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TRANSPORTATION RESEARCH BOARD

Simple Highway Capacity Manual Analysis Tools for Planning Applications

Monday, June 10, 2019
2:00-3:30 PM ET

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Purpose

To discuss The National Cooperative Highway Research Program (NCHRP) Research Report 825: Planning and Preliminary Engineering Applications Guide.

Learning Objectives

At the end of this webinar, you will be able to:

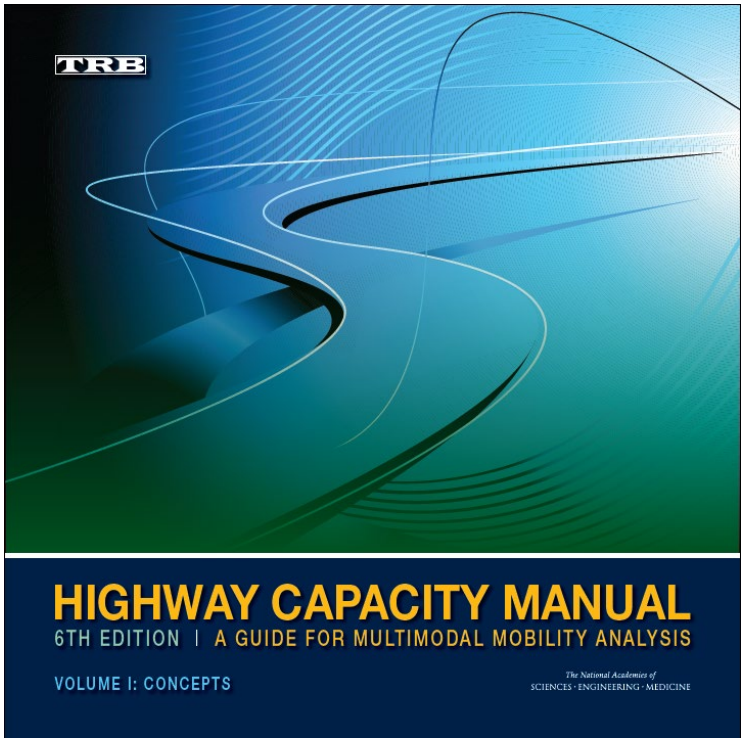
- Describe what "planning" and "preliminary engineering" mean in an HCM context
- Explain why the Guide was developed, its intended audience, and general structure
- Identify planning tasks to which HCM methods may be applied
- Describe case studies provided in the Guide and how they demonstrate the application of HCM planning methods to a variety of planning tasks

HCM – 6th Edition

Simple Highway Capacity Manual (HCM) Analysis Tools for Planning Applications

June 10, 2019

HCM Webinar Series



- Using the HCM for planning
- Freeway facility analysis
- Travel time reliability analysis
- Multimodal analysis
- Intersection control evaluation (ICE)
- Alternative intersection and corridor analysis

Instructor

- Paul Ryus, PE
  - Principal Engineer, Kittelson & Associates, Inc.
  - Former member, TRB Highway Capacity & QOS Committee
  - Co-author of *NCHRP Report 825: Planning and Preliminary Engineering Applications Guide to the HCM* (“Guide”)

Learning Objectives

- Describe what “planning” and “preliminary engineering” mean in an HCM context
- Understand why the Guide was developed, its intended audience, and its general structure
- Identify the planning tasks to which HCM methods can potentially be applied
- Learn about the case studies provided in the Guide and how they demonstrate the application of HCM planning methods to a variety of planning tasks

“Planning” in an HCM Context

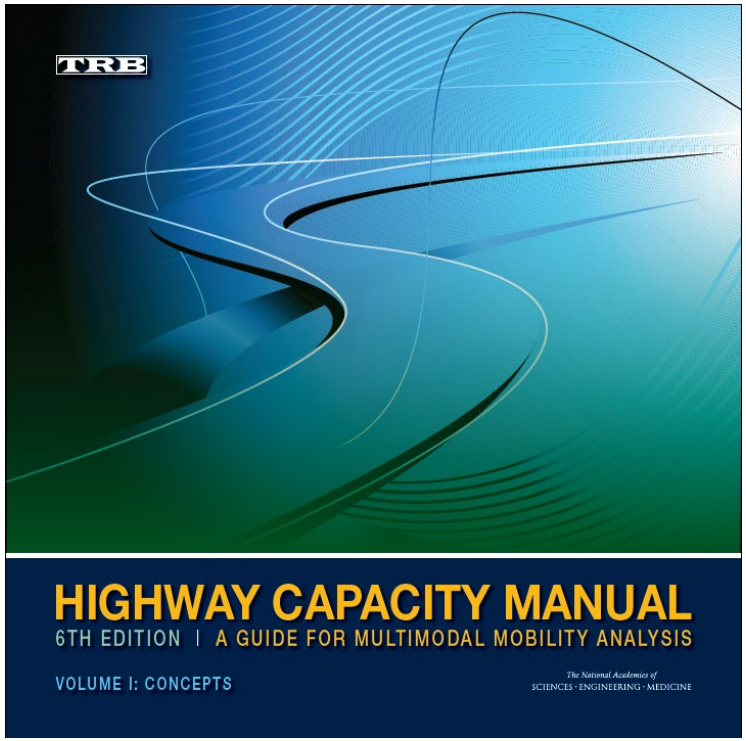
- **Planning analyses** are generally directed toward broad issues
  - Initial problem identification, long-range analyses, statewide performance monitoring
- **Preliminary engineering analyses** support moderately detailed issues
  - Planning decisions on roadway design concept and scope, alternatives analyses, and proposed systemwide policies

Presentation Overview

- Need for the Guide
- Overview of the Guide
- Case Studies
- Additional Resources

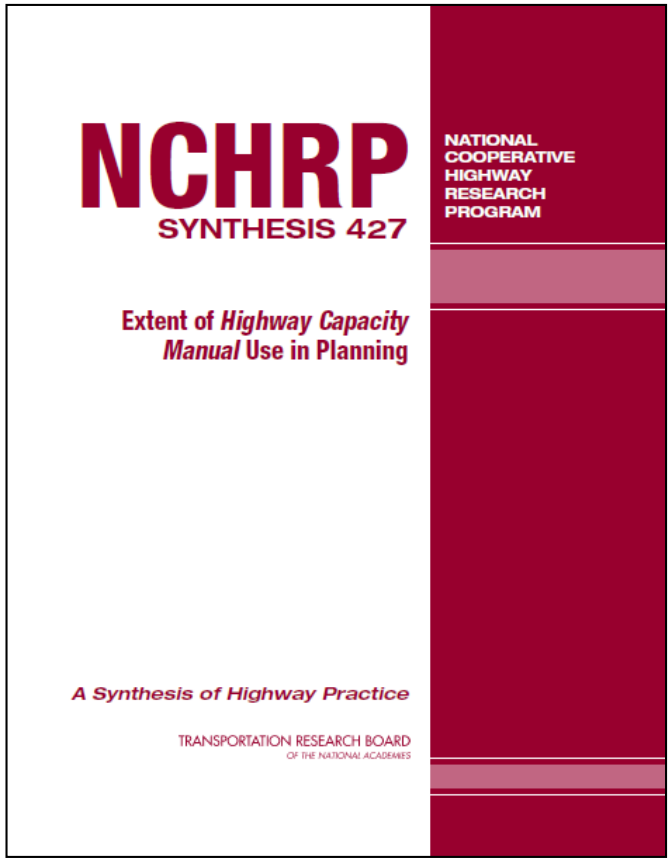
Potential Use of the Highway Capacity Manual in Planning

- The HCM is commonly used to evaluate current or forecast roadway operations
- The HCM can also reliably and cost-effectively support:
  - Planning efforts
  - Programming decisions
  - Performance monitoring
  - Roadway management
- But how well is it used for planning?



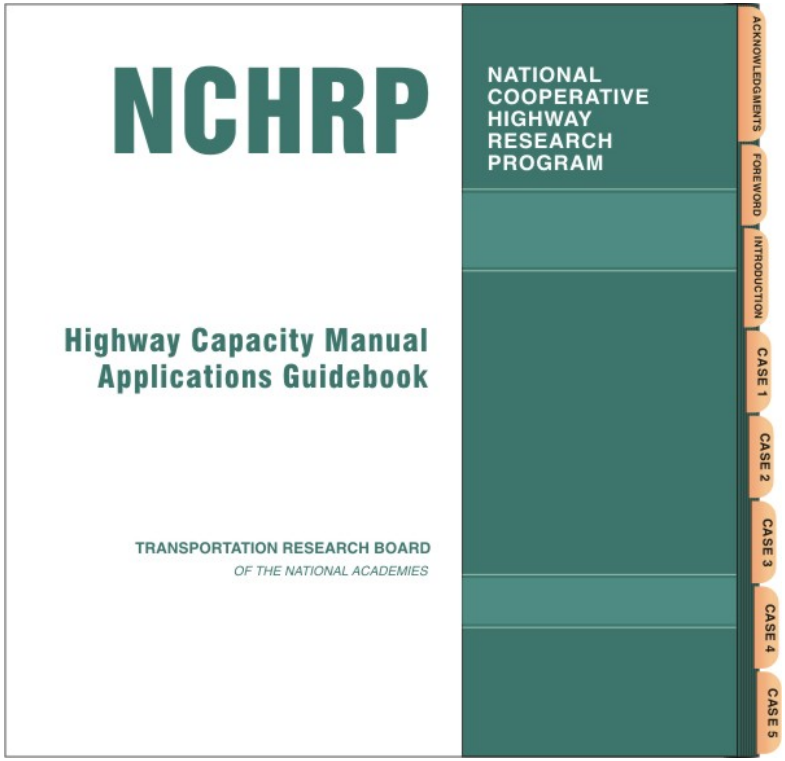
Actual Use of the HCM (2000) in Planning

- State DOTs, MPOs, local governments, and others were surveyed
- Less-experienced users less likely than expert users to see value in using the HCM for planning
- More use with short-term than long-term planning
- Need existed to describe HCM planning applications



HCM Applications Guidebook

- A similar need previously existed for detailed HCM computational methods
- The HCM Applications Guidebook (HCMAG) was created to demonstrate HCM applications to common analysis and design tasks



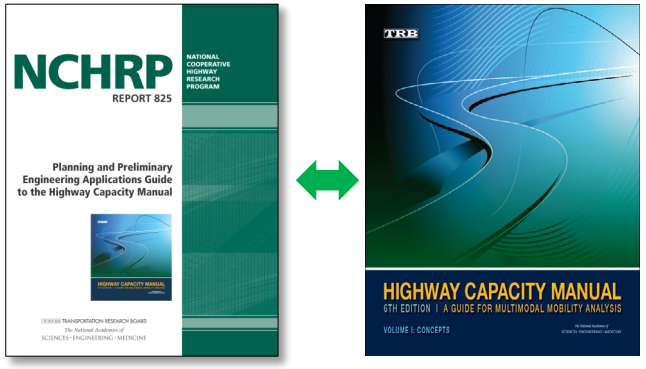
Available through online HCM Volume 4, www.hcmvolume4.org

Objectives for a Planning Guide

- NCHRP Project 07-22 was funded to develop a planning counterpart to the HCMAG
- The resulting Guide is NCHRP Report 825
- A follow-up project developed implementation material for the Guide

Guide's Relationship to the HCM: Similarities

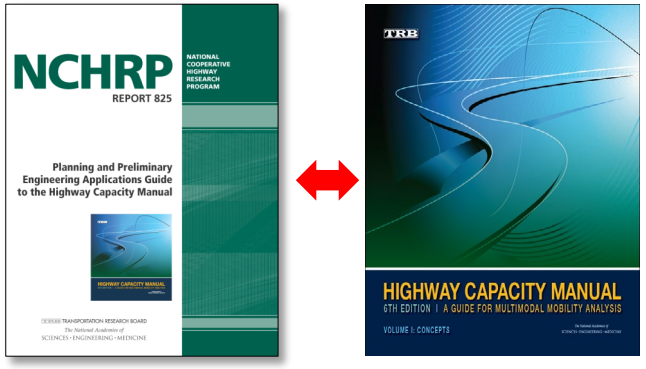
- Documents cross-reference each other
- Both documents present methods for estimating a variety of transportation performance measures



- Guide's methods are derived from, and consistent with, HCM methods
  - Simplified to reflect the amount and quality of data typically available for planning studies

Guide's Relationship to the HCM: Differences

- Guide is not intended to replace the HCM
- Guide's methods should not be used to make final decisions about roadway design features and traffic control
- Computational tools
  - HCM: Specialized software
  - Guide: Computations by hand, worksheets, spreadsheets



Presentation Overview

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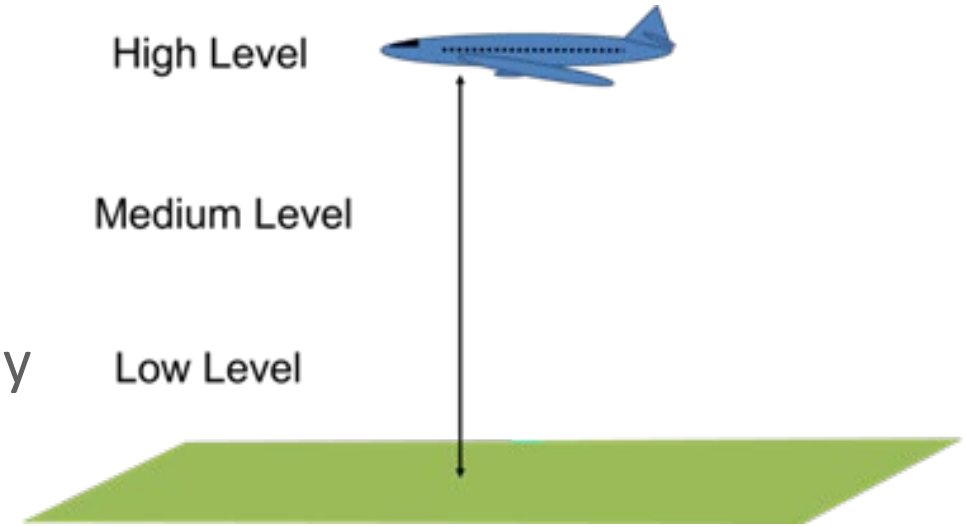
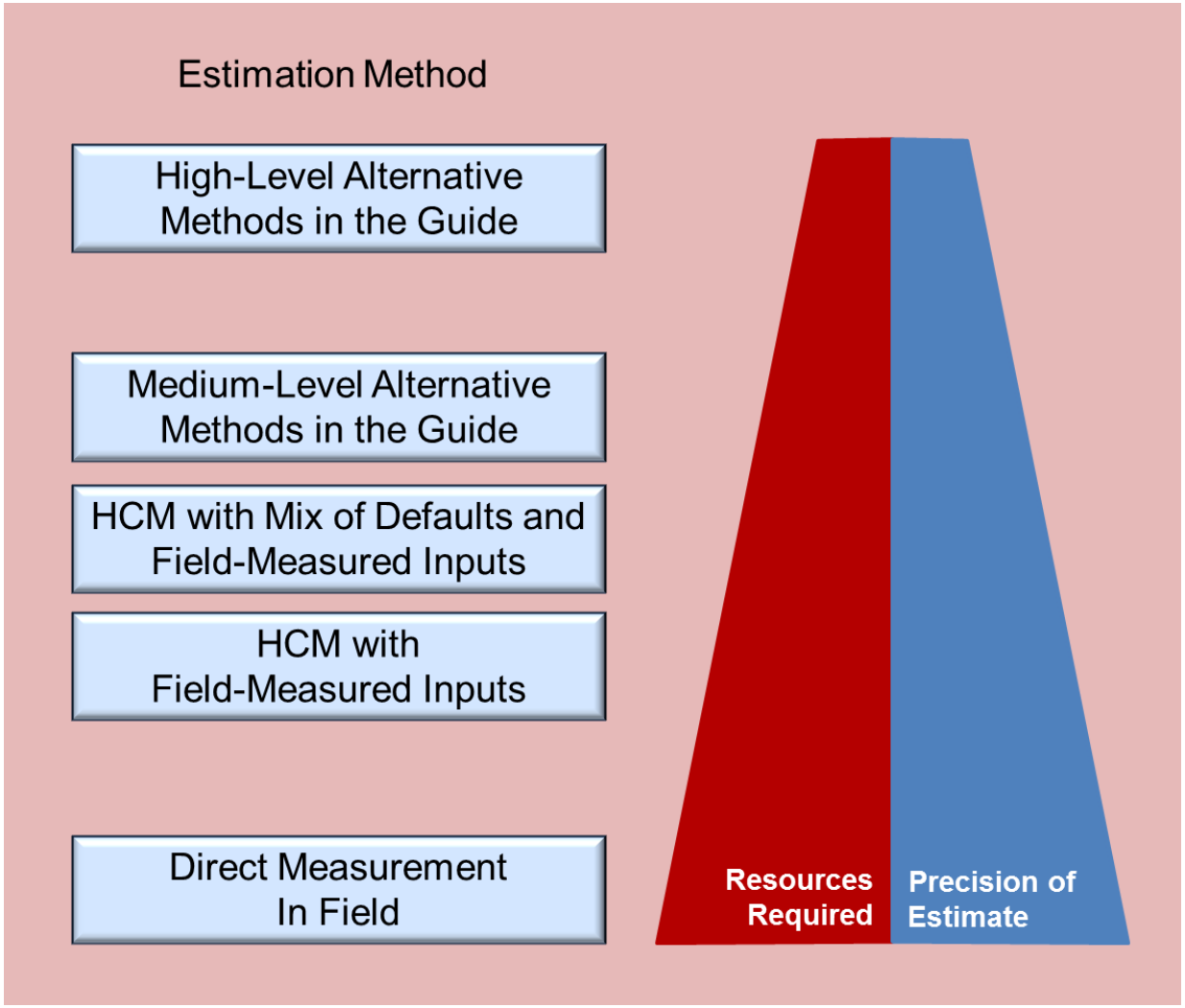
- Additional Resources

Levels of Planning Analysis

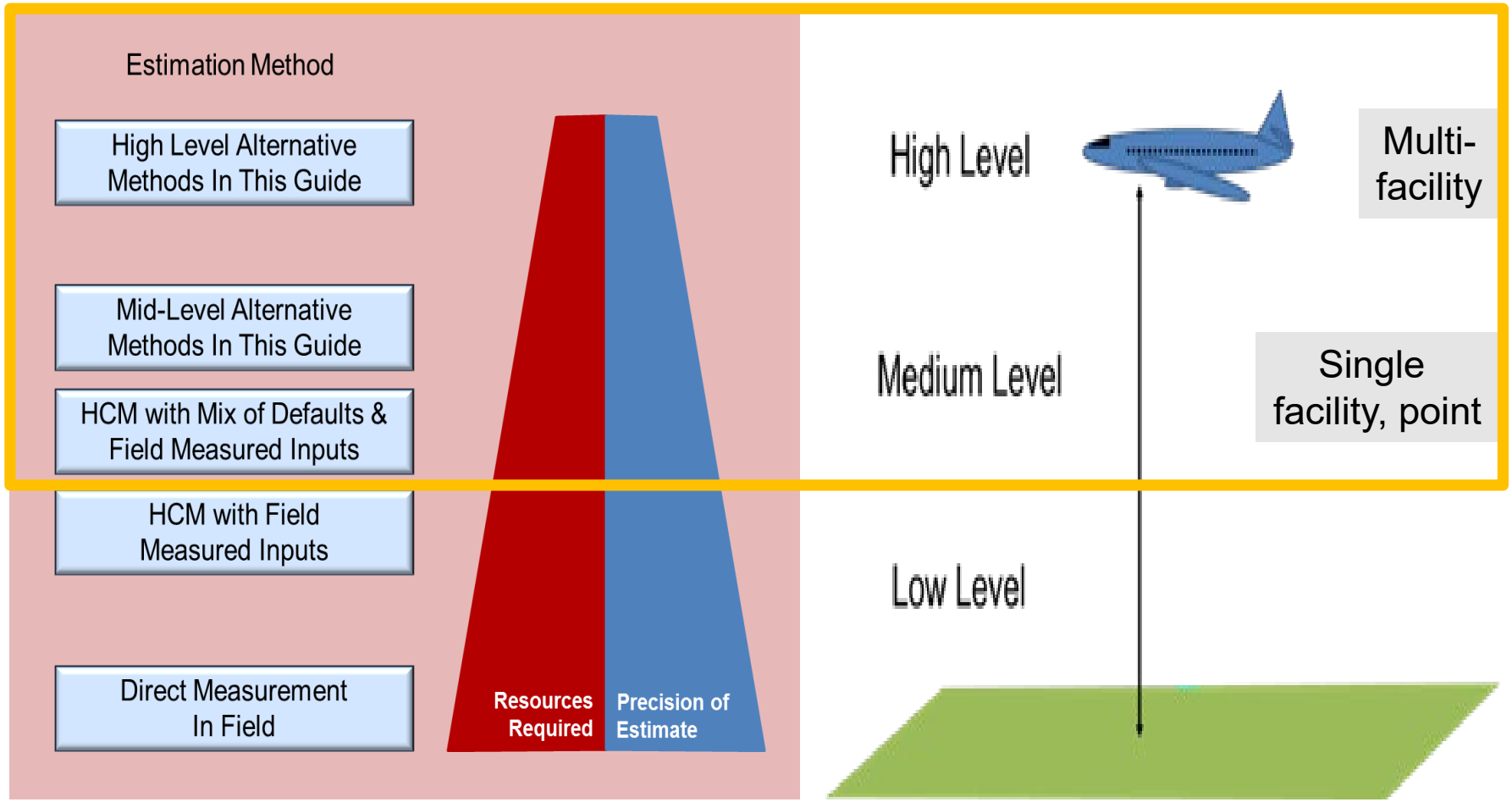
- High level
  - Large analysis area
  - Low detail
- Medium level
  - Focus on a single roadway facility, segment, or intersection
  - Greater detail
- Low level
  - Highly focused and highly detailed



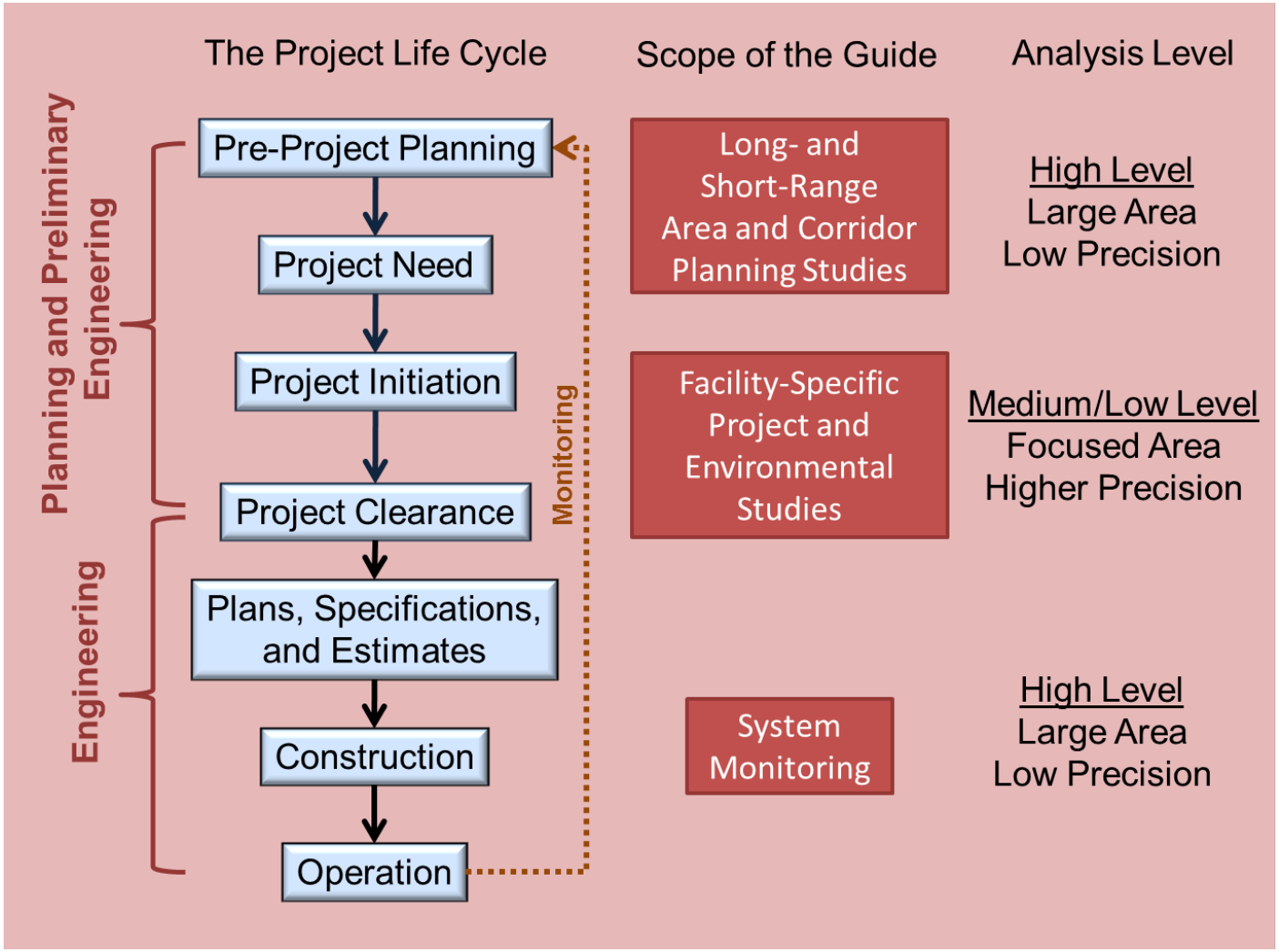
Relative Detail of HCM-Based Analysis Methods



Focus of the Guide



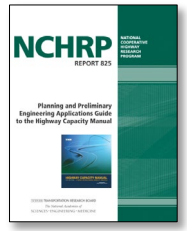
Guide's Relationship to the Planning Process



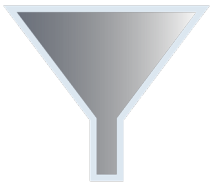
Example Use of the Guide Over the Project Life Cycle

Long-range planning

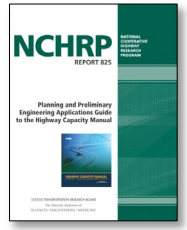
Screen large number of locations to identify potential needs



Alternatives analysis

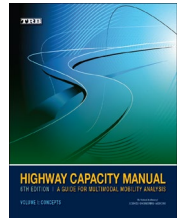


Confirm needs, evaluate potential solutions



HCM operations analysis

Confirm results, fine-tune identified solutions, apply alternative tools if needed



Final decisions

Guide Outline

- Part 1: Overview
  - Gateway to the Guide for non-HCM users
  - Information cross-referenced throughout the Guide
- Part 2: Medium-Level Analysis
  - Gateway to the Guide for current HCM users
  - Planning tools for HCM system elements
- Part 3: High-Level Analysis
  - Guidance on extending the HCM to corridors, areas, and transportation systems
- Part 4: Case Studies

Part 2 Outline

- H. Freeway Analyses
- I. Multilane Highways
- J. Two-Lane Highways
- K. Urban Streets
- L. Signalized Intersections
- M. Stop-Controlled Intersections
- N. Roundabouts
- O. Pedestrians, Bicyclists, and Public Transit
- P. Truck Level of Service

Typical Part 2 Section Outline

- Overview
- Applications
- Analysis Methods Overview
- Scoping and Screening Method
- Section Analysis Applying the HCM with Defaults
- Simplified HCM Facility Method
- Reliability (freeways, urban streets, signals)
- Multimodal LOS cross-reference
- Case study cross-reference

Scoping and Screening

- Applying generalized service volume tables
- Developing service volumes
- Applicable system elements:
  - Freeways
  - Multilane highways
  - Two-lane highways
  - Urban streets

Area Type	Terrain	Peak-Hour Peak-Direction (veh/h/ln)			AADT (2-way veh/day/ln)		
		LOS A-C	LOS D	LOS E (capacity)	LOS A-C	LOS D	LOS E (capacity)
Urban	**Level**	1,550	1,890	2,150	14,400	17,500	19,900
Urban	**Rolling**	1,480	1,810	2,050	13,700	16,700	19,000
Rural	**Level**	1,460	1,770	2,010	12,100	14,800	16,800
Rural	**Rolling**	1,310	1,600	1,820	11,000	13,400	15,200

Section Analysis Using the HCM with Defaults

- Applies the HCM operations method, but using default values for many inputs to reduce data requirements
- Requires access to HCM-implementing software
- Guide provides information on what input data are needed to apply the method
- Guide suggests default values for inputs that can be defaulted
- Applicable system elements:
  - Freeways, multilane highways, two-lane highways
  - Urban streets

Example Data Requirements for Multilane Highways

Input Data (units)	For HCM Section	For Facility Method	Default Value
Hourly directional volume (veh/h)	•	•	Must be provided
Number of directional lanes	•	•	Must be provided
Terrain type (level, rolling, etc.)	•	•	Must be provided*
Lane width (ft)	•	•	12
Total lateral clearance (ft)	•	•	12
Access points/mile	•	•	8 (rural), 16 (low-density suburban), 25 (high-density suburban)
Free-flow speed (mph)	•	•	Must be provided
Percentage heavy vehicles (%)	•	•	10 (rural), 5 (suburban)**
Peak hour factor (decimal)	•	•	0.88 (rural), 0.95 (suburban)
Section length (mi)		•	Must be provided
Intersection performance data		•	Must be provided

Simplified HCM Method

- Most HCM operations methods require specialized software to implement
  - Many target users of the Guide won't have access to this software
  - Using the HCM method with defaults may require more resources than available or appropriate for the analysis
- The Guide presents simplified methods that are HCM-compatible, but can be performed by hand or implemented in a basic spreadsheet
  - Multiple performance measures can be calculated
- Simplified methods available for all system elements

Example Data Requirements for the Simplified Signalized Intersection Method

Input Data (units)	Performance Measure					Default Value
	Cap	Del	LOS	MMLOS	Que	
Number of turn lanes	•	•	•	•	•	Must be provided
Other geometry	•	•	•	•	•	HCM Exhibit 19-11
Signal timing	•	•	•	•	•	HCM Exhibits 19-11 and 19-17
Peak hour factor (decimal)	•	•	•		•	0.90 (total entering volume <1,000 veh/h), 0.92 (otherwise)
Percentage heavy vehicles (%)	•	•	•	•	•	3%
Parking activity	•	•	•	•	•	None
Pedestrian activity	•	•	•	•	•	None
Volumes by movement (veh/h)		•	•	•	•	Must be provided
Analysis period length (h)		•	•		•	0.25 h

Cap = capacity, Del = delay, LOS = motorized vehicle level of service, MMLOS = motorized vehicle component of multimodal level of service, Que = queue length

Presentation Overview

- Need for the Guide
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- Case Studies
- Additional Resources

Case Studies

- Freeway master plan
- Adding BRT facilities to an urban street
- Regional planning
- Roadway system monitoring

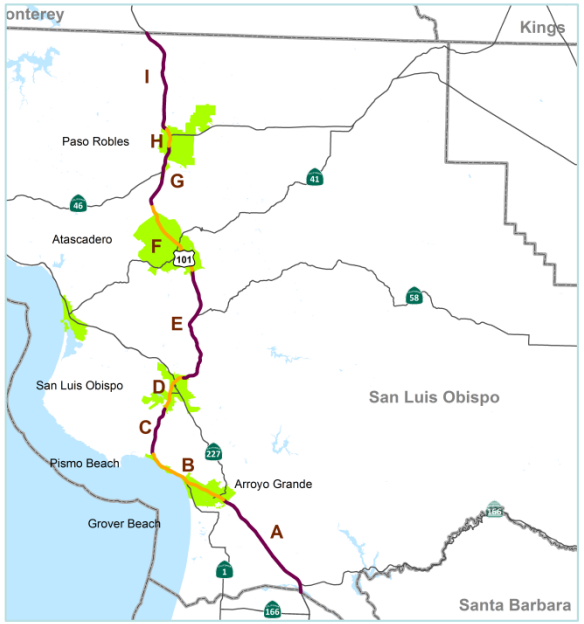
Case Study 1: Freeway Master Plan

- Master plan covers a 70-mile stretch of U.S. 101 in San Luis Obispo County, California

- Mostly four-lane freeway, with a six-lane section over a hill, and some multilane highway sections
- Objective of the planning analysis is to identify current and future problem areas and to prioritize projects for future capital programming

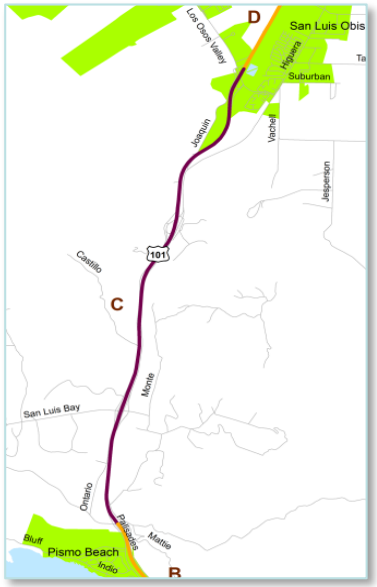
Develop Supersections

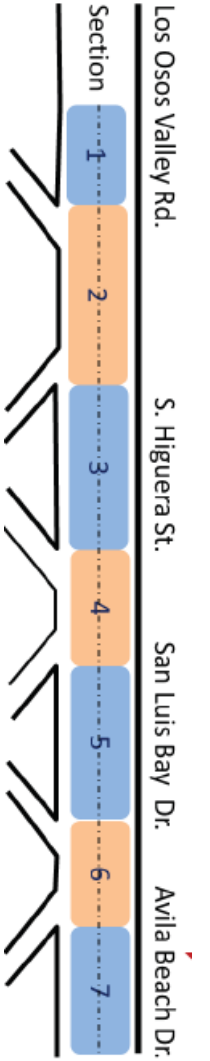
- Split facility into supersections with similar characteristics
  - Nine supersections identified, 3–13 miles in length
- Develop service volumes
  - Could use the Guide's defaults
  - Could develop local service volumes using known truck %, terrain type, and traffic peaking info
- Identify supersections operating near or below the facility's operational standard
  - Advance for further analysis (3 supersections identified)



Develop Sections and Determine Section Capacity

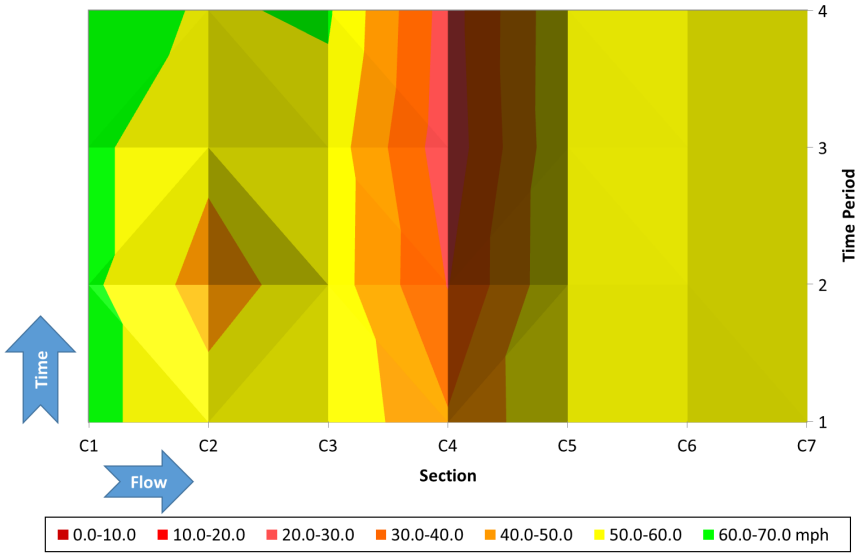
- Three section types used:
  - Basic, ramp, weave
- Determine section's capacity using simplified HCM method (by hand or spreadsheet)
- Compare demand to capacity
- Bottlenecks where demand exceeds capacity meter demand to downstream sections





Estimate Performance Measures

- Available measures:
  - Speed
  - Travel time, reliability
  - Density & LOS
  - Section 100% in queue



- Only input required for estimating speed, density, LOS, and queue is the demand-to-capacity ratio
- Travel times also require knowing the section length
- Results can be tabulated or shown in a diagram

Explore What-Ifs

- What if an auxiliary lane is added to the bottleneck section (Section C-4)?
  - Changes a ramp section to a weave section
- Auxiliary lane removes the bottleneck in Section C-4, but sends more demand downstream
- LOS is F in either scenario, but facility speed, density, queuing, and maximum demand-to-capacity ratio improve with the auxiliary lane

Maximum d/c Ratio by Scenario	C-1	C-2	C-3	C-4	C-5	C-6	C-7	Speed (mph)
Do Nothing	0.82	1.04	0.94	1.28	0.89	0.96	0.89	42.0
Add Lane	0.82	1.04	0.94	0.74	0.97	1.09	0.93	53.6

Case Study 2: Arterial Bus Rapid Transit

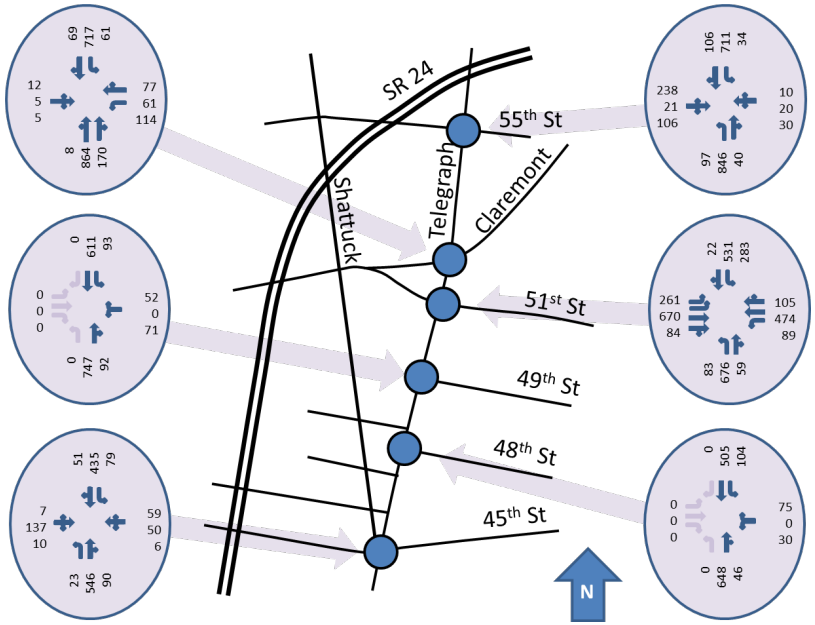
- Planning study for a proposed 14-mile BRT line through Oakland, California
- Demonstrates motor vehicle and multimodal planning methods for urban streets
- Proposed to remove one travel lane in each direction to create exclusive bus lanes

Develop Supersections

- Split facility into supersections with similar characteristics
  - Ten supersections identified
- Develop service volumes
- Identify supersections operating near or below the facility's operational standard
  - Advance for further analysis (6 supersections identified)

Estimate Signalized Intersection Capacity

- Gather data for each signalized intersection within a supersection
  - Lane configuration
  - Left-turn phasing
  - Turning movement volumes
  - Other inputs can be defaulted



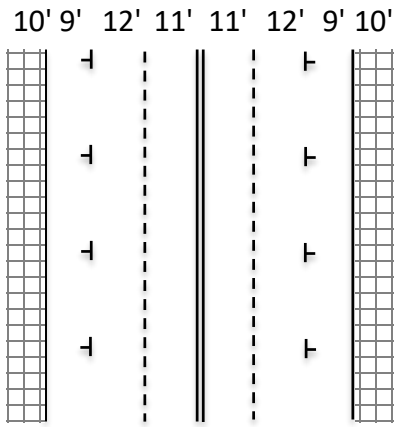
- Convert turning movement volumes into critical lane group volumes
- Estimate intersection volume-to-capacity ratio

Estimate Motor Vehicle Performance Measures

- Available measures:
  - Intersection control delay & LOS
  - Intersection average & 95th percentile queues
  - Section and facility average speed
  - Section and facility travel time
- Only input required for estimating delay, LOS, speed, and queue is the volume-to-capacity ratio
- Travel times also require knowing the section length

Estimate Pedestrian, Bicycle, and Bus Performance

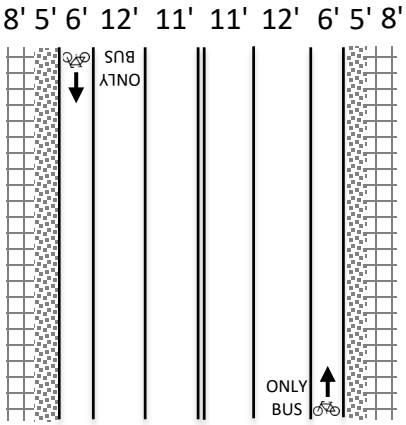
6 local buses/hour



Before

5 BRT buses/hour (stop once within the supersection)

4 local buses/hour (serve every stop)

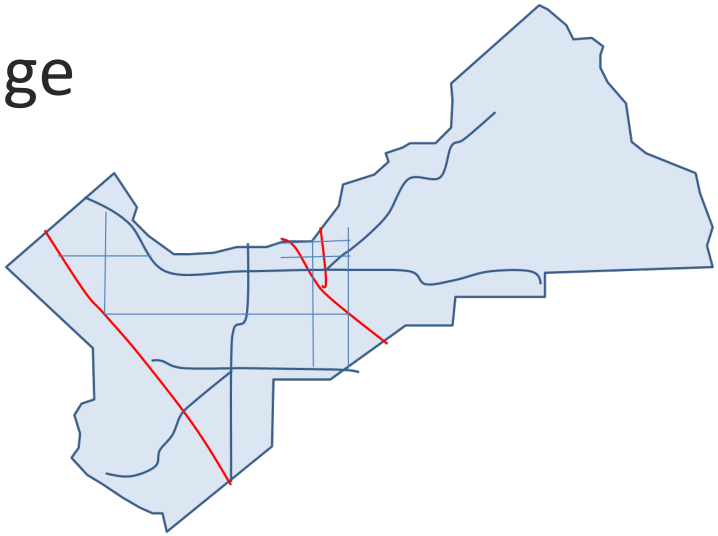


After

Mode	Service Measure	Before Value (LOS)	After Value (LOS)
	Auto speed	19.8 mph (C)	13.8 mph (E)
	Ped LOS index	1.98 (B)	0.88 (A)
	Bike LOS index	5.13 (E)	–3.99 (A)
	Transit LOS index	2.78 (C)	3.12/2.15 (C/B)

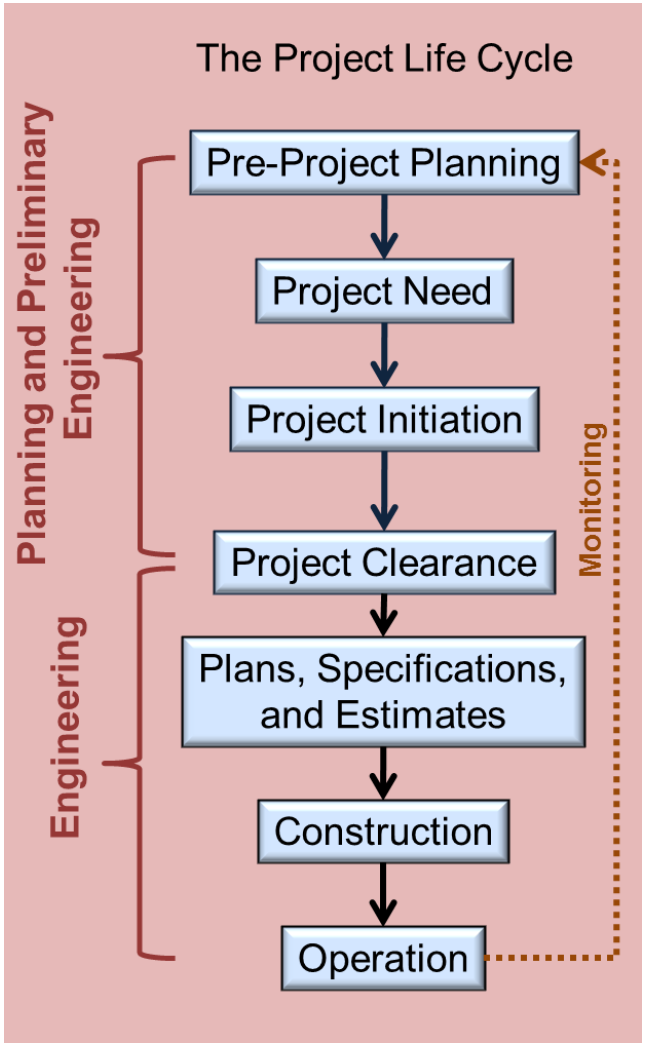
Case Study 3: Regional Planning

- A county is updating its long-range transportation plan
- Both urban and rural areas are included
- Desires to use HCM techniques where possible to provide more consistent analysis results now (traffic, air, noise), and in the future (project development)



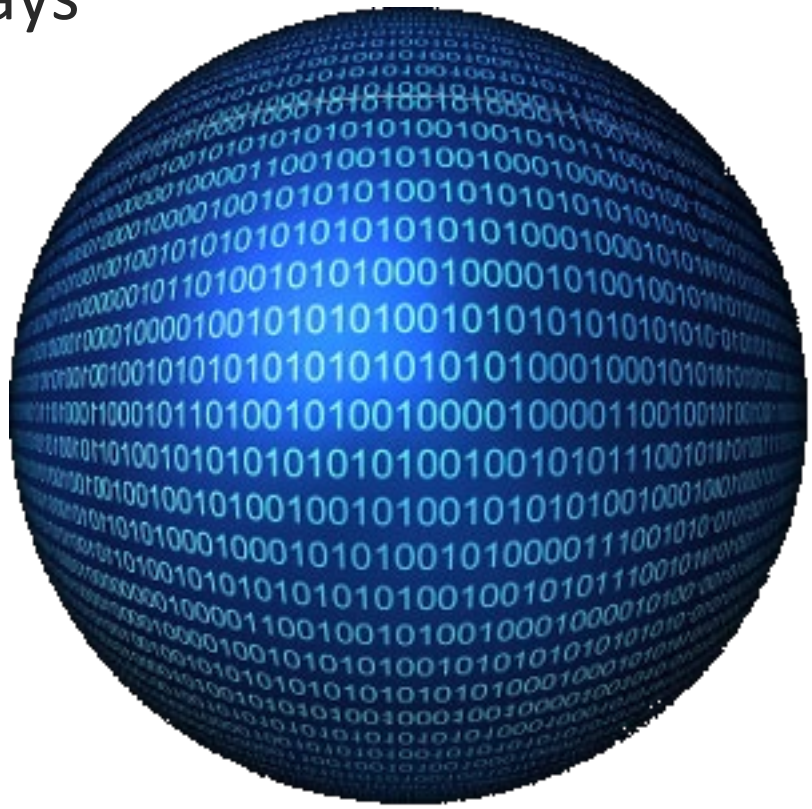
Why Go to the Trouble of Incorporating HCM Methods?

- Provides analytical consistency as a project progresses from need to concept to design
- Can allow a greater variety of project types to be modelled
  - Modernization
  - Traffic operations
  - Access management
- Takes advantage of the extensive research behind HCM methods



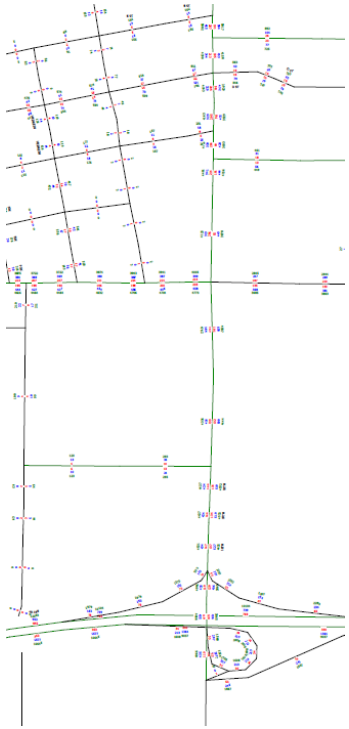
Why Go to the Trouble of Incorporating HCM Methods?

- More data about roadways is available in databases than ever before
  - Geometry
  - Traffic
  - Travel times
- Why not use these data to improve the accuracy and sensitivity of regional planning models?



Approaches for Developing Link Capacities

- Generalized
  - Create general categories of roadways
    - Suburban freeway, downtown arterial, etc.
  - Assign each link to one of these categories
  - Assign a free-flow speed to each category, and then calculate the corresponding HCM capacity to be used for that category of links



- Link-specific
  - Gather the data required to determine each link's free-flow speed and capacity
  - Calculate each link's HCM capacity and provide to the model

Pros and Cons of the Generalized Approach

- Pros
  - Applies default values—no new data collection needed
  - Only one capacity calculation needed per roadway category
  - Flexibility to choose how many categories to develop
    - More categories = more sensitivity
- Cons
  - Does not consider conditions on any given link that differ from the general category characteristics
  - Considers fewer factors that influence free-flow speed and capacity, relative to the detailed approach

Pros and Cons of the Detailed Approach

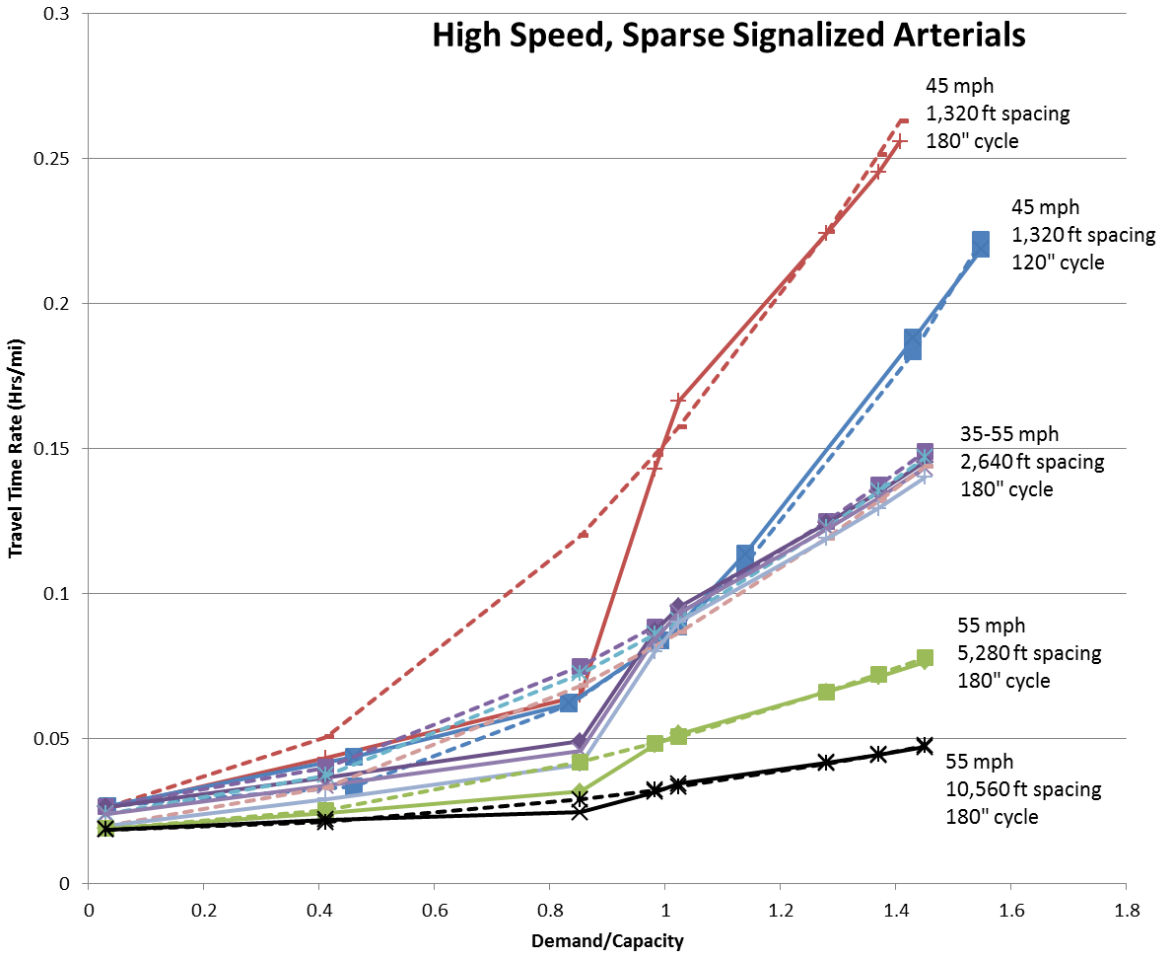
- Pros
  - Produces link-specific free-flow speeds and capacities
  - Could reduce model calibration effort, as capacities (and speeds) will more closely reflect actual roadway conditions
  - Effects of specific projects can be more accurately modeled
- Cons
  - Requires gathering additional data for every link in the model
    - Significant start-up effort
    - Many inputs can be defaulted, but with accuracy trade-offs
  - Link-specific free-flow speeds and capacities need to be imported for every link in the model

HCM Methods for Estimating Average Link Speed

- Chapters in Part 2 of the Guide provide simplified versions of HCM methods for estimating speed
  - Despite the simplifications, these are still too computationally intensive for a regional modeling application
- For modeling purposes, the Guide provides a simple equation for estimating average link speed, using:
  - Link capacity (already determined)
  - Link free-flow speed (already determined)
  - Link demand volume (estimated by the regional model)
- Approximates HCM results, calibrated to when demand greatly exceeds capacity (d/c = 1.9)

Calibration of the Guide's Method

- Calibration example for high-speed arterials with longer signal spacing
- Solid line = HCM value
- Dashed line = calibrated value



Estimating HCM-Based Speeds within Regional Model

- Guide identifies speed–flow curve calibration (*A* and *B*) parameters by facility type
- Determine a link's demand-to-capacity ratio
- Apply the calibrated speed–flow curve to a link to estimate its average speed

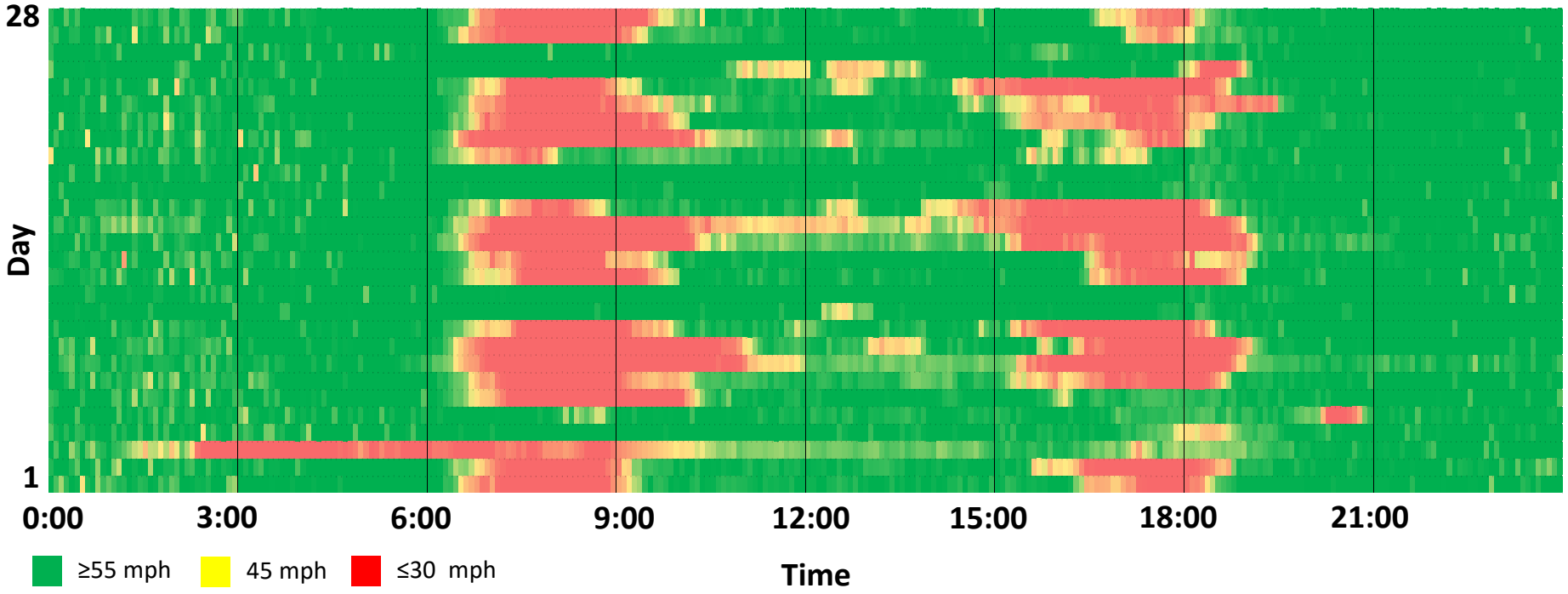
Link ID	Facility Type	Lanes	Demand (veh/h)	Capacity (veh/h)	Free-Flow Speed (mph)	BPR *A*	BPR *B*	d/c Ratio	Speed (mph)
A001	**Urban freeway**	4	8,220	7,200	60	0.17	7	1.14	42.0
A002	**Urban arterial**	3	1,740	2,100	35	2.19	2	0.83	14.0
A003	**Urban collector**	2	1,170	1,200	30	1.89	3	0.98	10.9
A004	**Rural freeway**	2	2,790	3,800	70	0.31	7	0.73	67.6
A005	**Rural principal highway**	2	1,490	3,400	55	0.18	8	0.44	55.0
A006	**Rural minor highway**	1	250	1,300	45	0.38	9	0.19	45.0

Additional Performance Measures by Post-Processing Model Output

- Link density and (for freeways) link LOS
- Vehicle-hours in queue by link
- Vehicle hours of delay by link
- Average annual travel time index (TTI) by link
- Systemwide average annual TTI
- 95th percentile TTI
- Percent of trips under 45 mph

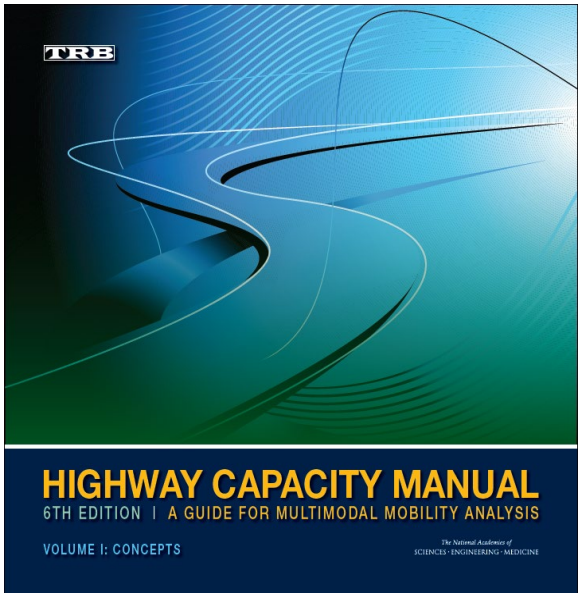
Case Study 4: Roadway System Monitoring

- A state DOT has an established roadway system monitoring program that collects roadway volumes and speeds at various locations



What Does the HCM Have to Offer System Monitoring?

- HCM is an authoritative reference for defining roadway operations performance measures
- Consistently defined measures facilitate comparisons
  - Over time & between locations



- HCM measures and methods can be used to:
  - Report current roadway performance
  - Diagnose operational issues
  - When calibrated to current conditions, forecast future operations

Using HCM Measures to Supplement Reporting

- HCM-based measures can help interpret results of roadway monitoring
  - Capacity (used to generate volume-to-capacity ratio)
  - Level of service
  - TTI (used to evaluate likelihood of congestion occurring)

Using Monitoring Results as Inputs to HCM Methods

- Outputs from roadway monitoring are frequently used as inputs to HCM methods
  - Free-flow speed (FFS)
  - Heavy-vehicle percentage (%HV)
  - Ratio of peak hour to daily traffic (*K*-factor)
  - Peak hour factor (PHF)
    - (hourly volume) / (4 × peak 15-minute volume)

Methods of Estimating Capacity for Roadway Monitoring

- Guide or local service volume table
  - Provides volume at capacity
  - Approximate value, due to extensive use of defaults
- Simplified HCM equations in the Guide
  - Freeways and multilane highways
  - Rural two-lane highways
  - Urban streets

Methods of Estimating LOS for Roadway Monitoring

- Guide or local service volume table
  - Provides maximum demands for each LOS
  - Approximate value, due to extensive use of defaults
- Direct calculation
  - Convert hourly flow from veh/h to pc/h using HCM's heavy-vehicle equivalence factor (typically 2 for level terrain)
    - Example: 1,000 veh/h with 10% trucks = 900 + (100 × 2) = 1,100 pc/h
  - Density = (hourly flow) / (number of lanes) / (average speed)
  - HCM tables convert freeway and multilane highway density to a LOS letter

Using TTI to Estimate Likelihood of Congestion Ocurring

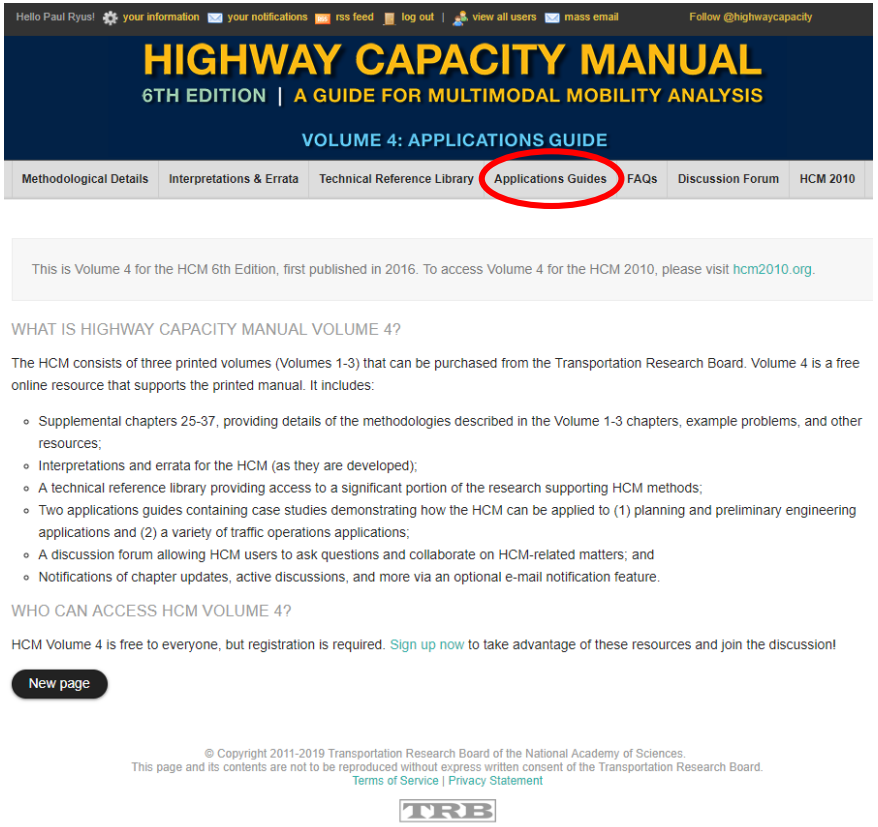
- HCM provides speeds at capacity for various free-flow speeds (FFS)
- Dividing the FFS by the speed at capacity gives the TTI at capacity
- Guidance:
  - High probability that segment is uncongested when TTI ≤ 1.05 (freeways, highways) or ≤ 2.50 (urban streets)
  - High probability that segment is congested when TTI ≥ 1.40 (freeways, highways) or ≥ 4.00 (urban streets)
  - Uncertain whether segment is over capacity or not for other TTI values

Presentation Overview

- Need for the Guide
- Overview of the Guide
- Case Studies
- Additional Resources

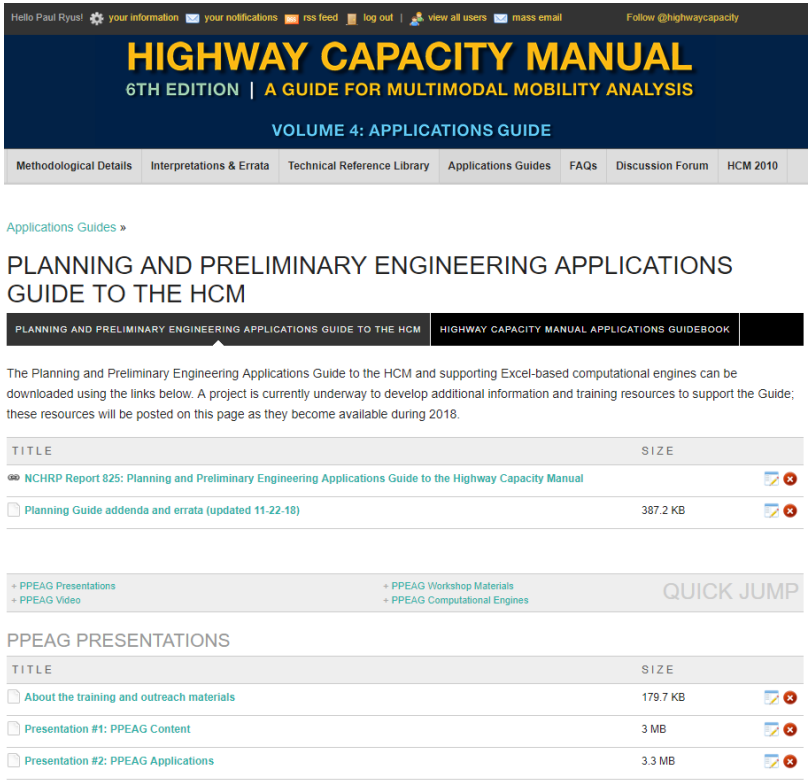
Where to Find PPEAG Resources

- Online HCM Volume 4
  - www.hcmvolume4.org
  - Free, one-time registration required
- Navigate to the "Application Guides" section, then select the Planning Guide



Available PPEAG Resources

- Download the Guide
- Addenda & errata
- Introduction video
- Presentations
  - Overview
  - Applications
- Workshop materials
- Computational engines

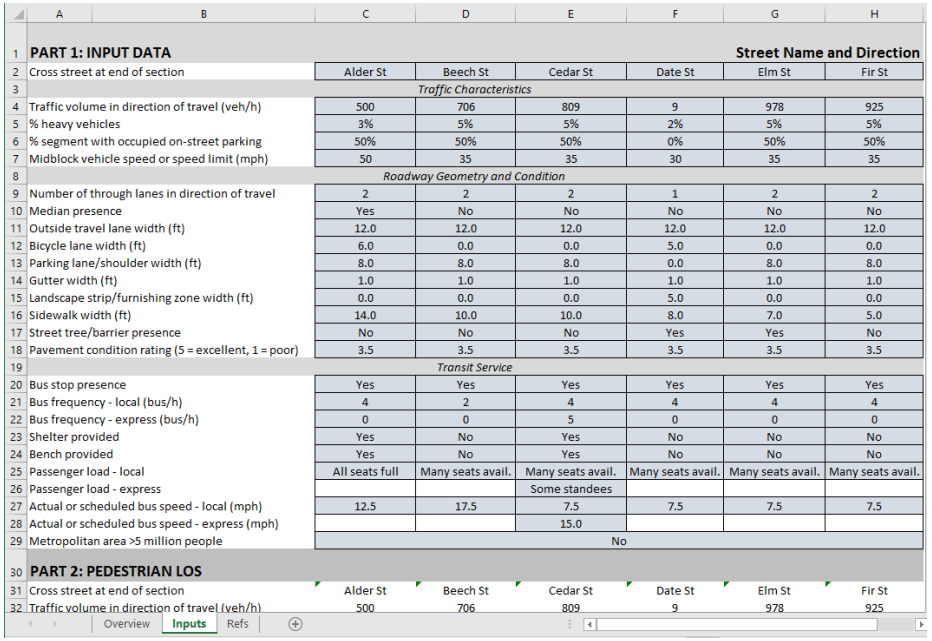


Workshop Materials

- 12 hours of training material
- Includes PowerPoint slides, instructor notes, and student packet for each workshop module
  - Welcome
  - Introduction to the Guide
  - Freeways
  - HCM Application to Regional Planning
  - Urban Street Motor Vehicle Operations
  - HCM Application to Roadway System Monitoring
  - Urban Street Multimodal Analysis

Computational Engines

- Freeways
- Signalized intersections
- Single-lane roundabouts
- Truck LOS
- Two-way stop intersections
- Urban streets
  - Motor vehicles
  - Multimodal (bicycle, pedestrian, bus)



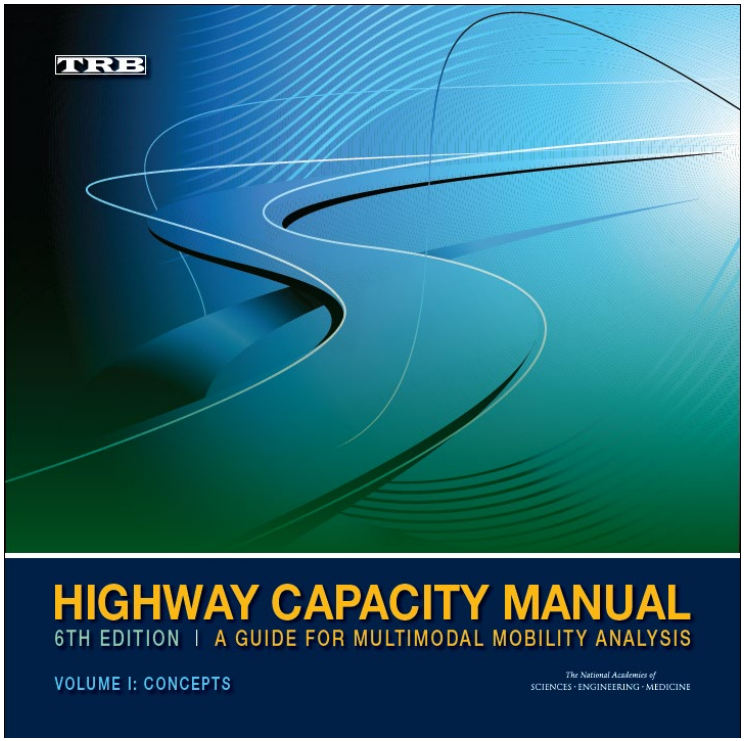
	A	B	C	D	E	F	G	H
1	**PART 1: INPUT DATA**						**Street Name and Direction**	
2	Cross street at end of section		Alder St	Beech St	Cedar St	Date St	Elm St	Fir St
3		*Traffic Characteristics*						
4	Traffic volume in direction of travel (veh/h)		500	706	809	9	978	925
5	% heavy vehicles		3%	5%	5%	2%	5%	5%
6	% segment with occupied on-street parking		50%	50%	50%	0%	50%	50%
7	Midblock vehicle speed or speed limit (mph)		50	35	35	30	35	35
8		*Roadway Geometry and Condition*						
9	Number of through lanes in direction of travel		2	2	2	1	2	2
10	Median presence		Yes	No	No	No	No	No
11	Outside travel lane width (ft)		12.0	12.0	12.0	12.0	12.0	12.0
12	Bicycle lane width (ft)		6.0	0.0	0.0	5.0	0.0	0.0
13	Parking lane/shoulder width (ft)		8.0	8.0	8.0	0.0	8.0	8.0
14	Gutter width (ft)		1.0	1.0	1.0	1.0	1.0	1.0
15	Landscape strip/furnishing zone width (ft)		0.0	0.0	0.0	5.0	0.0	0.0
16	Sidewalk width (ft)		14.0	10.0	10.0	8.0	7.0	5.0
17	Street tree/barrier presence		No	No	No	Yes	Yes	No
18	Pavement condition rating (5 = excellent, 1 = poor)		3.5	3.5	3.5	3.5	3.5	3.5
19		*Transit Service*						
20	Bus stop presence		Yes	Yes	Yes	Yes	Yes	Yes
21	Bus frequency - local (bus/h)		4	2	4	4	4	4
22	Bus frequency - express (bus/h)		0	0	5	0	0	0
23	Shelter provided		Yes	No	Yes	No	No	No
24	Bench provided		Yes	No	Yes	No	No	No
25	Passenger load - local		All seats full	Many seats avail.	Many seats avail.	Many seats avail.	Many seats avail.	Many seats avail.
26	Passenger load - express				Some standees			
27	Actual or scheduled bus speed - local (mph)		12.5	17.5	7.5	7.5	7.5	7.5
28	Actual or scheduled bus speed - express (mph)				15.0			
29	Metropolitan area >5 million people				No			
30	**PART 2: PEDESTRIAN LOS**							
31	Cross street at end of section		Alder St	Beech St	Cedar St	Date St	Elm St	Fir St
32	Traffic volume in direction of travel (veh/h)		500	706	809	9	978	925

Overview | Inputs | Refs

Summary

- The Guide provides a resource for both HCM users and planning professionals to:
  - Conduct quick back-of-the-envelope evaluations where neither a full HCM analysis nor simulation is necessary
  - Maintain consistency with the HCM throughout the project development process
  - Incorporate HCM methods into planning tools
- HCM Volume 4 provides many tools for learning more about the Guide and applying it to projects

HCM Webinar Series



- Using the HCM for planning
- Freeway facility analysis
- Travel time reliability analysis
- Multimodal analysis
- Intersection control evaluation (ICE)
- Alternative intersection and corridor analysis

Questions?

Today's Speakers

- Brian Dunn, *Oregon Department of Transportation*, brian.g.dunn@odot.state.or.us

- Paul Ryus, *Kittelson and Associates*, pryus@kittelson.com

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- ***Sponsoring Committee: AHB40***
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  - Create your account
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- Credits will be reported two to three business days after the webinar
- You will be able to retrieve your certificate from RCEP within one week of the webinar

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