OVERVIEW OF THE TRANSPORTATION SYSTEM SIMULATION MANUAL (TSSM)

Presentation for NCITE

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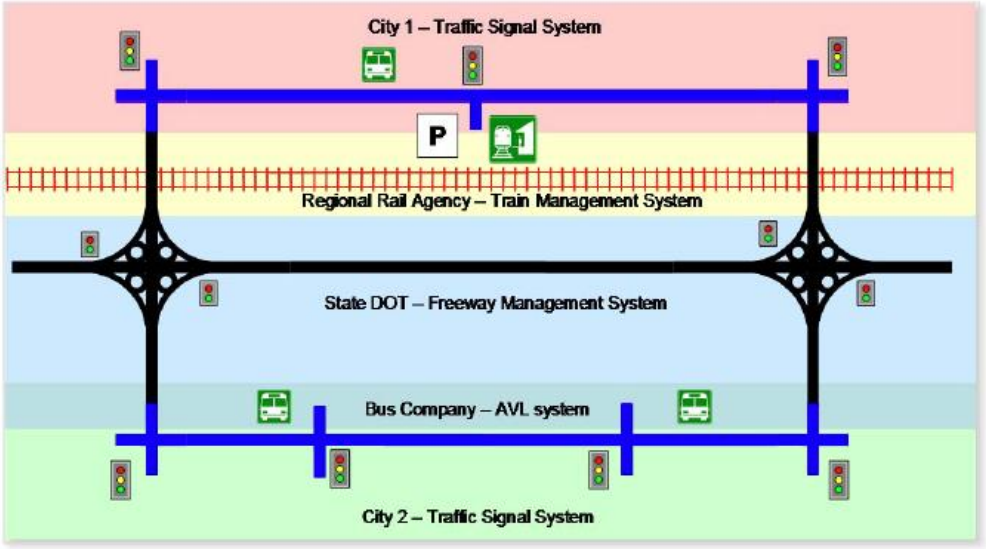
Motivation

- Networks are complex
  - Cascading queues, facility-to-facility impacts, freeway / arterial interactions
- They are often multimodal
  - Highway, rail, transit, bicycle, pedestrian, etc.
- Simulation is a very useful for analyzing these situations
- For consistency and quality, a reference guide would be useful
- The guide should be collaboratively developed and peer-reviewed



History

2005: Joint Simulation Subcommittee (SimSub) established under TFT

2012: Fort Lauderdale – Joint Summer Meeting, TFT and HCQS Committees
– Inspiration for the TSSM

2014: Original TSSM Development Contract (KAI Lead)

2015: System Simulation Task Force Established

2016: Second TSSM Development Contract (Leidos Lead)

2019: TSSM draft delivered to FHWA

2020: ACP80 established

2021: TSSM transferred from FHWA to TRB/ACP80

TSSM

The TSSM

- **Is a:**
  - Multi-author document with consensus-based materials
  - Guide for users, developers, modelers, reviewers
  - Descriptions of simulation options (e.g., micro-, macro-, and meso) and use
  - Discussions about problem scoping, inputs, outputs, validation, calibration
  - Example case studies showing the use of simulation
  - Document that can be used as a reference for classes, tutorials, workshops
  - Informed by national and international guidelines (see next slide)
- **Is not a:**
  - Single author or single agency document
  - Proscriptive guide for doing simulation analyses (Volumes 2 and 3 of HCM)
  - Guide to commercial software selection
  - Source of comparisons among commercial simulation software packages

Stakeholders with Varying Needs

FHWA, TRB, Academia

- Software-agnostic guidance
- Understanding of principles
- Algorithm development
- Practice adaptable
- Future-oriented

DOTs, Agencies

- Software-specific guidance
- Step-by-step instructions
- Example problems
- Case studies
- Practicality

The new stewarding committee, ACP80, has accepted the challenge of meeting these diverse needs. It has a mix of stakeholders from different areas with varying interests. Moreover, its mix of constituencies will help ensure funding is obtained for its further development.

Current Status

- The TSSM has been transferred to TRB by FHWA
- ACP80 has become the committee responsible for its further development.
- ACP80 needs to accept it before it can be released.
- Once that happens, it will be available for use and review.

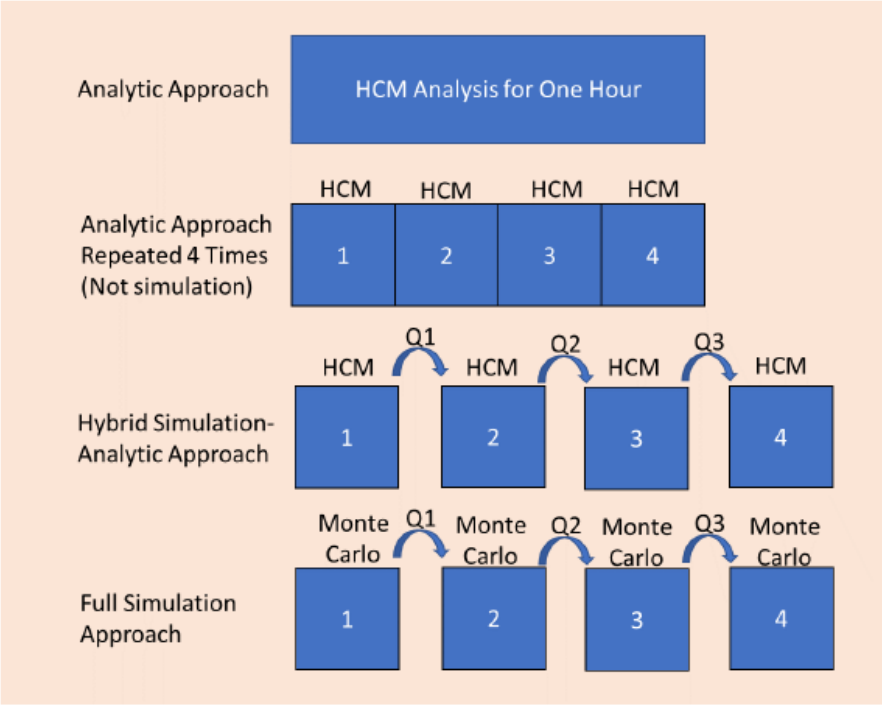
Structure

- **Volume 1**
  - Ch. 1: What is Simulation
  - Ch. 2: Simulation Options
  - Ch. 3: Principal Ideas
  - Ch. 4: Use Issues
- **Volume 2**
  - Ch. 5: Defining the Problem
  - Ch. 6: Data
  - Ch. 7: Creating the Network
  - Ch. 8: Verification, Calibration, and Validation
  - Ch. 9: Output Analysis
  - Ch. 10: Post-Project Validation
- **Volume 3**
  - Applications of TSSM principles
  - Ch. 11: Overview of the Volume
  - Ch. 12: Freeway System Case Studies
  - Ch. 13: Arterial System Case Studies
  - Ch. 14: Freeway/Arterial Case Studies
- **Volume 4**
  - Supplemental materials not in Vol 1-3, like the HCM
  - Not yet developed

Chapter 1: Definition and Description

- Distinctions between simulation and analytic analyses
- Guidance about when to use simulation

Figure 1: Illustration of Differences Between Simulation and Analytic Approaches



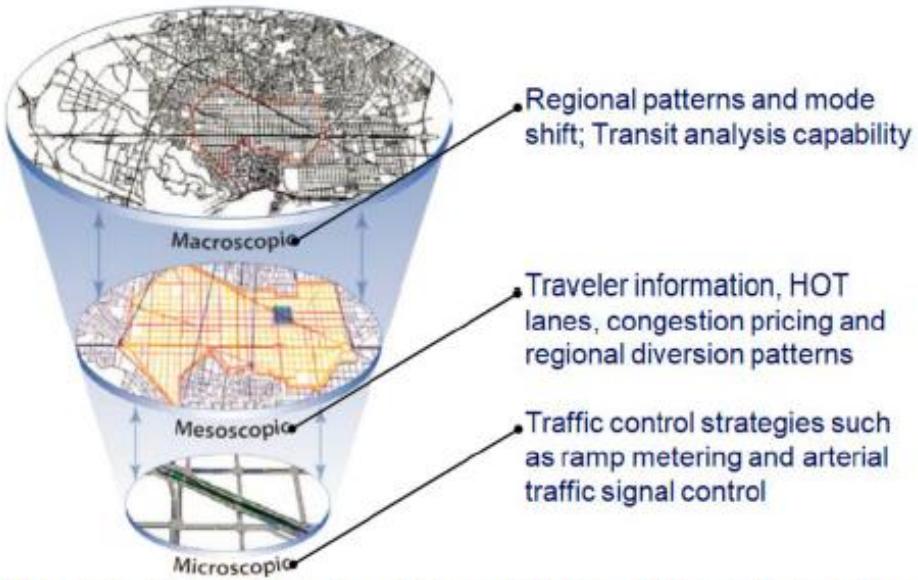
Note: The Highway Capacity Manual (HCM) method cited in this figure is an example of one of many analytic approaches.

Simulation should be used when it is the most cost-effective approach to achieving the desired accuracy with the appropriate sensitivities.

Chapter 2: Types of Simulation

- Microscopic, mesoscopic, and macroscopic models
- Multi-scale and multi-resolution modeling

Figure 2: The Varying Simulation Resolutions



Source: FHWA Traffic Analysis Toolbox Volume XIII, May 2012. Adapted from Cambridge Systematics, Inc., September 2009

Chapter 3: Simulation Principles

- Concepts:
  - Entities, agents, attributes, links, nodes, resources, states, queues, capacities (flow and storage), events, clock, performance measures, processing logic, deterministic, stochastic, uncertainty, randomness
  - Time or event based, state evolution (time or event based)
- Input data
- Performance measures and measurement techniques
- Scoping and budgeting

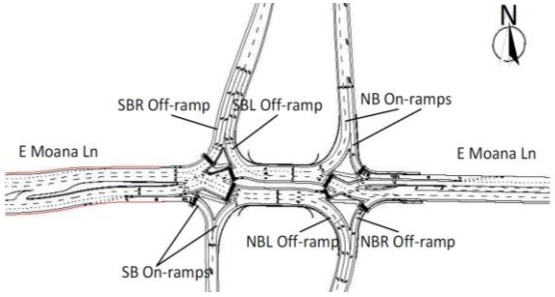
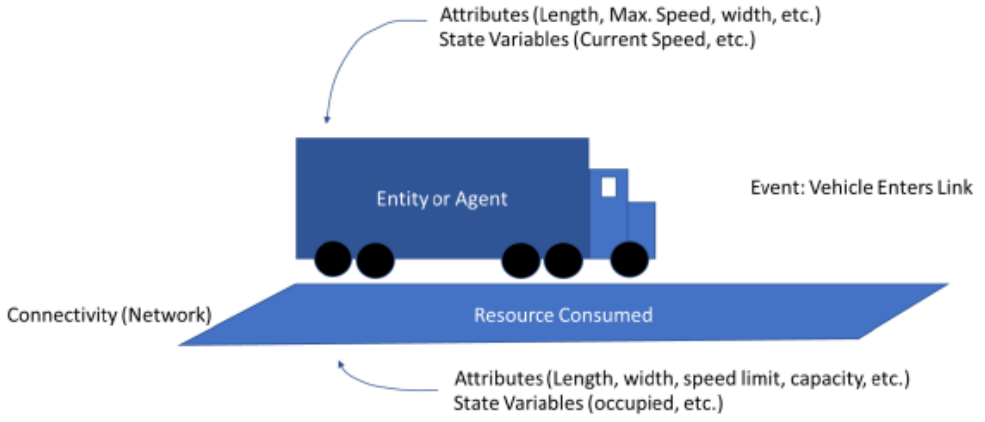


Figure 5: Basic Simulation Concepts



Chapter 4: Other Simulation Topics

- Scenario generation
- Static versus dynamic demands
- Real-time versus off-line simulation
- Hardware-in-the-loop, software-in-the-loop simulation
- Demand estimation versus throughput values
- Problem- versus reliability-focused simulations
- Trajectory management
- Stochasticity and its management
- Development of statistically defensible results
- Reconciliation of macroscopic and microscopic results

Chapter 5: Scope Setting

- Establishing the role of the simulation analyses
  - Simulation is often a key part of the solution to many analysis problems, but it is not the solution to all problems
- Setting the modeling requirements
  - Temporal and spatial bounds
  - Analysis capabilities
  - Updating procedure (spillover effects, new alternatives, etc.)
- Finding performance measures that can:
  - Evaluate design and operation alternatives
  - Help with verification, calibration, and validation
  - Determine if the simulation model is good / useful

Chapter 6: Data Assembly and Collection

INTRODUCTION	
DATA TYPES AND SOURCES	• Geometric Data | Traffic Count Data | Traffic Signal Ops Data | Calibration Data | Safety Data • First-Gen Probe Data | NPMRDS Data | Big Data Sources
DATA REQUIREMENTS (ANALYSIS TYPES)	• Signalized Intersections/Arterials | Transit Priority Lanes | Roundabouts | Non-traditional intersections | Ped-Bike Lanes | Freeways/Interchanges | Two-lane highways | Multilane highways | Work Zones | Toll Plazas | Managed Lanes/Ramp Metering | Safety Analyses
DATA REQUIREMENTS (MODEL TYPES)	• Macroscopic | Mesoscopic | Microscopic
DATA CHALLENGES	• Data Comprehensiveness and Reliability | Data Accuracy | Data Fusion and Aggregation | Data Quality Control
SAMPLE DATA CASE STUDIES/ APPENDICES	• Freeway Corridor | Freeway Interchange | Highway Corridor | Reliability | Sampling | Simulation Runs | Data Measurements with NGSIM

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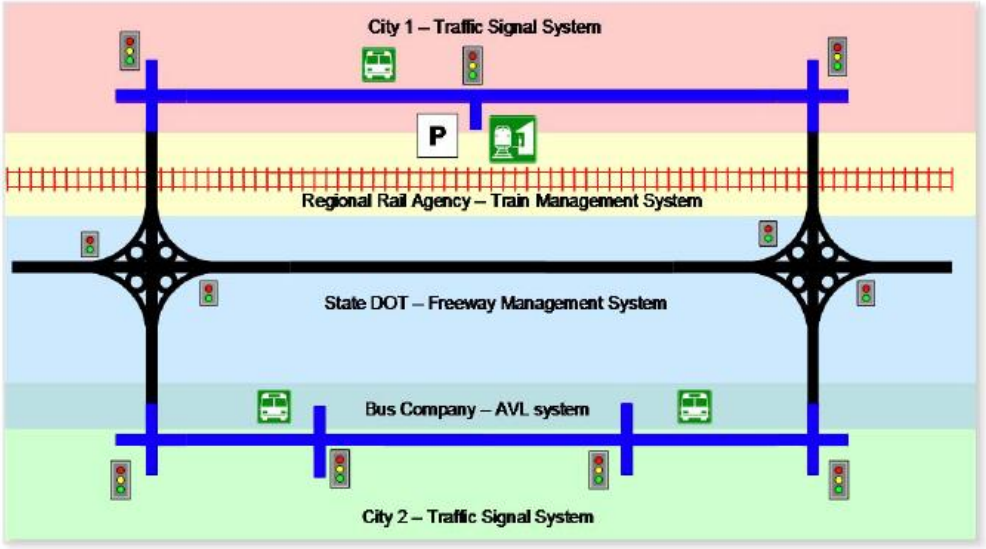
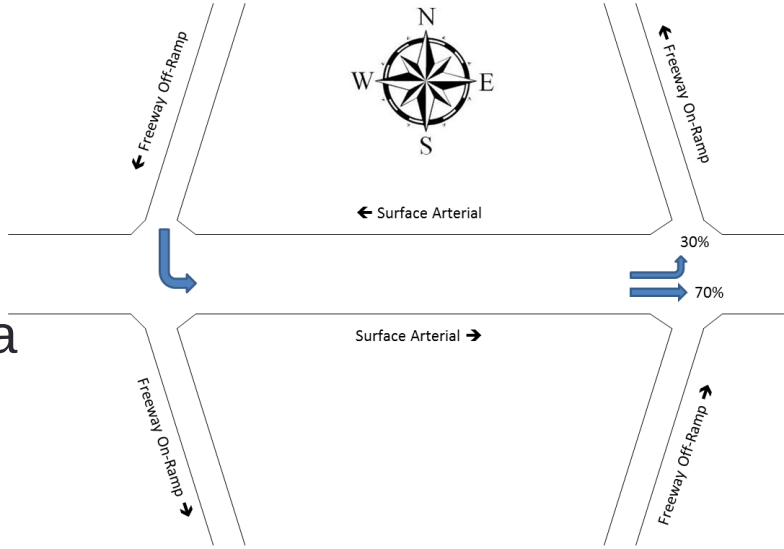


Chapter 7: Model Creation

- *Network*: nodes, links, connectors
- *Demands*: Spatial (OD) and temporal patterns, turning movements, demand versus throughput
- *Parameters*: car following, lane changing, look-ahead distances and times, gap acceptance, capacities and saturation flow rates (where applicable)
- *Run specifications*: number of runs, random number seeds, convergence criteria
- *Data entry:* options for how to move the data into the model files



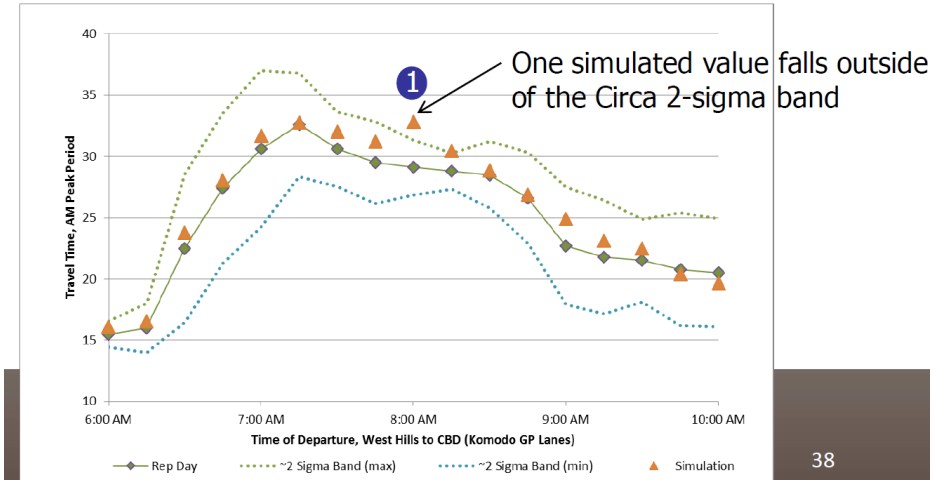
Chapter 8: Verification, Calibration, and Validation*

- *Basic tenets* of the VCV process
- *Performance metric* options for micro, meso, and macroscopic models
- *Verification* considerations in checking the simulation software's capabilities and the completeness of the input data
- *Calibration* perspectives: what to consider, what sequence to use, possible assessment metrics
- *Validity* checks: robustness, sensibility, assessment of limitations
- *Step-by-Step Process: to* ensure all aspects are addressed

*Follows the guidance in Volume III of the Traffic Analysis Toolbox very closely.

Metrics and Acceptance Criteria

- Operating conditions (OCs) of interest
- Datasets for each OC
  - Complete, not fabricated
- Representative day for each OC
- Parameter values for each OC
- Performance metrics (PMs)
- Individual element performance
  - inputs produce outputs
  - Queue lengths, delays
- System performance
  - Distributions for travel times / rates
  - Queue dynamics
  - Durations of congestion
- Double-checks using other OC datasets



Source: TAT Volume 3 Update

Chapter 9: Processing, Analysis, and Presentation

- Running simulation models
  - Run times, random seeds, keeping track of model runs
- Data processing
  - Output methods, data types, aggregation issues, data synthesis
- Analysis
  - Definitions, statistically understanding the results, interpretation
- Presentation
  - Multiple metrics, tables, charts, figures, visualization options, visualization tools, written documentation

Chapter 10: Post-Project Validation

- Suggests checking predictions for a near-term condition
- Discusses what aspects of the simulation model would be useful to check
- Uses examples to illustrate the value of doing such checks
- Suggests strategies for managing / archiving results

Volume III: Case Studies

- Highlight applications of the simulation principles presented in the TSSM
- Resolutions addressed
  - Microscopic (emphasized)
  - Mesoscopic (with DTA)
  - Macroscopic (e.g., Freeval)
- Spatial scopes
  - Arterial only, freeway only, combined arterial-freeway
- Real-world examples
- Commentary about how to use the guidance found in the TSSM
- Descriptions are tool-agnostic, even though specific tools were used
- Links are provided to additional information
  - Case study reports
  - Online publications
  - Journal publications
  - Other literature citations

Topics Addressed

Boise	VDOT	Moana		Boise	VDOT	Moana	
			Chapter 5: Defining the Problem				Chapter 8: VC&V
Yes	Mostly	Mostly	• Define scope, goals, approach, budget, objectives, performance measures	Yes	Yes	No	• Analysis of WHY the results are incorrect before deciding on next step
Yes	Yes	Mostly	• Study boundaries (temporal and spatial)	Yes	Yes	No	• Verifying that the software can model conditions of interest
Yes	No	Yes	• Role of microsimulation (should just be "simulation")	Yes	Yes	No	• Verifying that the input data are clean, congruent, and accurately repres
Partial	No	Partial	• Formation of project team and stakeholders	Yes	Minimal	No	• Validating the model's predictions for a broad range of conditions
Partial	No	Partial	• Identify needed resources	Yes	Yes	No	• Selection of both upper (e.g., sum of squared percent errors) and lower
Base	Base	Base	• Define forecast and base years	Yes	No	No	o Rank the SQMs in terms of importance
No	No	No	• Range of operational conditions to consider	Yes	Yes	Yes	• Focusing on a limited number of critical OD pairs
No	No	No	• Screening of initial alternatives through non-simulation methods	No	Yes	No	• Evaluation of PDFs or CDFs that describe distributions of the performa
Partial	No	Partial	• Explicit linking of performance measures to agency goals or project objectives	No	Minimal	No	• Ensuring that links perform in accordance with the fundamental diagram
				No	No	No	• Analyzing reasonableness of vehicle trajectories
			Chapter 6: Data	No	No	No	• Using vehicle trajectories to calibrate certain parameters (e.g., car follov
				No	Minimal	No	• Calibrating the speed-density-flow relationships for macroscopic model
Yes	Yes	Yes	• Detailed description of the origins of data used in the analysis	No	No	Yes	• Having "a second set of eyes" review the data
No	No	No	• Description of speed measurement method	Yes	No	No	• The calibration effort needs to deal with episodic demands
No	Yes	No	• Collection of vehicle type classifications	Yes	No	No	• Selection of a preferred calibration sequence (e.g., driving behavior, rou
No	No	No	• Pedestrian volume counts	No	Yes	No	• Identification of key problem spots where performance must be predict
Yes	Yes	Yes	• Obtaining signal timings from the field or the DOT	No	Yes	No	• Validate with separate datasets to see if the calibrated model can produ
Yes	Yes	Minimal	• Collection of calibration data (e.g., queuing, travel times, throughput)	Yes	Yes	No	• Review the best-case and worst-case scenario outcomes
No	No	No	• Collection of crash data and roadway alignments				
Aerial	Aerial	Aerial	• Use of probe data, NPMRDS, vehicle trajectories, aerial imagery				Chapter 9: Data Processing, Analysis, and Presentation
No	No	No	• Application of data processing principles (e.g., aggregation, fusion, imputation)				
No	Minimal	No	• Statistical analysis of field data sample size	No	No	No	• Using a naming structure for the scenario datasets
				No	Yes	No	• Automated post-processing analysis (e.g., commercial statistical softwa
			Chapter 7: Creating the Network	No	No	No	• Weighted aggregation of performance measures
				No	Yes	Yes	• Analysis of stochastic model outcomes under different random number s
No	No	No	• Intelligent selection of initialization fill time	No	No	No	o Determining the number of replications needed
No	No	No	• Analyzing the consequences of inadequate study boundaries	No	No	No	• Intelligent choice of bin size for histograms and probability density functi
No	No	No	• Informed selection of overall data entry method	No	Yes	No	• Use of probability density functions and cumulative density functions
Yes	No	No	• Use of pre-processors and/or OpenStreetMap	No	Yes	No	• Use of confidence intervals
Yes	No	Yes	• Entry of demands instead of throughput volumes	Yes	Yes	No	• Use of statistical hypothesis testing
Yes	No	Yes	• Analysis of O-D demands	No	Yes	No	• Analysis of lane-specific results
No	No	No	• Application of a specific volume balancing method	Yes	Yes	Yes	• Use of multivariate outputs and accompanying visualizations
No	No	No	• Application of conditional turn movements	No	No	Yes	• Presentation of percent changes instead of raw numbers
No	Yes	No	• Application of data entry methods to achieve pre-positioning and custom lane utiliza	Yes	Yes	Partial	• Final documentation of assumptions, unknowns, and recommendations
No	No	Yes	• Entry of detector (sensor) data	Yes	Yes	Minimal	• Presentation of static graphics and moving vehicle animation
No	No	No	• Entry of freeway warning sign distances				
No	No	No	• Entry of operating condition data				
Yes	Yes	Partial	• Selection of key input parameters for calibration				
Yes	Yes	Partial	• Identification of key network locations for calibration				

Volume IV: Supplemental Material*

* Yet to be developed

- Calibration / Validation Examples
- Mesoscopic Simulation Discussion
- Connections to Traffic Flow Theory
- Connections to the HCM
- Traffic Flow Theory Monograph
- Additional Simulation-Based Studies

Enhancement Possibilities

- Case studies more closely aligned with the TSSM
- Discussions about multi-scale modeling
- Further guidance for data preparation (the importance of simultaneity)
- Further guidance about verification, calibration, and validation
- Further guidance about doing simulations (e.g., capturing residual delay, geographic and spatial scope, hidden bottlenecks)
- Guidance about safety assessments
- Supplemental material for Volume 4

Enhancement Thoughts (2)

- Further guidance about managing simulation efforts
- Data fusion and QA/QC checking
- More options for presenting results
- Ways to archive models for future use
- Push practice by describing advanced modeling practices (e.g., for AVs)
  - Programmers can add to their own simulation models
  - Software providers and create add-ons and enhancements
- Encourage software vendors to standardize basic algorithms

Funding is the Key

- Options
  - NCHRP, Pooled-fund studies, FHWA projects, individual state efforts
- NCHRP – Research Needs Statements
  - Simulating Work Zones
    - Research best practices, develop tools to simulate WZ dynamics
  - Doing Data Fusion and Assembly
    - Research best practices, develop guide for data-driven simulation
  - Simulating Mixed Traffic Flows
    - Trucks and autos, CAVs and non-CAVs
  - Coordinating Multi-Tool Analyses
    - Combinations of various types of software
    - Based on agency practice
    - Examples: parallel macro-, meso-, micro; embedded micro
  - Using Simulation Models in Agency Decision-Making
    - How should agencies use simulation in decision making

These are the ideas prepared in the TSSM project. The committee may see other priorities.

Questions and Answers

Thank You