databases – Private Sector & Other

Database	Description	Extents
INRIX, HERE, Waze	Real-time, historical and predictive traffic information using anonymous, real-time aggregated GPS probe data from a wide array of commercial vehicle fleets, connected cars and mobile apps.	Nationwide
Streetlight Data	Collection of anonymized location records created by mobile phones, GPS devices, connected cars, commercial trucks, fitness trackers, etc.	Nationwide
Airsage	Collection of real-time mobile signals, GPS and other location data to produce and process billions of anonymous data points every day.	Nationwide
American Transportation Research Institute (ATRI)	Real-time anonymized freight truck GPS data (e.g., periodic time, location, speed) sourced through unique industry partnerships.	Nationwide

CALIBRATION

Current References





September 2002

JULY 2004

Calibration Criteria: Current Microsim State of the Practice

- Traffic Analysis
 Tools Volume III
 (2004)
 - » "FHWA criteria"
 - » (ActuallyWisconsin)

Criteria and Measures	Calibration Acceptance Targets
Hourly Flows, Model Versus Observed	
Individual Link Flows	
Within 15%, for 700 veh/h < Flow < 2700 veh/h	> 85% of cases
Within 100 veh/h, for Flow < 700 veh/h	> 85% of cases
Within 400 veh/h, for Flow > 2700 veh/h	> 85% of cases
Sum of All Link Flows	Within 5% of sum of all link counts
GEH Statistic < 5 for Individual Link Flows*	> 85% of cases
GEH Statistic for Sum of All Link Flows	GEH < 4 for sum of all link counts
Travel Times, Model Versus Observed	
Journey Times, Network	
Within 15% (or 1 min, if higher)	> 85% of cases
Visual Audits	
Individual Link Speeds	
Visually Acceptable Speed-Flow Relationship	To analyst's satisfaction
Bottlenecks	
Visually Acceptable Queuing	To analyst's satisfaction

Other State References

Other State References

- » Oregon DOT's Protocol for VISSIM Simulation
- » Washington DOT's Protocol for VISSIM Simulation
- » Maryland DOT's VISSIM Modeling Guide
- » Virginia DOT's Traffic Operations and Safety Analysis Manual & VISSIM User Guide,
- » Wisconsin DOT's Traffic Engineering, Operations & Safety Manual - Chapter 16 Section 20 Microscopic Simulation Traffic Analysis
- » Florida DOT's Traffic Analysis Handbook
- » Iowa DOT's Microsimulation Guidance
- » Arkansas DOT's Guidelines for the Use of Microsimulation on AHTD Projects
- » Delaware Valley Regional Planning Commission's VISSIM Standards Project
- » Louisiana DOT's Microsimulation Modeling Policy

Other Valuable References

International References
 MULTITUDE (2014)



- Other FHWA Traffic Analysis Toolbox Reports: https://ops.fhwa.dot.gov/trafficanalysistools/index.htm
 - » Volume XIII: ICM AMS Guide
 - » Volume XIV: Guidebook on DTA Modeling
 - » And others

Key Concerns with Previous FHWA Guidance

- Fully Integrate Time-Dynamic Representation of Congestion
- Require Better Representation of Recurrent and Non-Recurrent Conditions
- Remove Subjective Calibration Criteria
- Emphasize Accurate Bottleneck Modeling

Forthcoming Volume III Update

- New Volume III Update Report is completed, but not yet published
- Workshops introducing this new methodology are being conducted by FHWA
- Publication date still TBD

New FHWA Guidance

Select Performance Measures

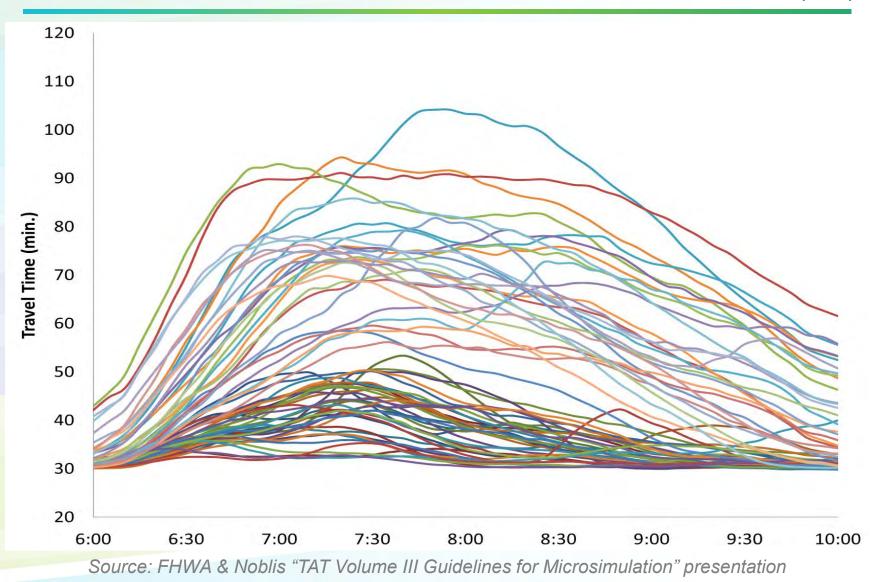
- Calibrate selectively, only for key performance measures.
- Performance measures for calibration must have good observed data.
- Calibration Process (For each travel condition)
 - 1. Identification of representative days.
 - 2. Preparation of variation envelopes.
 - 3. Assessment of simulation results against four calibration criteria:
 - Control for Maximum Number of Outliers
 - Control for Minimum Number of Inliers
 - Bounded Average Error
 - Bounded Systematic Error

Source: FHWA Volume III Update Workshop

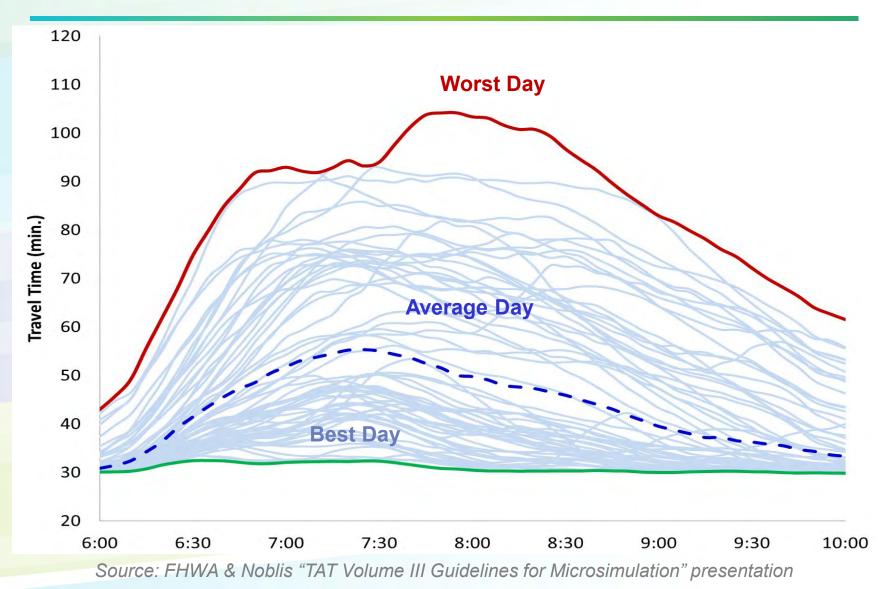


Real Systems Have Good Days & Bad Days

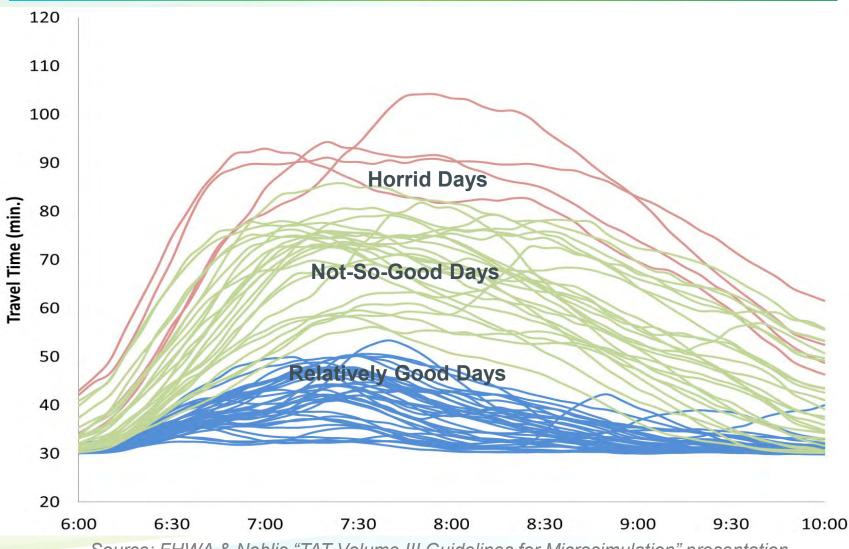
2012 Southbound AM Peak Travel Times, I-405 Corridor (WA)



Even An Average Day Captures Only a Fraction of System Dynamics

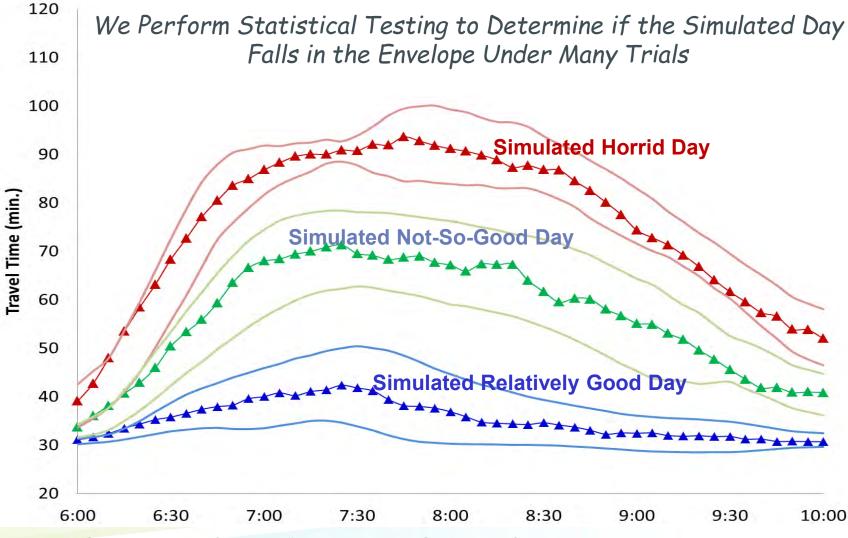


Use Cluster Analysis to Identify Distinct, Dissimilar Operational Conditions



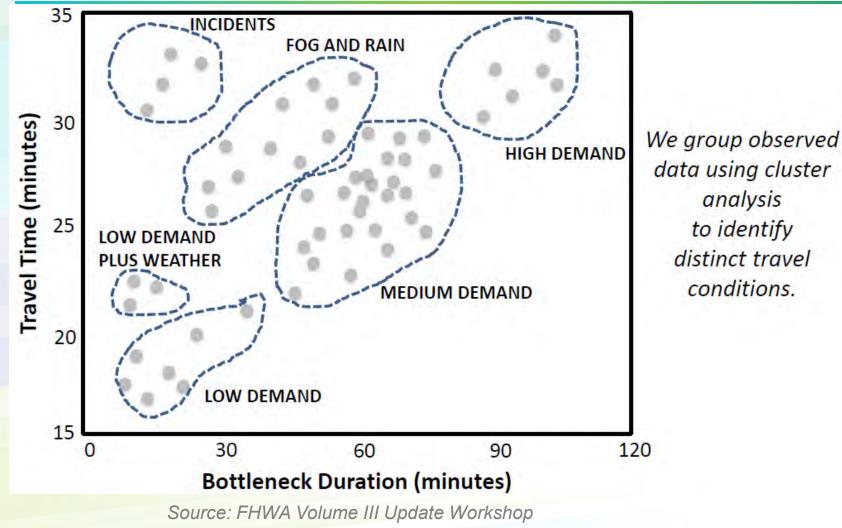
Source: FHWA & Noblis "TAT Volume III Guidelines for Microsimulation" presentation

Simulations Are Calibrated to Lie Within the Statistical Envelope

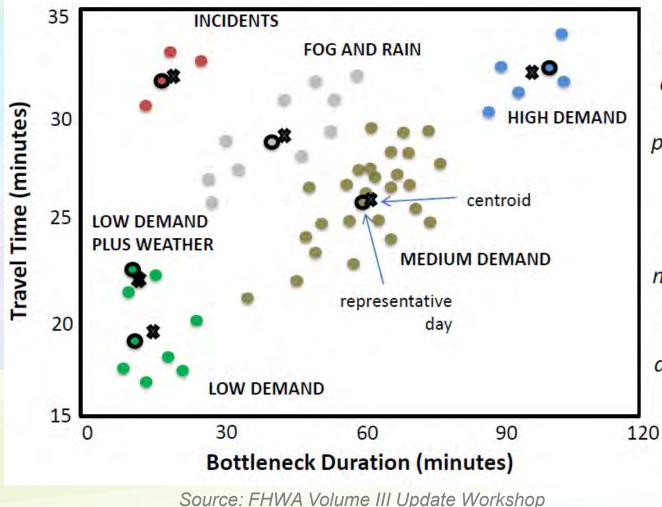


Source: FHWA & Noblis "TAT Volume III Guidelines for Microsimulation" presentation

Develop Clusters of Conditions



Select Representative Days



We calculate a centroid for each cluster that is the arithmetic mean performance in the cluster.

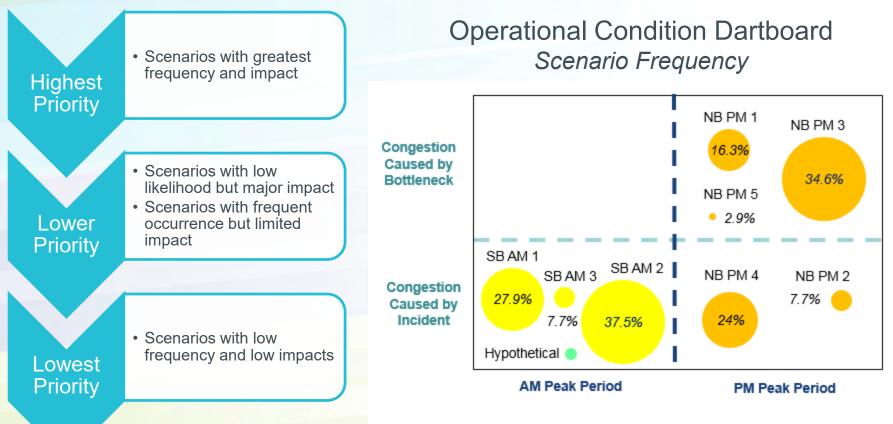
Then, we use relatively simple methods to find an actual day (i.e., representative day) that is closest to the centroid.

Example: San Diego ICM AMS Scenarios

Summary of Best Matching Incident Results

	Baseline	and the second	ation from uster Ana		Baseline Period	Post-Deployment Period				
#	Cluster by Direction and Time Period	Days in Cluster	Total Cluster Day Impact (min.)	% of Total Analysis Time Period	Date	ID		DSS Plan Type Implemented	DSS Response ID	
1	NB PM 4	25	63.25	24.0	10/12/12	7/7/14	639956	Ramps, Signals, ATIS	19536	
2	SB AM 2	39	108.03	37.5	10/2/12	2/9/15	754666	Signals, ATIS	27929	
3	NB PM 5	3	18.75	2.9	11/21/12	2/19/15	760369	Signals, ATIS	28292	
4	SB AM 3	8	34.64	7.7	10/1/12	5/7/15	804238	Ramps, Signals, ATIS	30028	
5	n/a, hypothetical	-	7	1.9	2.1	5/26/15		None. Managed lanes opened.		
6	SB AM 1	29	49.88	27.9	1/30/13	5/27/15	817649	Signals	30332	
7	NB PM 2	8	23.36	7.7	1/15/13	6/9/15			30451	
8	NB PM 1	17	41.82	16.3	1/28/13	6/16/15	845922	Ramps, Signals, ATIS	30617	
9	NB PM 3b	36	99.72	34.6	1/30/13	5/5/14 853963 Ramps, Signals, ATIS			31039	

Experimental Design for Analysis of Different Operational Conditions



Note: The size of each circle represents the percent of total analysis time period.

CALIBRATION PROCESS REVIEW

Overall Calibration Process

- Establish calibration objectives.
- Identify the performance measures and critical locations against which the models will be calibrated.
- Determine the statistical methodology to be used to compare modeled results to the field data.
- Determine the strategy for model calibration and identify parameters that are the focus of adjustments.
- Assemble field data previously collected for comparison to model outputs
- Conduct model calibration runs following the strategy and conduct statistical checks.
- Validation: Test or compare the calibrated model with a data set not used for calibration

Model Calibration Methods

- Traffic Network Calibration
- Route Choice Calibration
- Demand Calibration

- Ideally in that order
- Reality is an iterative process

Network Calibration Parameters

- Network Representation
 - » Accurately represented
 - Posted speeds, lane channelization, grades, visibility, speeds on curves, etc.

Driver Behavior

» Car following parameters, lane changing parameters, desired speed distributions, etc.

Controls

- » Driver reaction to signals / stop controls
- » Gap acceptance model parameters

Route Choice Parameters

- Cost functions
- User costs
- Vehicle type restrictions
- DTA use and settings
- Value of time / Willingness to pay

Demand Calibration

- Initial OD source / estimation
- OD Matrix Estimation (ODME) process (if used)
 - » Static
 - » Dynamic
- Trip Length Frequencies
- Temporal profiles

Calibration Parameter Checks

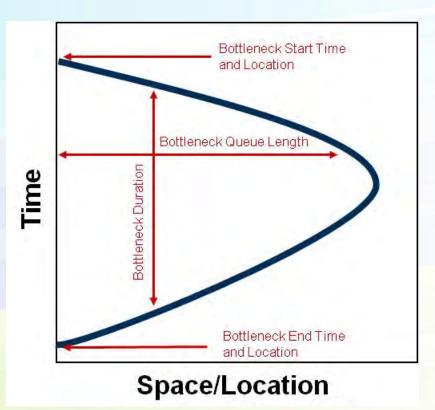
- Use of heavy local adjustments is not good calibration
 » Some are evitable
- Global and/or roadtype adjustment are preferred
 Or rules based application of parameter changes
- Adjusting too many parameters is not good practice
 Adjust key parameters the modeler has confidence in
- Avoid overfitting of model to field data
- Are enough random seed runs being performed?
 » Statistical significance of results

MODEL REVIEW PROCESS

Review of Calibration Results

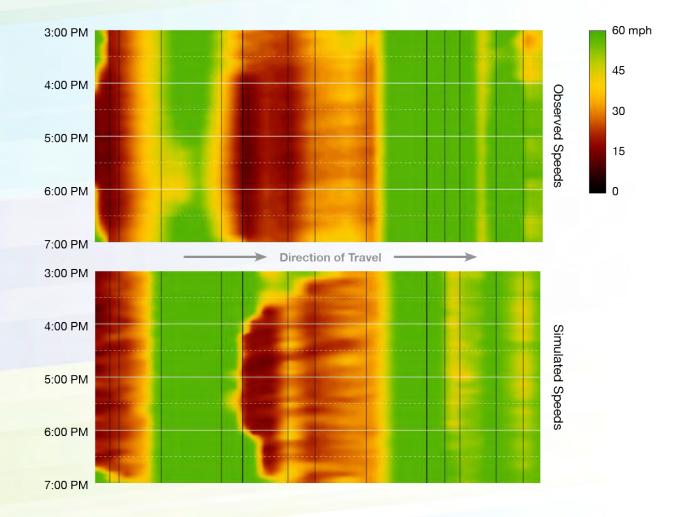
- Simulation Runs
 - » Replicate the existing calibration results
 - » Review / identify problematic areas
 - Areas of poor fit
 - Low speeds
 - High densities
 - Low flow rate
 - Prolonged queuing
 - Unintuitive routes

Example Speed Contour Diagram

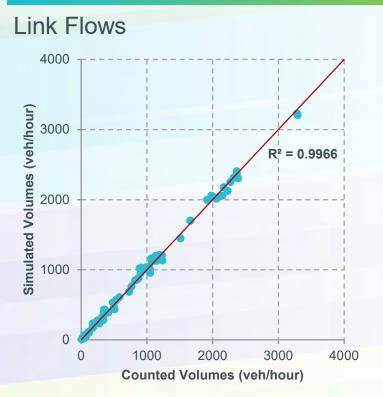


Linden Ave	I-94	Dunwoody Bivd	W of [Wirth Pkwy	W of TH 100	Xenia Ave	Colorado Ave	Louisiana Ave	Winnetka Ave	General Mills Blvd	TH 169	Shelard Pkwy	CR 73	Ridgedale Dr	Plymouth Rd	E of I-494	W of 1-494	
291.	290.0	288.0 5174->402 36	282.0		279.0 #	278.0		276.0	275.0	274.0	273.0		271.0		269.0	268.0	1
26~0204	0.00	0.07	0.60	0.01	0.70	1 20	1 M	128	0 IN	0.07	0.05	0.07	2007		0.05	0.20	M
50.0	0.08	0.07	0.68	DOT	0.88	0.68	0,44	649	700		70,0	70.0	6.66	0.88	0.05	0.20	M.
50.0	0.08	70.0	68.0		626	54.5	8.68	54.5	9.65	70.0	0.05	0.07	70.0		0.07	95.0	М
50.0	9.98	6.95 8.49	67.8	T BH T AB	8.53	848 528	93.9 53.7	643 643	70.0	0.07	9.96	0.05	9.98		0.07	66.0	M M
50.0	0.08	8.68	678	8.60	120	618	13.5	613	188	8.90		0.07	70.0			0.8	M
50.0	0.08	0.07		0.07	0.85	0.35	0.43				0.05	0.01			0.07	0.65	M
50.0	69.9	0.01	68.0	79.01	0.00	0.239	64,0	643	70.0	70.0	0.07	69.9	8.90	67.8	70.0	0.68	М
50.0	e se	E 66	0.88	70.0	143	1.82	6.02	545	SAL	6.66	70.0	10.01	700		0.07	0.88	М
50.0 50.0	T-80 0.00	68.2 08.7	678	100	10	E MI	101	543	70.0	70.0	70.0	0.0T 69.9	0.00		70.0	0.89	<u>М</u> . М.
0.0C	50.6	69.2	618	8.00	0.70		2.63	658	0.08	TRA	0.05	0.01	70.0			0.20	M
50.0	0.00	0.99	818	TLUT.	1.10	EME	101			8.96	70.0		70.0		0.07	0.30	M/
50.0	0.08	66.2	87.9	1.01	0.52	645	1.01	544	70.0	70.0	70.0	0.05	70.0		0.07	0.88	M/
50,0	1.00	68.2	67.8	1.00	3.66	0.微	64.0	848	8.85		70.0	59.8	6.69		8.83	95.0	M/
50.0	59.6	8.98	619	8.00	1.10	8.84	1.63	6.88	540	1 80	89.5	593	8.98			55.0	<u>M</u> /
50.0 50.0	8.08. 9.08	8.95	67.8	1.00	815 64.7	613	512	539	572	1.86	68.2 89.2	926 828	70.0		9.98	0.65	M) M)
50.0	0.08	67.2	0.80	57.1	LE	54.1	54.7	49.9	822	678	6.69	0.68		878	1.82	0.8	M/
50.0	53.2	0.89	54.0	2.55	2.00	54.8	54.6	48.8	588	165	6.66	898	E.86	110	8.89	0780	M/
49,64	2.68	643	118	8.00	9.02	54.2	54.2	48.5	47.9	4.58	6.90	5.83	8.66		8.83	55,0	M/
50.0	53.8	8.88	62.4	5.88	57.4	516	48.2	385	1.75	98.2	70.0	70.0	70.0		0.01	85.0	M/
50.0	547	7.48 8.52	571	62.1 1.50	52.4 51.2	53.6	52.6	41.7	4.04	57.4	888 89.2	593 1 694	5.68		8.88	85.0	M) M)
50.0	54.5	1 18	1.32	110	4.82	338	36.0	318	354	63.1	5.80	550	518	848	5 20	650	M2
49.6	53.8	38.2	46.7	46.2	0.EE	1.11	21.9	28.3		2.02	6.3	655	670			1 10	M/
49.8	52.8	5.00	39.0	34.0	22.1	16.5	ê.Wî	6.01	23.1	18.5	85,0	64.1	67.1	05.6	1.00	64.0	M/
49.0	53.5	54.7	37.0	12	28.4	0.01	9. QE	3.0	212	25.3	E73	6.68	8.73		878	64.6	M/
48.8	52.4	54.2	36.5	187	5.02	4.01	8.05	11	39.8		8.90	8.69	8.68		0.07	0.80	M/
49.	57.9	51.2	36.5	17.4	\$31 T.M	4.81 9.81	0.527	88	1.00 9.00	70.0	8.96	528	9.98 9.98		9.68 8.48	850	М. М.
49.	55.0 52.1	51.6	363	0.87	4.21	6D	1.11	010	6.81	8.98	0.07	59.9	0.02		0.07		M/
49	542	46.6	36.2	817	1.81	20.9	4.84	649	0.05	700	8.88	895	1.99.7			95.0	M.
46.5	47.6	43.7	36.2	176	16.2	562	63.7	65.0	6.80	70.0	8,98	693	587	67.8	F.60	65.0	MA
41.8	37.5	50.3	36.3	E.17	\$12	62.2	0.58	646	685	8.86	8.88	68.5	E.98	676	5.68	66.0	MA
.24	38.5	48.3	36.4	17.4	0.22	SIR	5.07	543	e en	70.0	88.5	888	E 98		A.80	0.88	MA
14 14	385	34.6 27.0	35.4	222	64.2	A BR	8.68	659	0.00	70.0	8.88	898	8.63		8.98	0.20	<u>M</u> / M/
44	30.0	1.0E	36.5	28.9	8.1.0	LM	1.63	0.28		0.00	6.98		1 80		8.68	0.20	MA
24	31.8	1.0E	543	38.5	1.53	10	100	85.0	18.5	0.68	6.60	88.6	160	67.7	1.00	0.88	M/
45.0	EAE	33.4	48.5	36.4	0.40	234	E CR	650	ERR	70.0	8.98	6.66	8.68	9.78	5.68	0.80	M,
43.0	337	30.2	52.0	878	E30	8.88	1.61	646	1.66	8.80	£,90	66.4	68.5	878	1.00	2.48	M/
45.0 45.0	34.8	48.5	552	582	8.00	4.08	R 538	840	100	70.0	1.00	0.88	0.00		0.60	9.40	M/ M/
-00 -00	41.3	50.3	49.2	548	142	2.40	107	550	1.82	8.96	E 88	T80 888	9.99 8.08		8.96	0.80	M/
46	47.6	6.0	1.62	3.10	205	DIS	1.02	848	19.7	A.06	8.88	6.88	4-86		8.30	0.00	M/
47.9	44.5	54.1	53.5	6.63	0.00	110	8.68	849	FRE	0.98	8,66	666	1 60	1.00	i as	8.48	M/
45.1	0.80	56.8	63.6	8.68	0.44	818	8,68	THE	0.60	6.68	64.4		9.30		TRE	64.5	M,
45.	46.6	54.9	612 593	1.00	84.1	112 115	2.02	54.7	57.3	0.88	83.6	512	E.MB		63 1	140	M.A M.A
40.	40.9	8.38	858	1.00	540	0.40	100	54.5	EBE	1.68	6.78	64.9 56.5	開き		8.48	0.80 T.60	M/
47.	4.74	64.5	84.9	818	240	8.20	4 28	848	THE	4.98	E tà	848	4.13	656	61.1	248	M/
46.	49.6	0.52	613	8.86	\$ \$0.	010	1.00	543		882	£.08	56.5	8.18	1.00	54.0	1 10	M/
47.6	1.84	1.08	583	64.6	ED	1.07	82.5	621	f da	£.88	50.1	55.5	1.00	518	e.ee	4.50	MA
47.9	47.5	1.15	8.00	1.50	12	816	12	828	172	6.98	31.1	610	2.86	1.00	18	10	M/
49.0	49.8	1.80	57.4	110	20	8.08	0.63 \$.529	835	181	188	38.4 54.0	852	1.13	1 38 1 78	1.00	0.80	M.A M.A
40	40.1	0.53	556	0.40	10	3.08	101	835	Eite	575	1.53	e de		2.00	1 70	0.48	M/
48.	54.6	840	555	1.50	19		1.68	OEB	6.68	6.00	66.1	57.3	8.68	1.58	6.18	0.50	MA
49.1	53.2	0.50	55.8	0.05	2.03	0.1.0	1.68	540	6.90	TIN	0.00	68.0	1.00	67.9	8.00	0.00	MA
5 Ob	8.72	5.43	Pina	11.242	1710	200	1.00	2.2.2		0.04	E 00			5.53	5.05	0.50	MA

Speed & Bottleneck Validation



Volume Validation Scatterplot: Local Micro Example

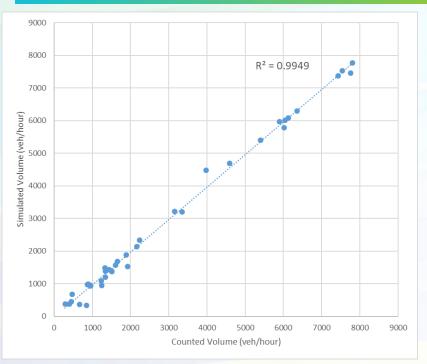




Criteria	Counts Satisfying Criteria	Percentage Satisfying Criteria	Target
GEH < 2	67	77.9%	n/a
GEH < 5	86	100%	> 85%
GEH < 10	86	100%	n/a

Criteria	Counts Satisfying Criteria	Percentage Satisfying Criteria	Target
Within 15%, for 700 veh/h < Flow < 2700 veh/h	41	100%	> 85%
Within 100 veh/h, for Flow < 700 veh/h	43	100%	> 85%
Within 400 veh/h, for Flow > 2700 veh/h	2	100%	> 85%

Volume Validation Scatterplot: Subregional Micro Example



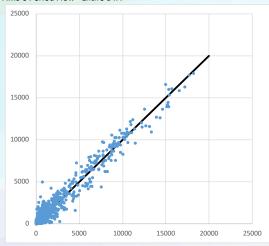


	Counts Meeting	Percentage of			
	Criteria	Counts			
GEH < 2	22	55%			
GEH < 5	34	85%			
GEH < 8	35	88%			
GEH < 10	38	95%			

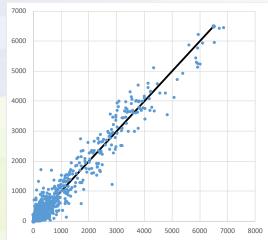
Criteria and Measures	Counts Meeting	Percentage of
	Criteria	Counts
>85% within 100 veh/h, for	3	60%
Flow < 700 veh/h (>85%)	3	00 %
>85% within 15%,	40	86%
for 700 veh/h < Flow < 2700 veh/h	18	80%
>85% within 400 veh/h,	40	0.20/
for Flow > 2700 veh/h	13	93%

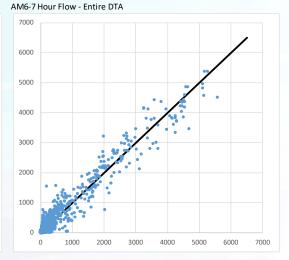
Volume Validation Scatterplot: Regional Meso Example

AM6-9 Period Flow - Entire DTA

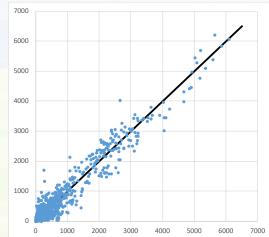


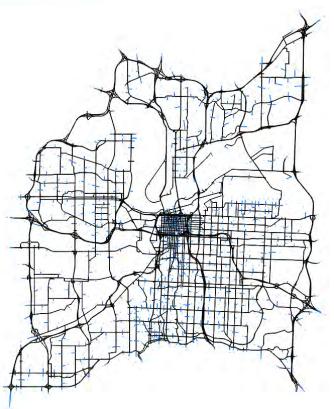
AM7-8 Hour Flow - Entire DTA











Volume Validation Regional Meso Example Total Error and RSME %

AM Peak Period - All Counts

					Average	Average	Avg
Fac#	Facility	Counts	Sum Count	Sum Model	Count	Model	Error
1	Freeways	148	1,235,701	1,223,770	8349	8269	-1%
2	Expressways	26	112,550	104,913	4329	4035	-7%
3	Princ.Art	130	203,504	191,701	1565	1475	-6%
5	Minor Art.	158	120,446	114,681	762	726	-5%
7	Collector	98	57,701	50,216	589	512	-13%
8	Ramp	273	220,404	260,226	807	953	18%
9	Fwy-Fwy Ramp	63	105,742	117,568	1678	1866	11%
>0	All Roads	896	2,056,048	2,063,075	2295	2303	0%

AM Peak Period - Focus Area Counts

					Average	Average	Avg
 Fac#	Facility	Counts	Sum Count	Sum Model	Count	Model	Error
1	Freeways	31	227,697	229,431	7345	7401	1%
2	Expressways	12	49,723	48,087	4144	4007	-3%
3	Princ.Art	17	18,822	12,563	1107	739	-33%
5	Minor Art.	30	25,709	19,232	857	641	-25%
7	Collector	31	18,873	12,116	609	391	-36%
8	Ramp	64	57,590	58,866	900	920	2%
 9	Fwy-Fwy Ramp	20	43,868	49,873	2193	2494	14%
 >0	All Roads	205	442,281	430,168	2157	2098	-3%

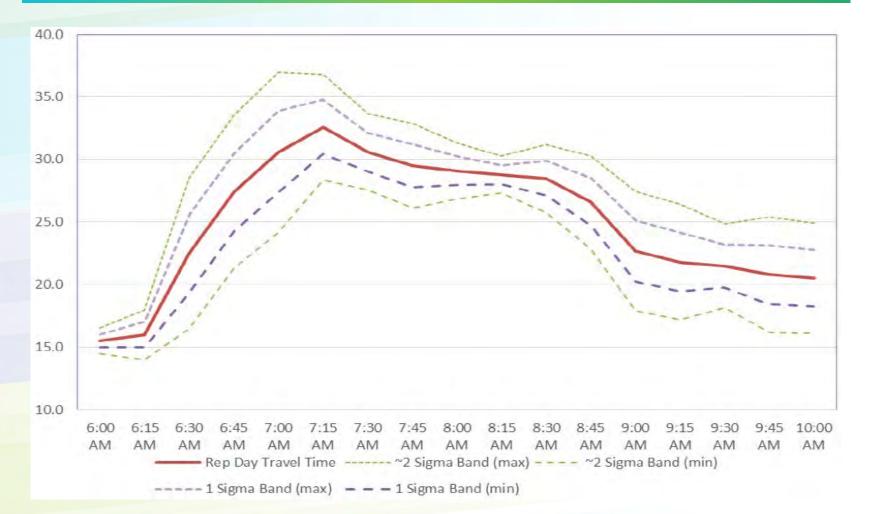
RSME% by Hour - All Counts

	6-7 AM	7-8 AM	8-9 AM	3 Hour
Facility	Hour	Hour	Hour	AM Peak
Freeways	0.16	0.15	0.15	0.12
Expressways	0.35	0.20	0.27	0.22
Princ.Art	0.65	0.41	0.41	0.42
Minor Art.	1.01	0.86	0.83	0.83
Collector	0.77	0.77	0.83	0.72
Ramp	0.82	0.57	0.60	0.59
Fwy-Fwy Ramp	0.61	0.50	0.55	0.52
All Roads	0.38	0.33	0.34	0.30

RSME% by Hour - Focus Area Counts

	6-7 AM	7-8 AM	8-9 AM	3 Hour
Facility	Hour	Hour	Hour	AM Peak
Freeways	0.16	0.19	0.18	0.16
Expressways	0.40	0.17	0.31	0.23
Princ.Art	0.66	0.48	0.56	0.51
Minor Art.	0.87	0.81	0.78	0.76
Collector	0.89	0.73	0.72	0.69
Ramp	0.85	0.56	0.60	0.57
Fwy-Fwy Ramp	0.37	0.35	0.41	0.34
All Roads	0.40	0.35	0.38	0.33

New FHWA Guidance: Time Variant Variations



New FHWA Guidance: Four Criteria

Criterion I:

Criterion I: Control for Time-Variant Outliers

This criterion constrains the number of outliers in simulated results.

<u>CRITERION I</u>: 95% of simulated outputs fall within the ~2 Sigma Band, $c_r(t) \pm 1.96\sigma(t)$. Note that if fewer than 20 time intervals are used to characterize time-dynamics, Criterion I is relaxed to allow for one simulated result outside the ~2 Sigma Band.

Criterion II:

Criterion II: Control for Time-Variant "Inliers"

This criterion ensures the majority of time-variant simulated results fall close to the representative day, and that during the most congested time periods the simulated results are close to the observed data.

CRITERION II: Two-thirds of the simulated results (and both critical time intervals) fall within the 1 Sigma Band for this operational condition.

New FHWA Guidance: Four Criteria

Criterion III:

Criterion III: Bounded Dynamic Absolute Error (BDAE)

This criterion ensures that, on average, simulated results are close to the observed representative day. The criterion involves a test to ensure that the average simulated absolute error from the representative day over all time intervals is less than or equal to differences from the representative day seen across all days in the operational condition. Let:

- c, (t) Observed value of representative day during time interval t
- $c_i(t)$ Observed value of non-representative day within the cluster during time interval t
- $\sigma_{c}(t)$ Simulated performance measure during time interval t
- N_T Number of time intervals

N_{chaster} Number of days in the cluster representing this operational condition

Next, calculate the BDAE Threshold:

$$BDAE Threshold = \frac{\sum_{i=r} \sum_{i} \frac{|c_r(t) - c_i(t)|}{N_r}}{N_{chaster} - 1}$$

(12)

CRITERION III is met when:

$$\frac{\sum_{r} |c_{r}(t) - \tilde{c}_{r}(t)|}{N_{T}} \leq BDAE Threshold$$

(13)

New FHWA Guidance: Four Criteria

Criterion IV:

Criterion IV: Bounded Dynamic Systematic Error

This criterion ensures that the simulated data are not excessive over- or under-estimators. In this case, the criterion utilizes a similar test to Criterion III but with respect to average simulated error (not absolute).

CRITERION IV is met when:

$$\frac{\sum_{r} c_r(t) - \tilde{c}_r(t)}{N_T} \leq \frac{1}{3} \times BDAE Threshold$$

(14)

Review of Calibration Results

- Test Simulation Runs
 - » Replicate the existing calibration results
 - » Review / identify problematic areas
 - Areas of poor fit
 - Low speeds
 - High densities
 - Low flow rate
 - Prolonged queuing
 - Unintuitive routes

Additional Validations

- Ideally validate to a second set of data
 - » A similar representative day
- Model stability tests
 - » Test different random seeds
 - » 'Local link removal' test
- Model reasonableness tests
 - » Does the model respond in a logical way to a change?

ADDITIONAL QUESTIONS?