U.S. Department of Transportation
Federal Highway Administration

Traffic Analysis Capability Maturity Framework (CMF)

Project Summary

June 9, 2022

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Project Overview and Understanding

- Traffic analysis is vital; supports and justifies agency decisions.
- Tools and methods are evolving to accommodate technologies and strategies:
  - Active transportation and demand management (ATDM), connected and automated vehicles (CAV), multi-modal systems, integrated corridor management (ICM), managed lanes, shared mobility, real-time simulation, emerging data sources, multi-resolution modeling, multi-scenario modeling.
- Increasing need to assess agency capabilities for traffic analysis and to identify a course of actions to improve the capabilities.

Project Goals and Objectives

- Assist agencies in assessing their strengths and weaknesses for incorporating traffic analysis activities into their business process.
- Recommend actions to improve capabilities in using analytical tools.
- Support agencies in identifying opportunities for improvement.
- Help agencies in developing a programmatic focus for traffic analysis.
- Create analytical consistency and uniformity across State departments of transportation (DOTs) and Federal/regional/local transportation agencies.
- Proposed approach:
  - Develop a Traffic Analysis CMF based on the original transportation systems management and operations capability maturity model (TSMO CMM*).

* Federal Highway Administration. (2012). *Creating an Effective Program to Advance Transportation System Management and Operations,* Primer No. FHWA-HOP-12-003, Washington, DC. https://ops.fhwa.dot.gov/publications/fhwahop12003/fhwahop12003.pdf

Project Deliverables and Schedule

- Most work occurred in the first half of 2021:
  - Stakeholder webinars
  - Annotated outline development
  - Final report development
- Final deliverables:
  - Full final report
  - Project summary tech brief
  - Project summary presentation

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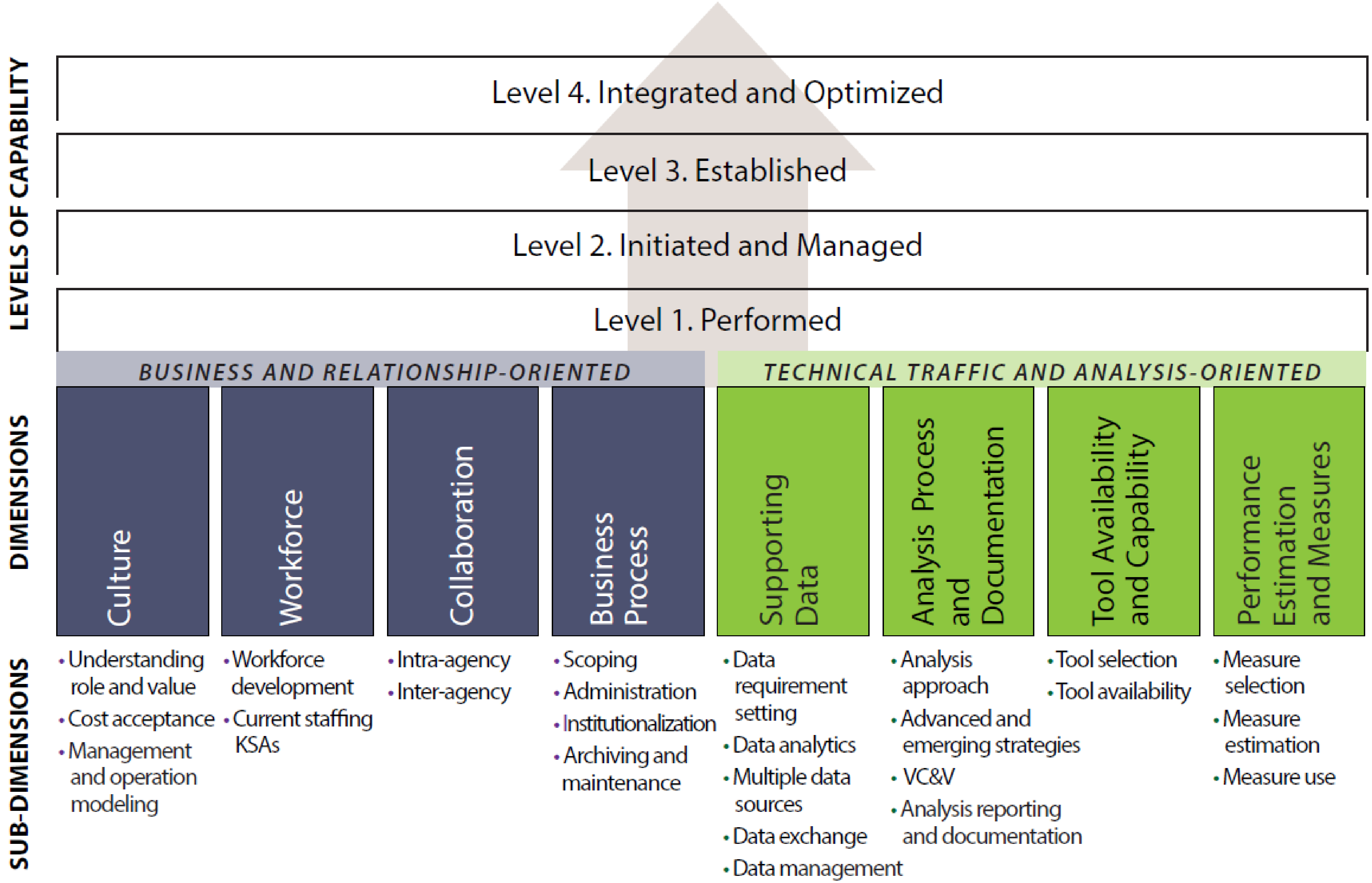


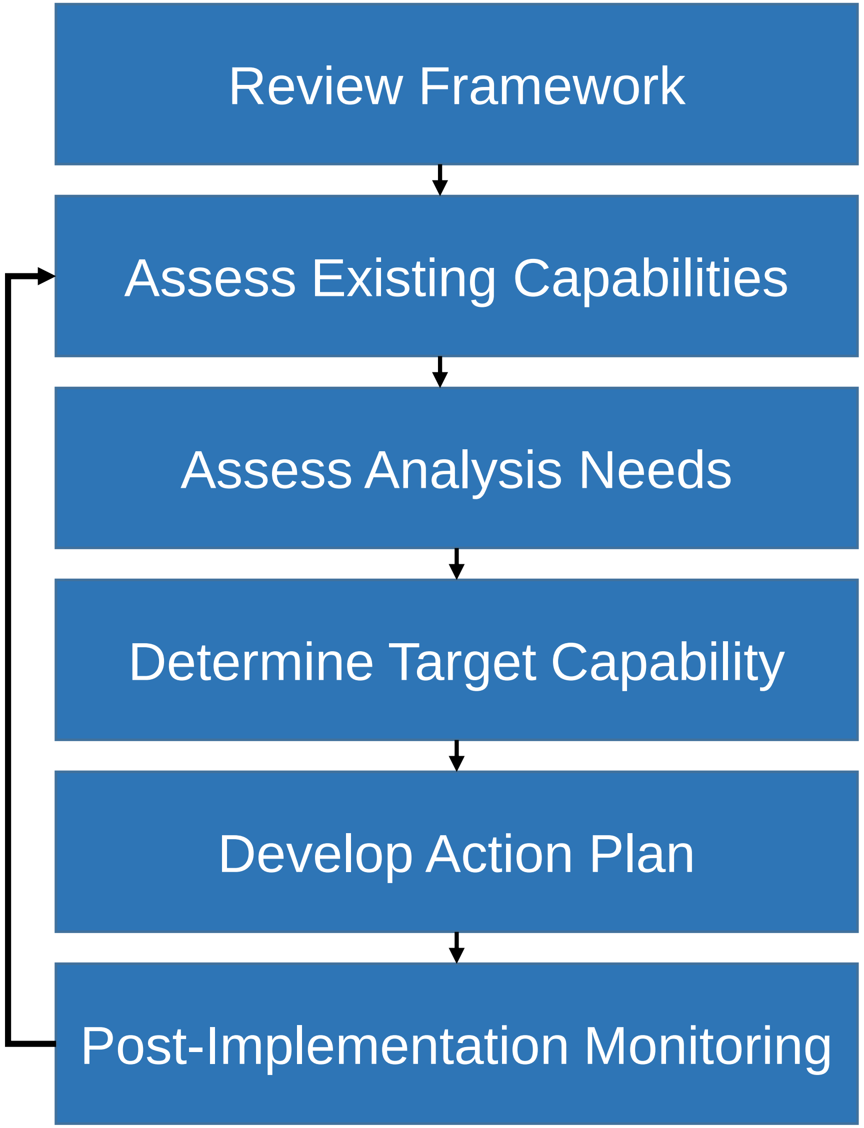
Source: FHWA.

KSAs - knowledge, skills, and abilities, TSMO - transportation system and management, VC&V - verification, calibration, and validation

Final Report Outline

- Chapter 1: Introduction
- Chapter 2: Overview of the capability maturity framework
- Chapter 3: Assessment of current capability
  - Tabular approach (tables 1 through 8)
  - Multiple-choice questions
- Chapter 4: Identification of actions to improve capability
  - Tabular suggestions (tables 9 through 16)
  - Detailed discussion of suggestions

Steps to Utilize the CMF



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Source: FHWA.

Self-Assessment (Tabular) for Tool Capability Dimension

Sub-Dimension	Level 1–Performed	Level 2–Initiated and Managed	Level 3–Established	Level 4–Integrated and Optimized
Tool selection	Ad-hoc selection by project public agency manager and project consultant.	Selection based on national, Statewide, or agency-wide guidance. Selection constrained by available tools, knowledge, and experience.	Tool selection based on detailed agency-wide criteria and analysis type-specific criteria. Selection not constrained by available tools, knowledge, and experience.	Tool selection reflects agency staff's direct experience with using a wide variety of analysis tools from a wide variety of developers and vendors. Agency staff are also familiar with the developers' future plans and directions for these tools.

Self-Assessment (Tabular) for Tool Capability Dimension (cont.)

Sub-Dimension	Level 1–Performed	Level 2–Initiated and Managed	Level 3–Established	Level 4–Integrated and Optimized
Tool availability	Agency staff only have access to one preferred tool or are uncomfortable with the thought of using other tools beyond their preferred tool.	Agency staff only have access to a few preferred tools (possibly from the same vendor) or are uncomfortable with the thought of using other tools beyond their few preferred tools. Limited use of supplemental or add-on tools.	Agency staff have access to a variety of tools for most types of traffic analysis. However, for certain types of traffic analysis, tool availability may be limited or sub-optimal. Limited use of data analytics tools to assess and improve the quality of the data used for traffic analysis.	Full access to a wide variety of traffic analysis tools and data analytics tools from a wide variety of developers and vendors, which can be utilized based on project requirements.

Self-Assessment (Multiple-Choice) for Tool Capability Dimension

Q21: How do you select the tool(s) for your traffic analyses?

a. The selection of the specific tool for the analysis is ad-hoc by the project public agency manager and the project consultant.

b. Tool selection reflects national, Statewide or agency-wide guidance. However, the selection is constrained by the available tools, knowledge, and experience.

c. Tool selection reflects agency-wide and analysis type-specific criteria, in addition to requirements and criteria written specifically for the project. In general, the selection is not constrained by the available tools, knowledge, and experience.

d. Tool selection reflects agency staff's direct experience with using a wide variety of analysis tools from a wide variety of developers and vendors. Agency staff are also familiar with the developers' future plans and directions for these tools.

Self-Assessment (Multiple-Choice) for Tool Capability Dimension (cont.)

Q22: How do you describe your core capabilities in using analysis tools and the availability of these tools considering different levels ranging from sketch planning tools to microscopic simulation tools?

a) Agency staff only have access to one preferred tool or are uncomfortable with the thought of using other tools beyond their preferred tool. We have the capability to regularly use less complex tools and limited capabilities to use more advanced tools.

b) Agency staff only have access to a few preferred tools (possibly from the same vendor) or are uncomfortable with using other tools beyond their few preferred tools. We routinely use deterministic and/or microscopic simulation tools to meet project objectives. There is some ad-hoc use of DTA for a very limited number of projects. We have very limited supporting tools to assist in developing, calibrating, validating, and using the results of the models.

Self-Assessment (Multiple-Choice) for Tool Capability Dimension (cont.)

Q22: How do you describe your core capabilities in using analysis tools and the availability of these tools considering different levels ranging from sketch planning tools to microscopic simulation tools?

c) Agency staff have access to a variety of tools for most types of traffic analysis. However, for certain types of traffic analysis, tool availability may be limited or sub-optimal. We routinely use deterministic and/or microscopic simulation tools and have the capabilities to use DTA and MRM to meet project objectives. We have limited use of supporting tools to assist in developing, calibrating, validating, and using the results of the models.

d) Agency staff have full access to a wide variety of traffic analysis tools and data analytics tools from a wide variety of developers and vendors, which can be utilized based on project requirements. We have the capability to use modeling tools of different resolution and data analytic tools including statistical analysis, machine learning, and visualization in an integrated analysis and decision support environment. Supporting tools are integrated into the environment to assist in developing, calibrating, validating, and using the results of the models.

Actions to Reach the Next Level (Tabular) for Tool Capability Dimension

Sub-Dimension	Level 1 to 2	Level 2 to 3	Level 3 to 4
Tool selection	Apply tool selection guidance	Apply agency-wide and analysis type-specific criteria	Develop direct experience with a wide variety of tools from various developers and vendors
Tool availability	Obtain access to alternative tools	Obtain access to a variety of tools for most analysis types	Obtain access to a wide variety of traffic analysis and data analytics tools from a wide variety of developers

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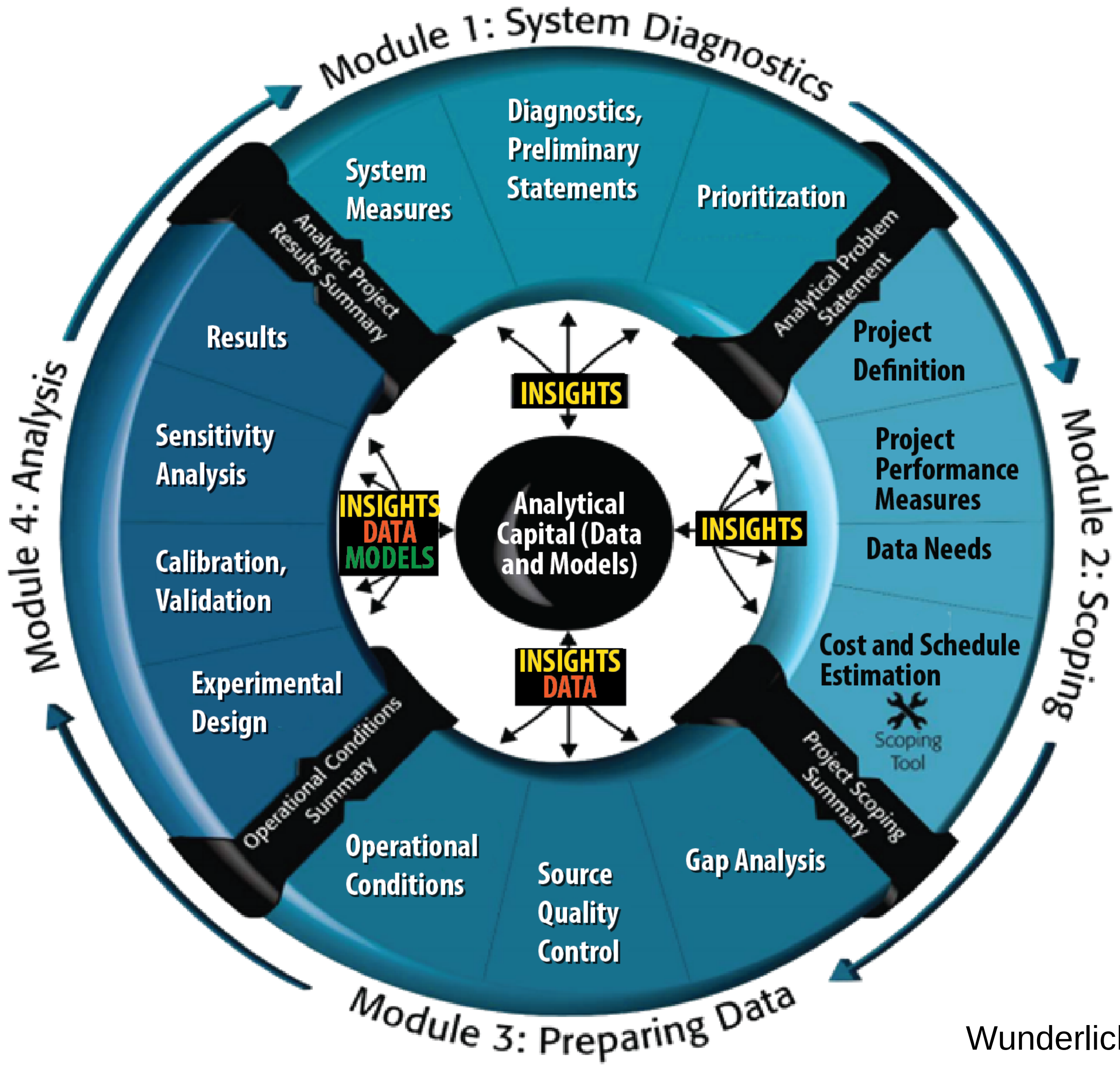
Actions to Reach the Next Level (Detailed)

- Major dimension
  - Sub-dimension
    - Description and Importance
    - Action(s) to move from level 1 to level 2
    - Action(s) to move from level 2 to level 3
    - Action(s) to move from level 3 to level 4

*25 sub-dimensions * 3 actions = 75 total actions*

Sample Actions (Business Process)

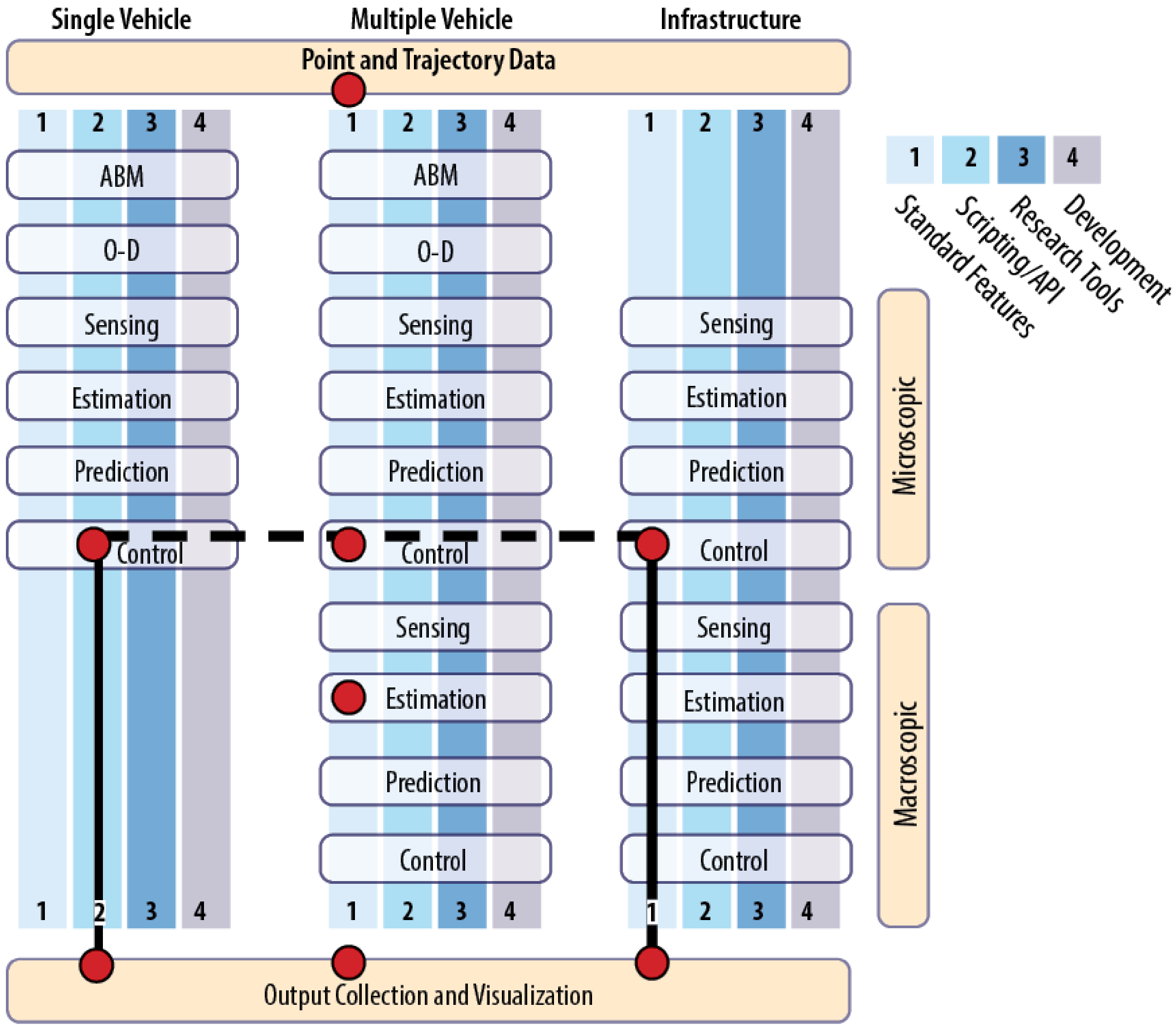
- Adopt scoping procedures and policies



Wunderlich et al. 2017

Sample Actions (continued)

- CAV scoping procedures and policies



ABM – activity based models
API = application programming interface
O-D = origin-destination

Abbas et al. 2020

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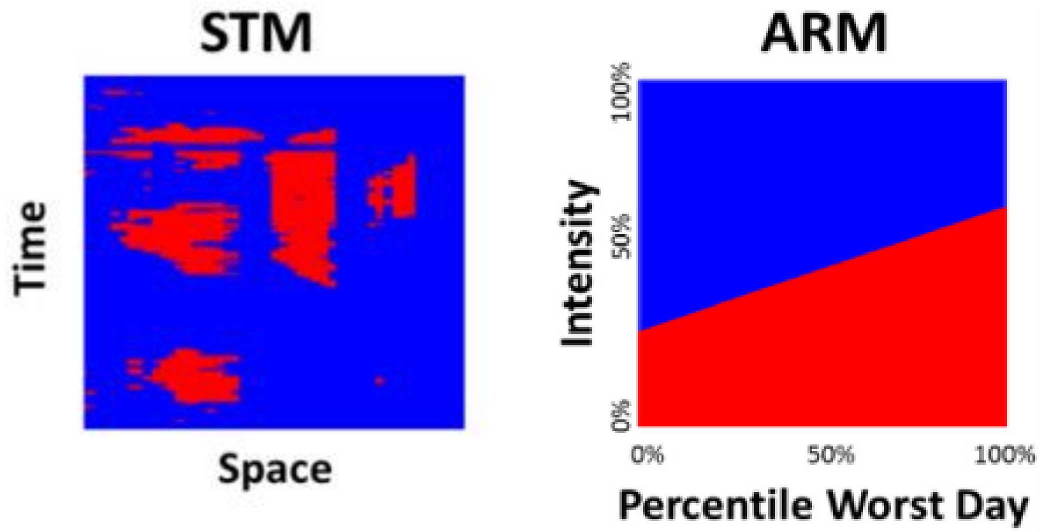
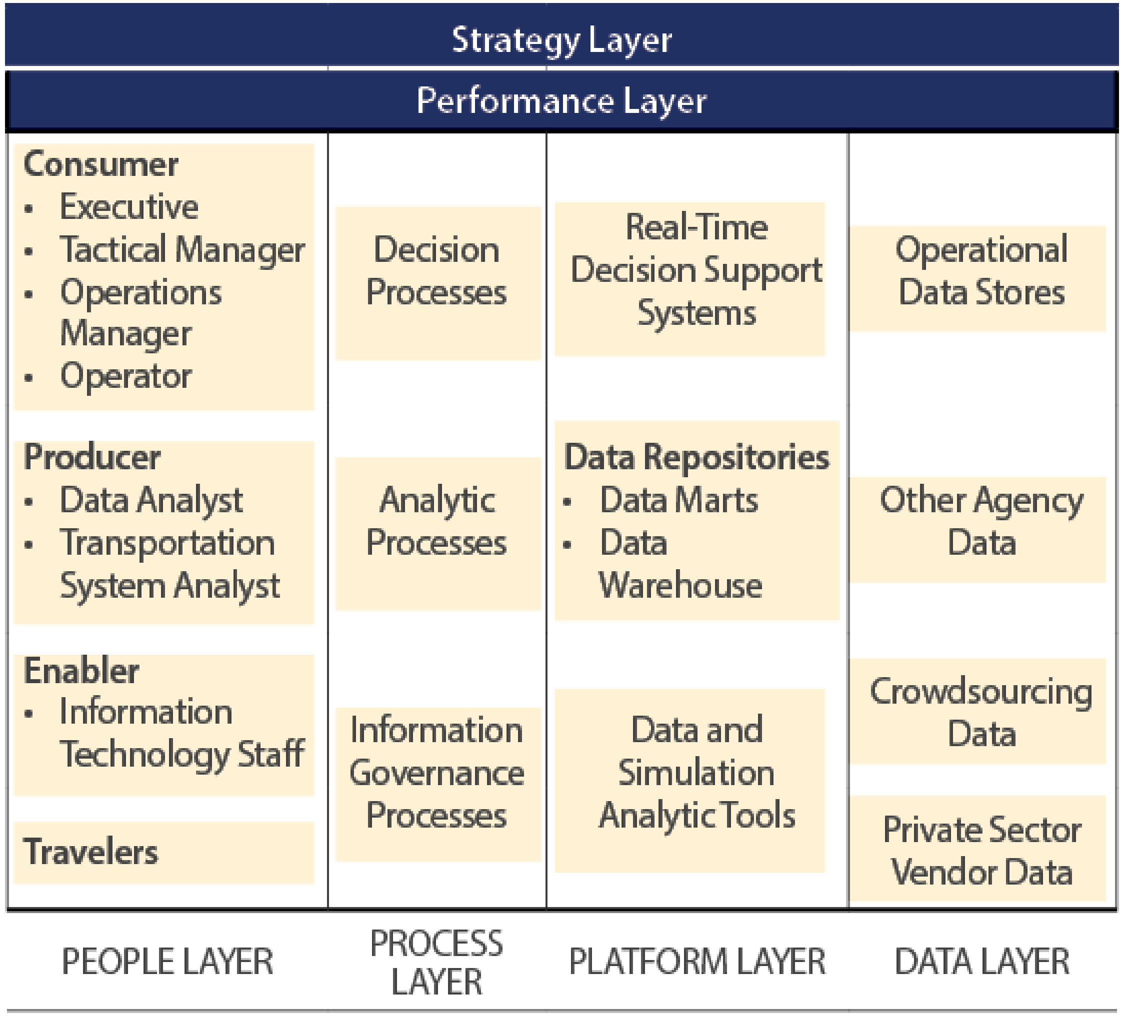
Sample Actions (Supporting Data)

- Develop and adopt data tools
- Use integrated modeling and data environment



STM = spatiotemporal matrix
ARM = annual reliability matrix

Hale et al. 2016, 2021



Hadi et al. 2020

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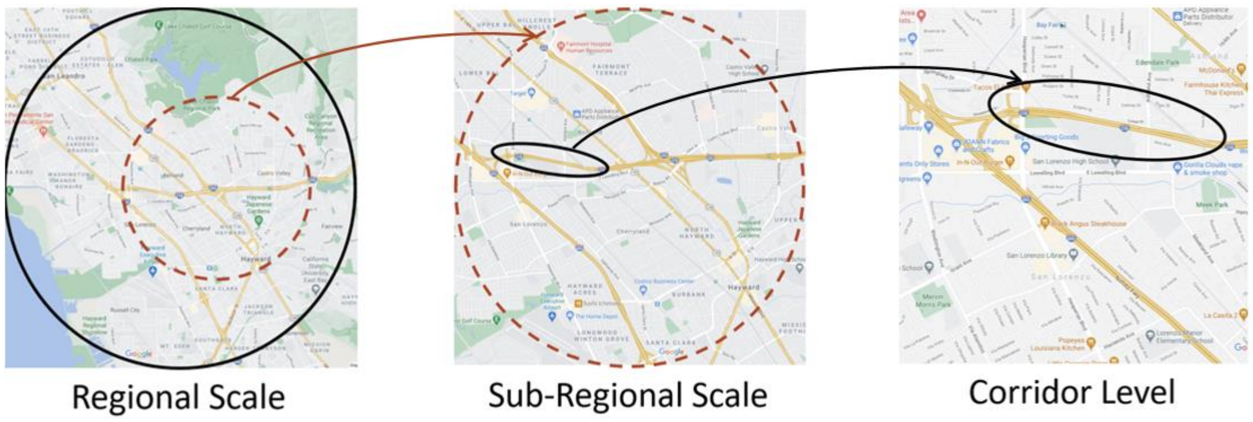
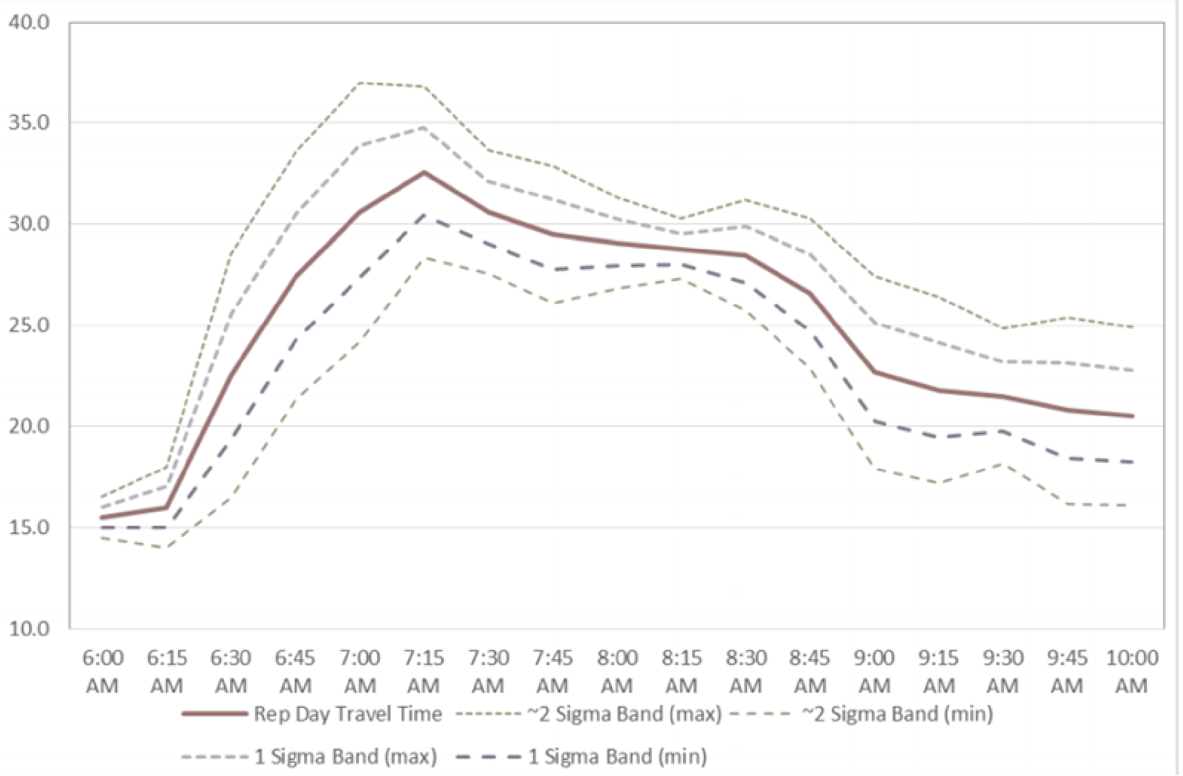
Sample Actions (Analysis Process)

- Build capability to apply DTA and MRM
- Adopt VC&V procedures



Adapted from Sloboden et al. 2012



DTA = dynamic traffic assignment
MRM = multiresolution modeling
VC&V = verification, calibration, and validation

Wunderlich et al. 2019

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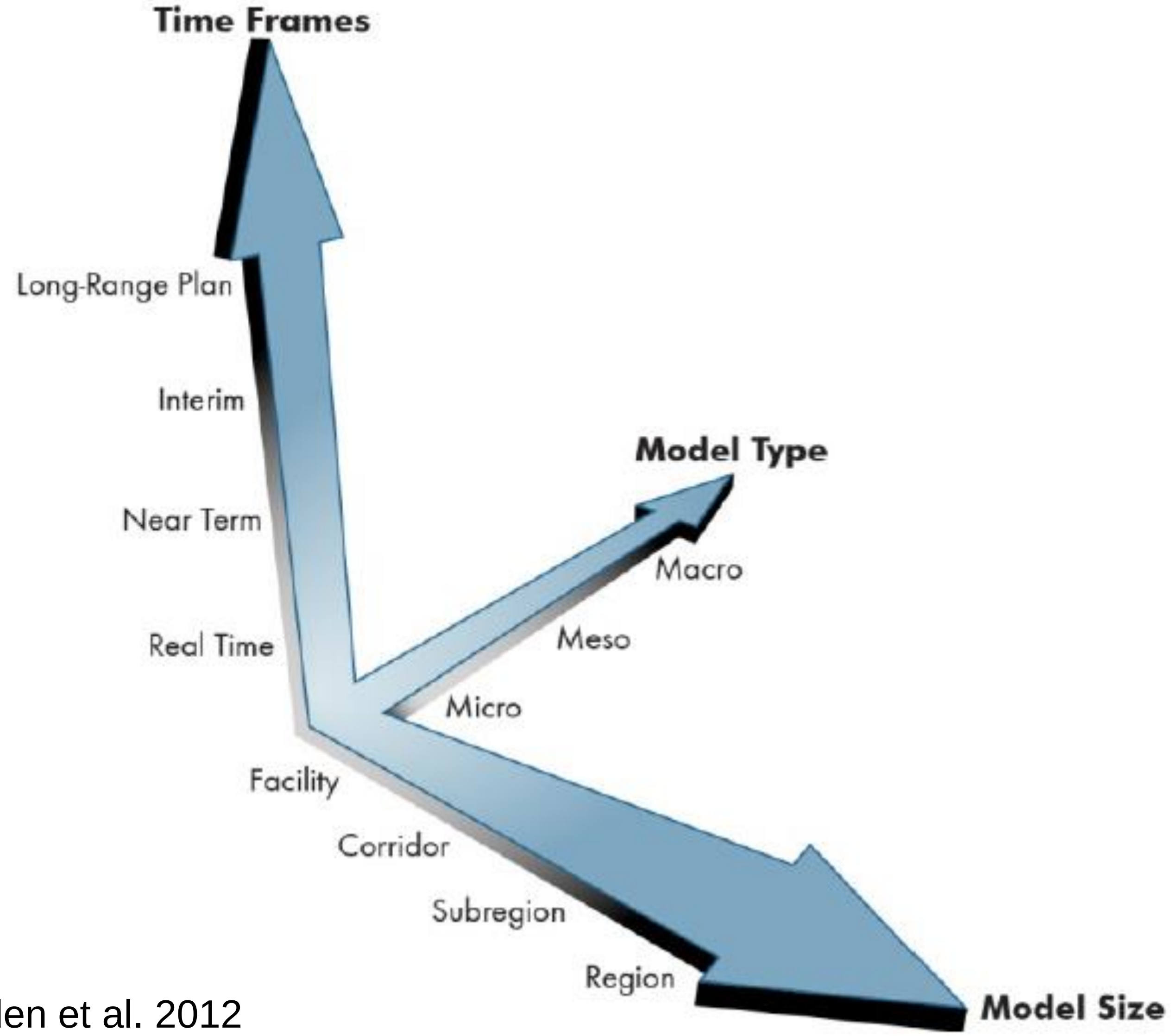
Sample Actions (Tool Capability)

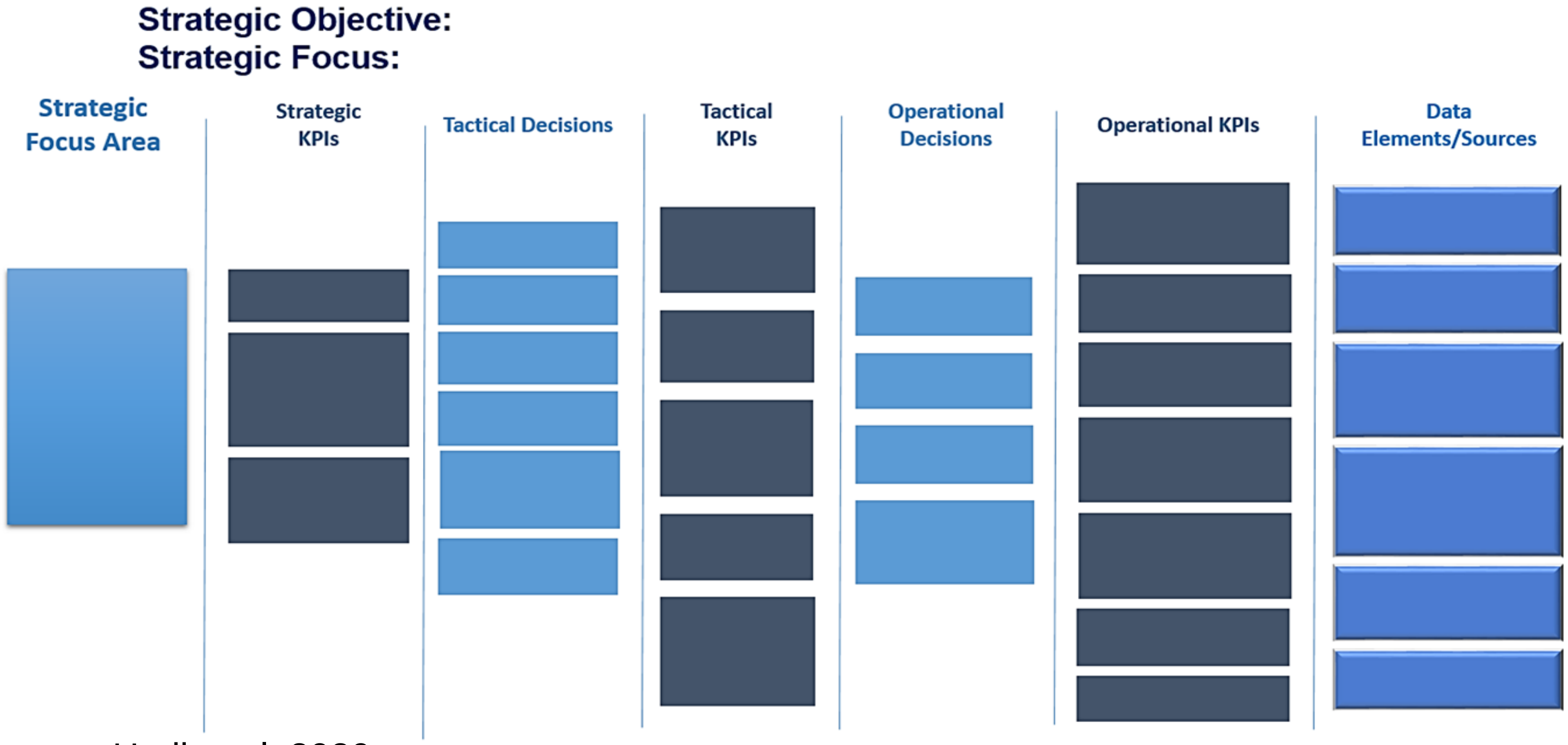
- Increase use of DTA, MRM, and data analytics
- Adopt tool selection procedures



Sloboden et al. 2012

Sample Actions (Performance Measures)

- Adopt performance measure definitions and selection methods
- Apply integrated business intelligence and decision support



Hadi et al. 2020

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Sample Actions (Culture)

- Engage upper management
- Have extra funds available for advanced modeling
- Recognize importance of modeling advanced and emerging strategies

Source: FHWA.

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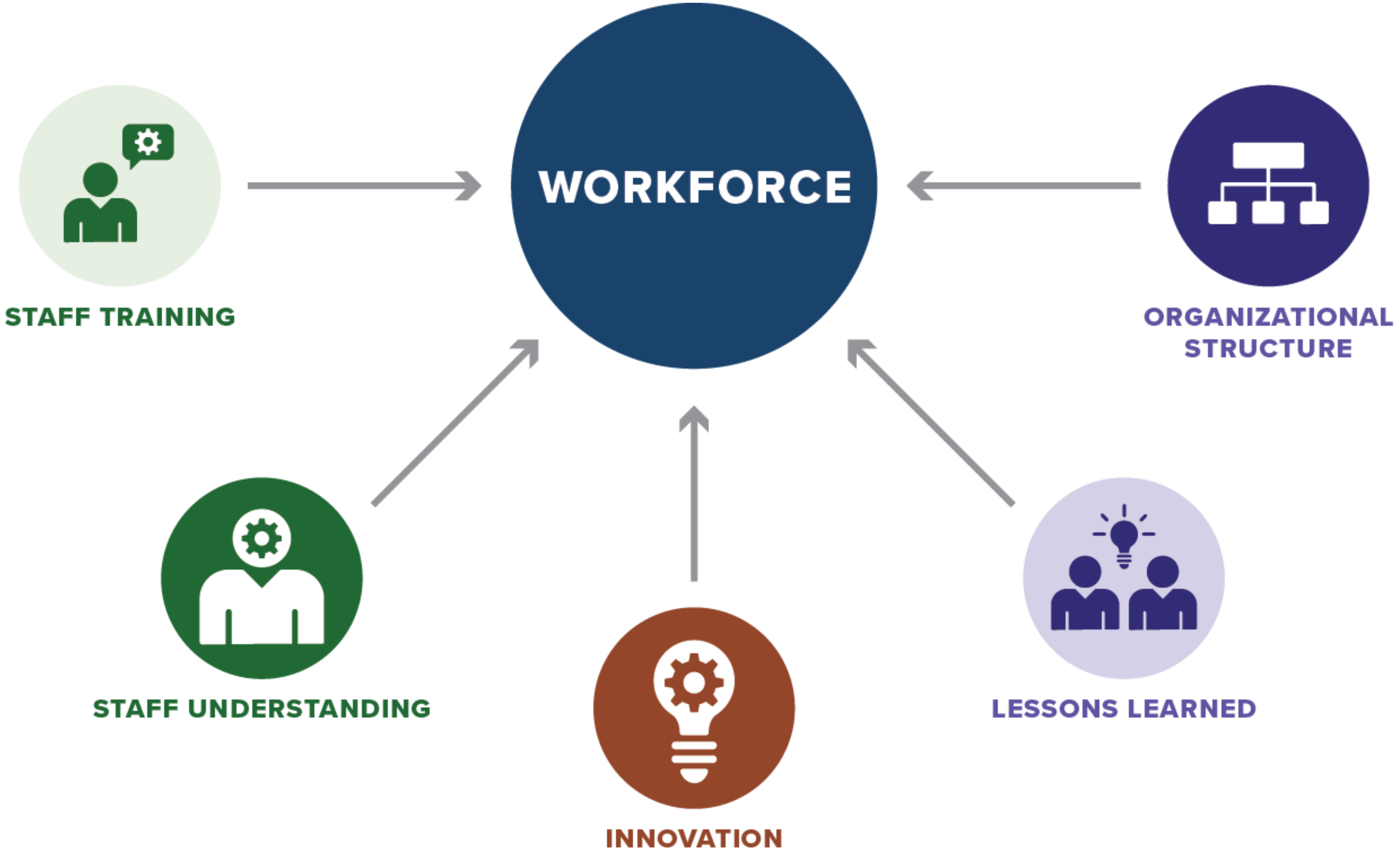
Sample Actions (Workforce)

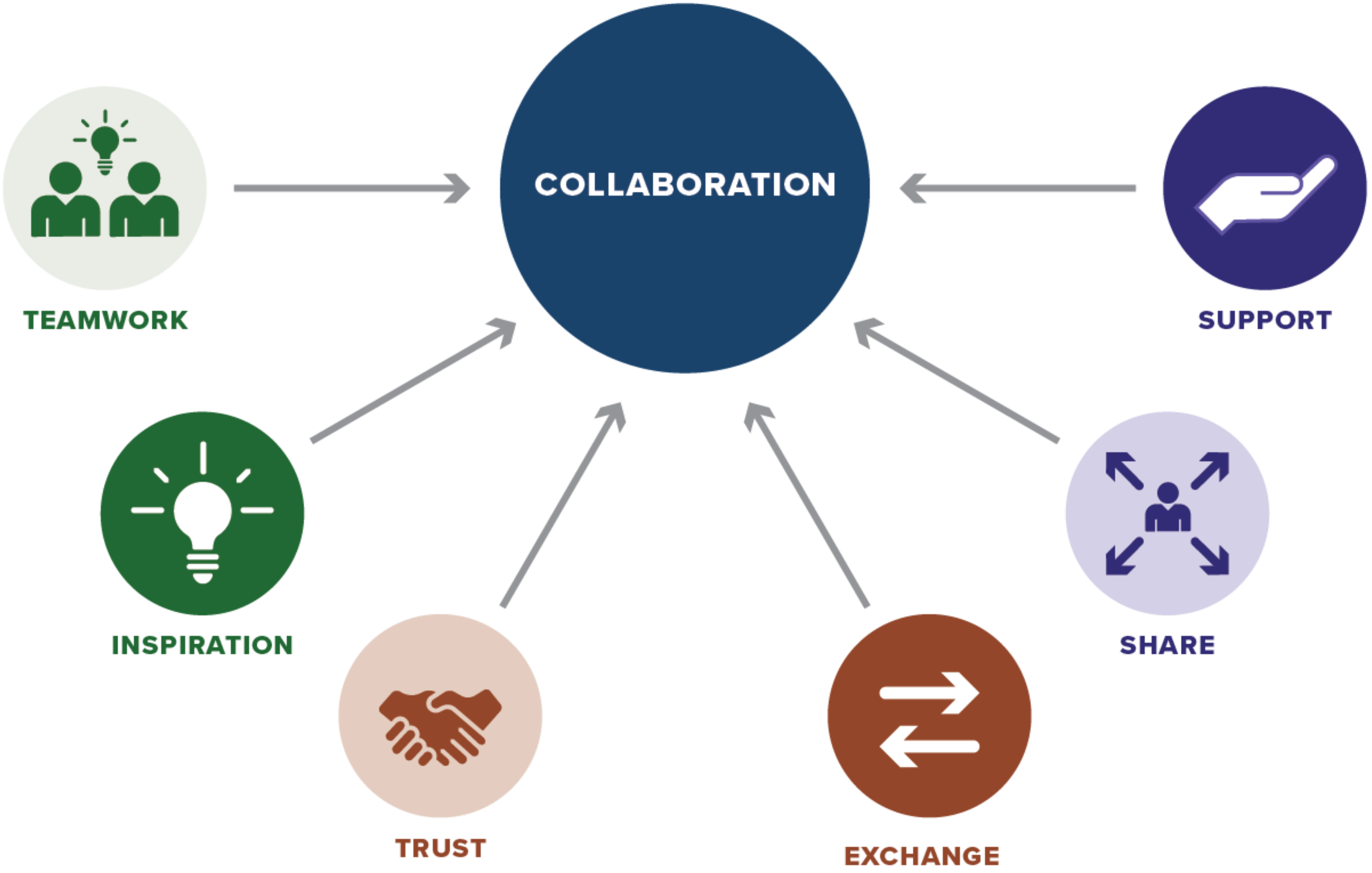
- Plan for development, training, recruitment, and retention
- Establish good review and analysis capabilities



Source: FHWA.

Sample Actions (Collaboration)

- Establish formal process supported by MOUs
- Harmonize regional collaboration with best practices



MOU = memorandum of understanding

Source: FHWA.

Contact Information

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FEHR PEERS

Updates to the HCM: The 7th Edition

Dave Stanek, PE PTOE RSP1

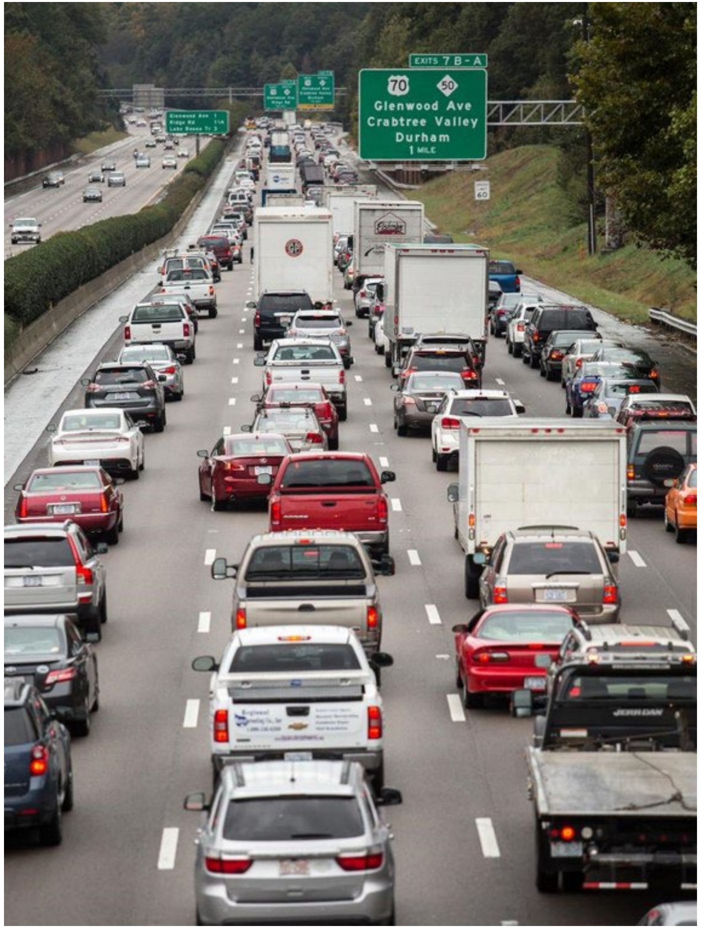
HCM 7TH EDITION

Highway Capacity Manual

What is it?

The HCM provides capacity analysis methods for multiple travel modes across different transportation facilities:

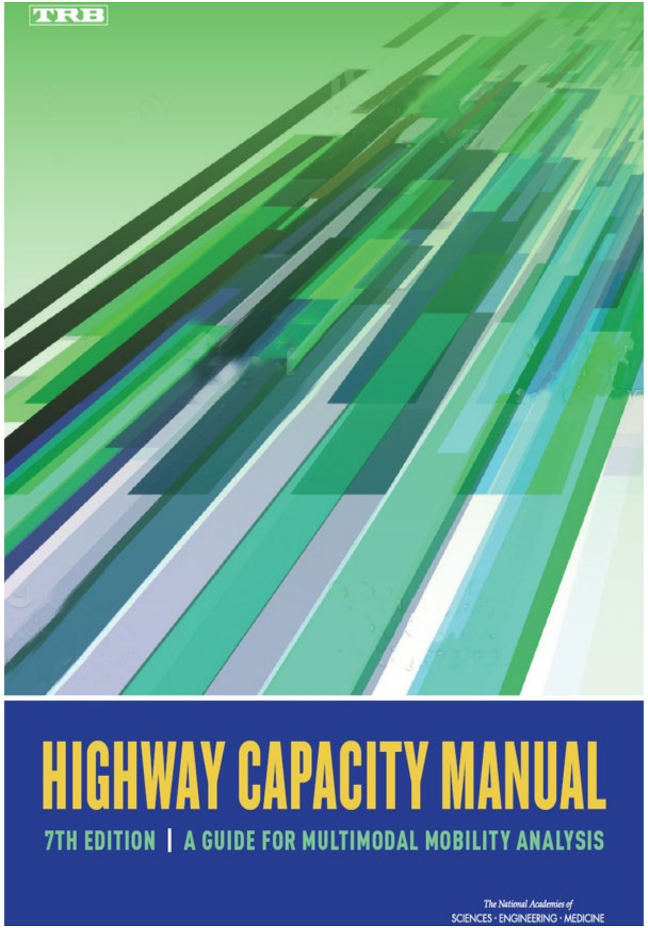
- Freeways and highways
- Urban streets
- Intersections and interchanges



7th Edition

What's new?

- Pedestrian delay
- CAV adjustment factors
- Two-lane highway method
- Network analysis method



Enhanced Pedestrian Volume Estimation and Evaluation Method

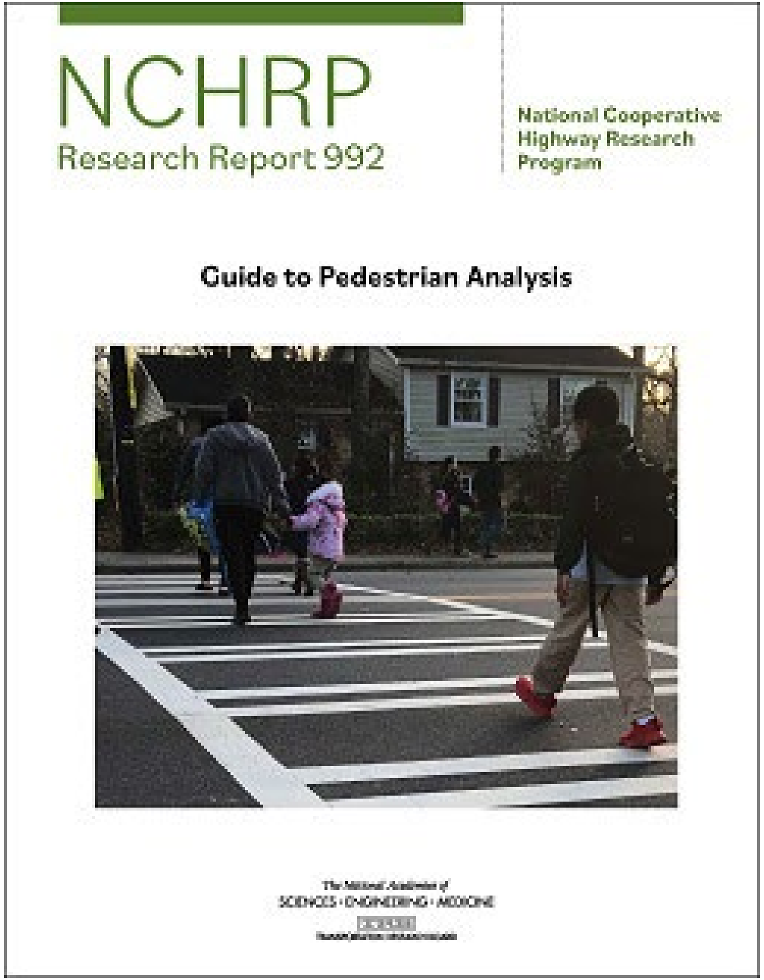
Research Source

NCHRP 17-87

Enhancing Pedestrian Volume Estimation and Developing HCM Pedestrian Methodologies for Safe and Sustainable Communities

HCM Chapter Updates

- Chapter 18 – Urban Street Segments
- Chapter 19 – Signalized Intersections
- Chapter 20 – TWSC Intersections
- Chapter 30 – Urban Street Segments: Supp
- Chapter 31 – Signalized Intersections: Supp
- Chapter 32 – SC Intersections: Supp



Uncontrolled Crossings (TWSC & Mid-block)

Current Method (HCM 6)

- LOS based on pedestrian delay
- LOS depends on:
  - Hourly traffic flow rate
  - Motorist yielding rate

Uncontrolled Crossings (TWSC & Mid-block)

New Method (HCM 7)

- ~~LOS based on pedestrian delay~~ LOS based on percentage (dis)satisfied pedestrians
- LOS depends on:
    - Hourly traffic flow rate
    - Motorist yielding rate
    - AADT
    - Specific crossing treatments (e.g. marked crosswalk, median island, RRFB)
- Delay still calculated and sensitive to the design pedestrian
- Corrections to HCM 6 motorist yielding procedure

Uncontrolled Crossings (TWSC & Mid-block)

New Method (HCM 7)

Exhibit 20-3: LOS Criteria: Pedestrian Mode

LOS	Condition	Comments
A	$P_D < 0.05$	Nearly all pedestrians would be satisfied
B	$0.05 \le P_D < 0.15$	At least 85% of pedestrians would be satisfied
C	$0.15 \le P_D < 0.25$	Fewer than one-quarter of pedestrians would be dissatisfied
D	$0.25 \le P_D < 0.33$	Fewer than one-third of pedestrians would be dissatisfied
E	$0.33 \le P_D < 0.50$	Fewer than one-half of pedestrians would be dissatisfied
F	$P_D \ge 0.50$	The majority of pedestrians would be dissatisfied

Note: P_D = proportion of pedestrians giving a "dissatisfied" rating or worse.

Signalized Crossings

Current Method (HCM 6)

- Delay estimated for single-leg, single-stage crossing
- Guidance to sum delay results for multiple-leg crossings
- LOS based on “pedestrian LOS score”
- Corner and crosswalk circulation area calculated before delay & LOS

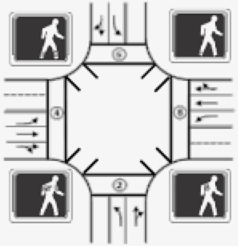
Signalized Crossings

New Method (HCM 7)

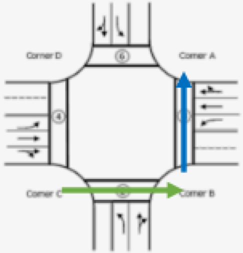
- ~~Delay estimated for single-leg, single-stage crossing~~ Delay also estimated for multiple-leg and multiple-stage crossings
- ~~Guidance to sum delay results for multiple-leg crossings~~ Delay calculation recognizes that second stage/leg arrival is not random
- LOS based on “pedestrian LOS score”
- Corner and crosswalk circulation ~~area calculated before delay & LOS~~ are optional calculation steps

Signalized Crossings

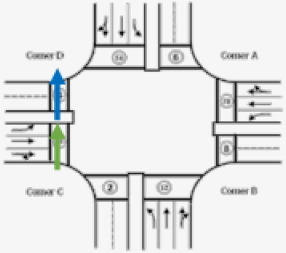
New Method (HCM 7) – Multiple-leg and multiple-stage crossings



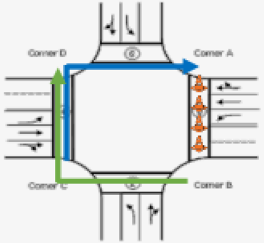
Barnes dance / pedestrian scramble



Two-leg crossing



Two-stage crossing with median refuge

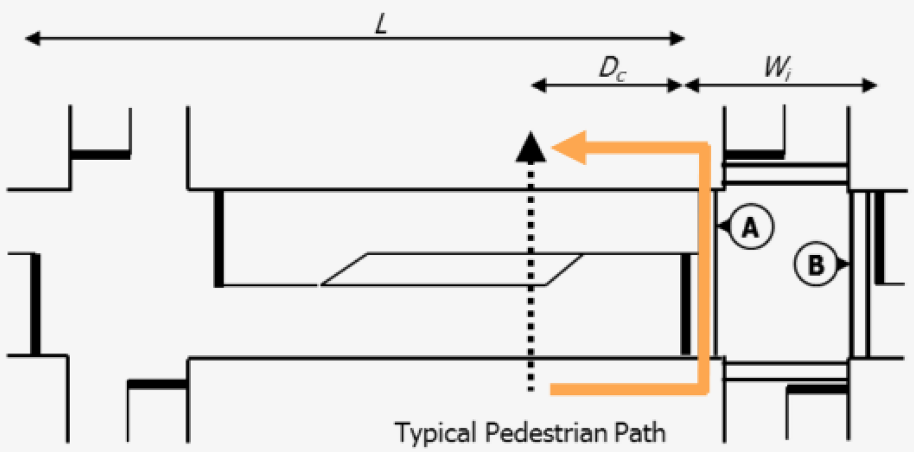


Crosswalk closure (three-leg crossing)

Urban Street

Current Method (HCM 6)

- Segment pedestrian LOS influenced by ease of crossing the urban street between signalized intersections
- Current method has little sensitivity to diversion length

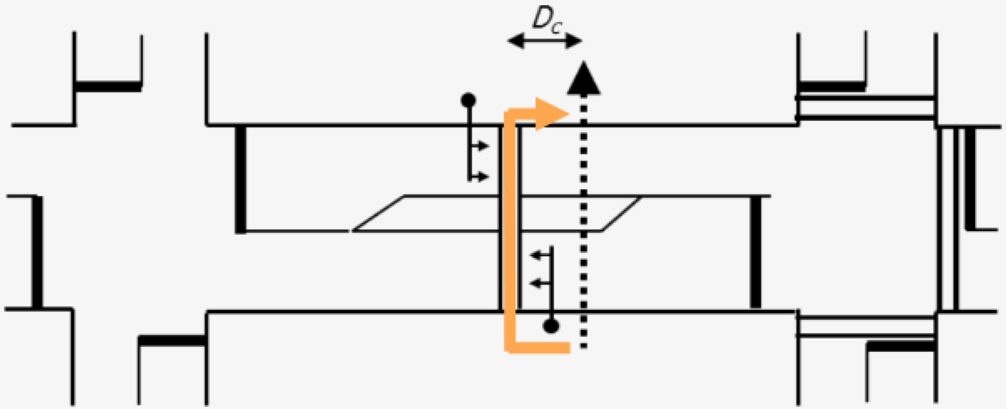


(a) Divert to Nearest Boundary Intersection

Urban Street

New Method (HCM 7)

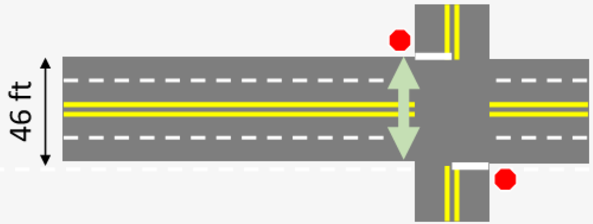
- Segment pedestrian LOS influenced by ease of crossing the urban street between signalized intersections
- ~~Current method has little sensitivity to diversion length~~ Increased sensitivity to diversion length



(b) Divert to Midsegment Signalized Crosswalk

Example: Uncontrolled Intersection

1,700 veh/h (peak hour), D = 0.50, AADT = 21,250, average pedestrian



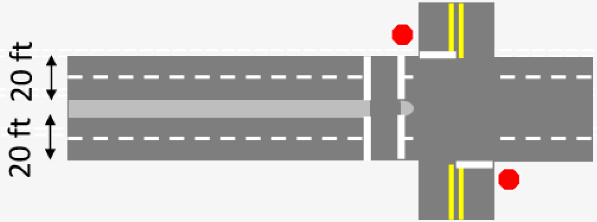
Existing:

- Local yielding rate = 0%
- P(delayed crossing) = 99.7%, average delay >> 60 s
- P(dissatisfaction) = 86.2% → LOS = F

Pedestrian Level of Service				
Flow (ped/hr)	1	1		
Two-Stage Crossing	No	No		
Pedestrian Platooning	No	No		
Conflicting Vehicular Flow (veh/h)	1700	1700		
Average Delay (s)	760.6	760.6		
Prob. of Non-Delayed Crossing, P_{nd}	0.003	0.003		
Level of Service (LOS)	F	F		

 HCS™ TWSC Version 2022 TWSC2_A-PedCrossUnmarkedNoMedRefuge.xtw Generated: 5/11/2022 10:11:12 AM

Example: Uncontrolled Intersection



Marked crosswalk + median island:

- Local yielding rate = 50%
- P(delayed crossing) = 76%, average delay = 6 s
- P(dissatisfaction) = 21% → LOS = C

Pedestrian Level of Service				
Flow (ped/hr)	1	1		
Two-Stage Crossing	Yes	Yes		
Pedestrian Platooning	No	No		
Conflicting Vehicular Flow (veh/h)	1700	1700		
Average Delay (s)	6.0	6.0		
Prob. of Non-Delayed Crossing, P_{nd}	0.481	0.481		
Level of Service (LOS)	C	C		

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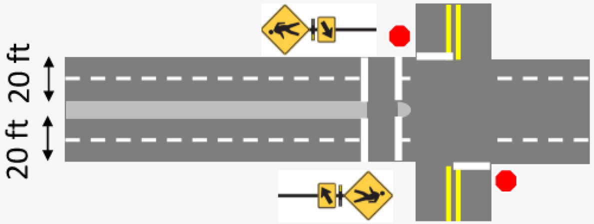
Example: Uncontrolled Intersection



Marked crosswalk + median island + RRFB:

- Local yielding rate = 80%
- P(delayed crossing) = 76%, average delay = 3 s
- P(dissatisfaction) = 3% → LOS = A

Pedestrian Level of Service				
Flow (ped/hr)	1	1		
Two-Stage Crossing	Yes	Yes		
Pedestrian Platooning	No	No		
Conflicting Vehicular Flow (veh/h)	1700	1700		
Average Delay (s)	2.9	2.9		
Prob. of Non-Delayed Crossing, P_{nd}	0.670	0.670		
Level of Service (LOS)	A	A		

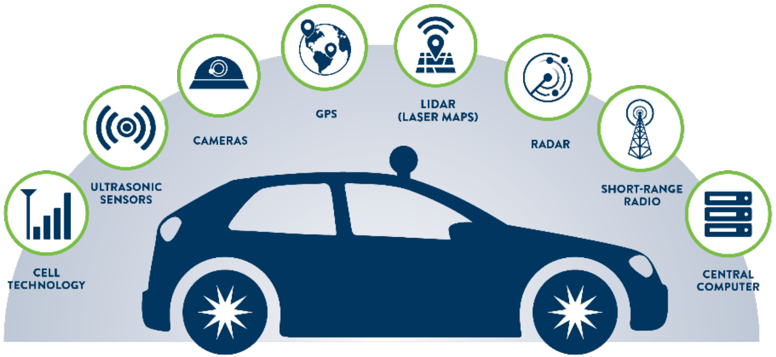
 HCS™ TWSC Version 2022 TWSC2_C-PedCrossMarkedMedRefugeRRFB.xtw Generated: 5/11/2022 10:16:04 AM

Capacity Impact for Connected and Automated Vehicles (CAVs)

What are CAVs?

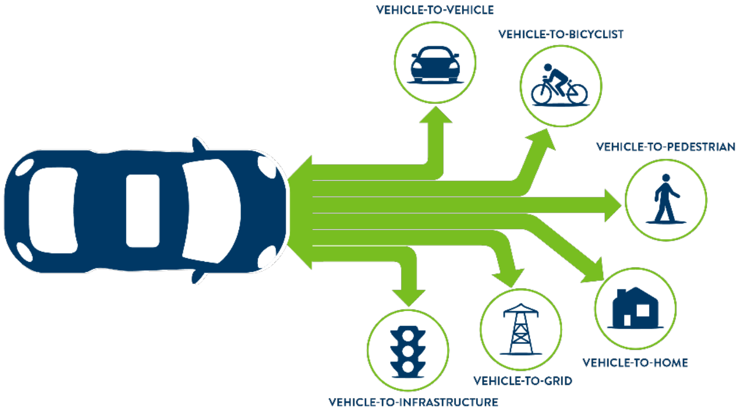
Automated Vehicles (AV)

Steer, accelerate, and brake with little to no human input



Connected Vehicles (CV)

Communicate with each other, traffic signals, signs, and other road items, or obtain data from the cloud



Why CAVs?

Increased safety

Greater mobility and equity

Economic and workforce development

Maximize health and environment

Efficiency

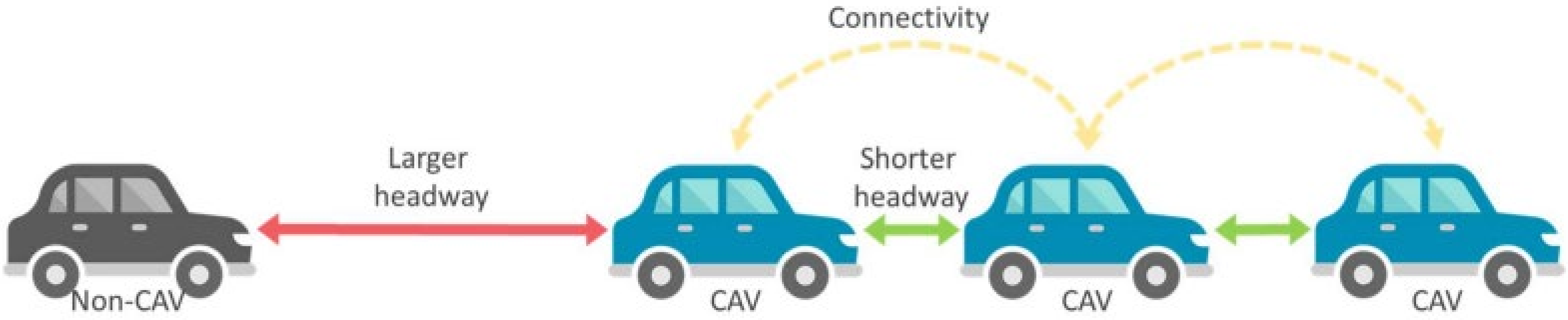
CAVs' Traffic Impact

Capacity Adjustment Factors (CAFs)

Given a market penetration rate of CAVs, what percent increase in capacity can be expected?

Service Volume Tables

Given a market penetration rate of CAVs, what hourly and/or daily service volumes are achievable for planning applications?



CAVs as NEW Content in HCM 7

Chapter 26
Freeway and Highway Segments: Supplemental

Chapter 31
Signalized Intersections: Supplemental

Chapter 33
Roundabouts: Supplemental

CHAPTER 26
FREEWAY AND HIGHWAY SEGMENTS: SUPPLEMENTAL

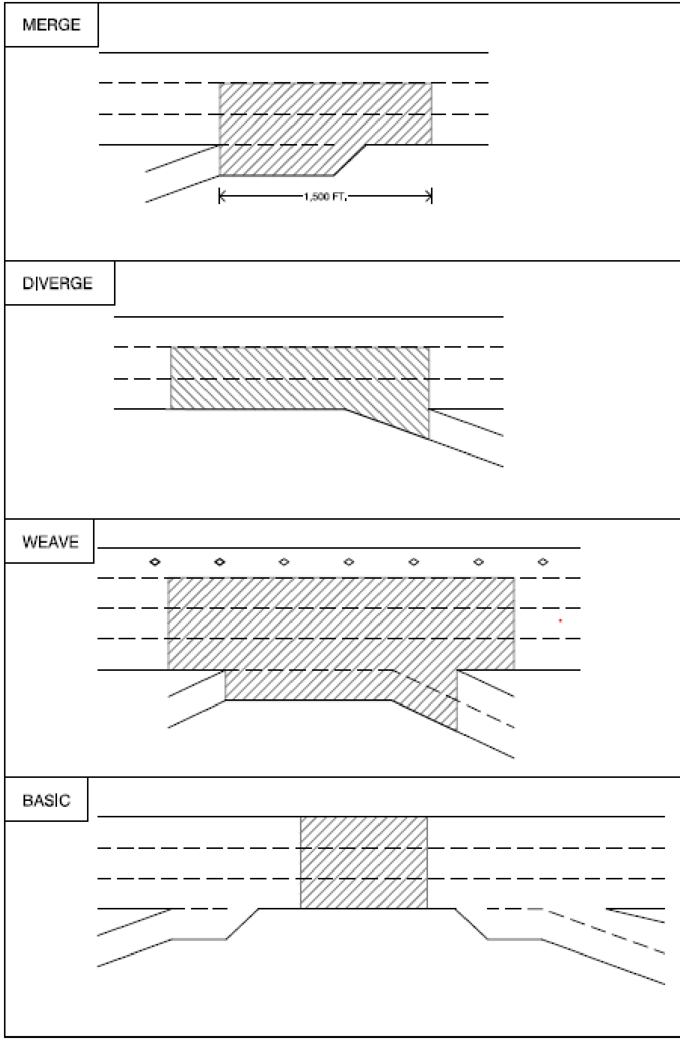
HCM 7

CONTENTS

Chapter 26 - Freeways

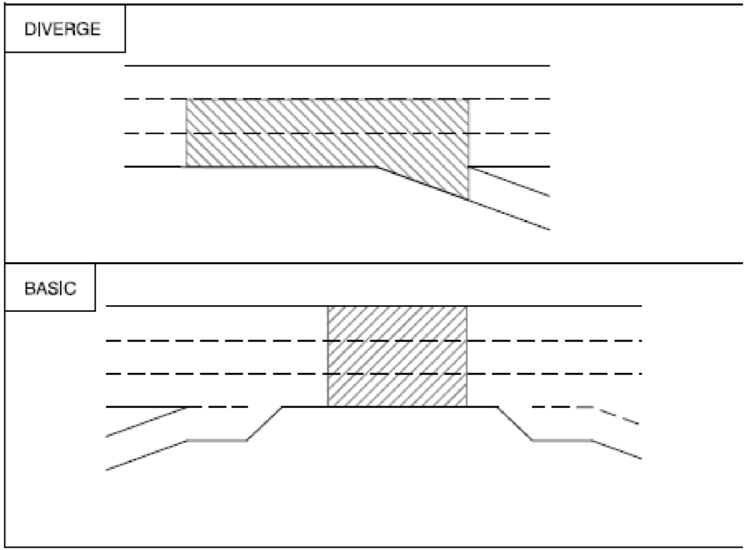
User Input

- Market Penetration (0% - 100%): What % of the traffic stream is comprised of CAVs?
- Studied Conditions
    - ✓ Basic Freeway Segments
    - ✓ Merge, Diverge, and Weaving
    - ✓ Service Volume Table – Daily & Hourly
- Unstudied Conditions
    - Managed Lane Segments
    - Oversaturated Conditions
    - CAV trucks



Chapter 26 - Freeways

Capacity Adjustment Factors (CAFs)



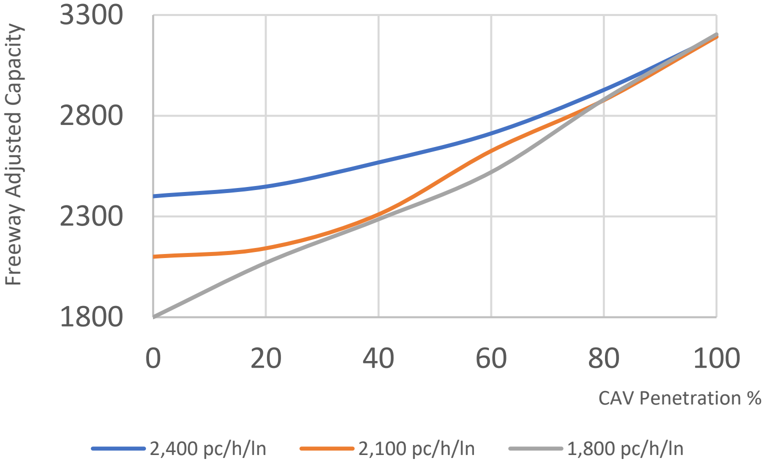
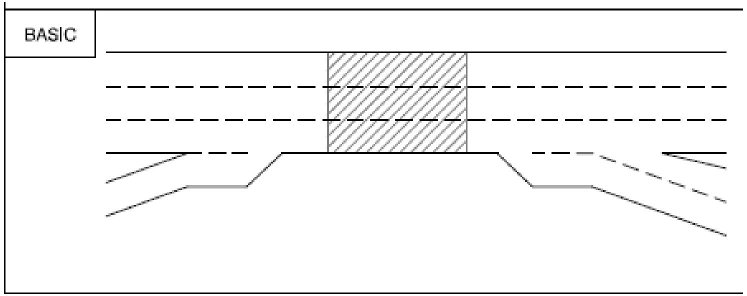


Exhibit 26-15: Capacity Adjustment Factors for CAVs for Basic Freeway and Freeway Diverge Segments

Proportion of CAVs in Traffic Stream	Adjusted Segment Capacity		
	2,400 pc/h/ln	2,100 pc/h/ln	1,800 pc/h/ln
0	1.00	1.00	1.00
20	1.02	1.02	1.15
40	1.07	1.10	1.27
60	1.13	1.25	1.40
80	1.22	1.37	1.60
100	1.33	1.52	1.78

Chapter 26 - Freeways

Service Volume Table



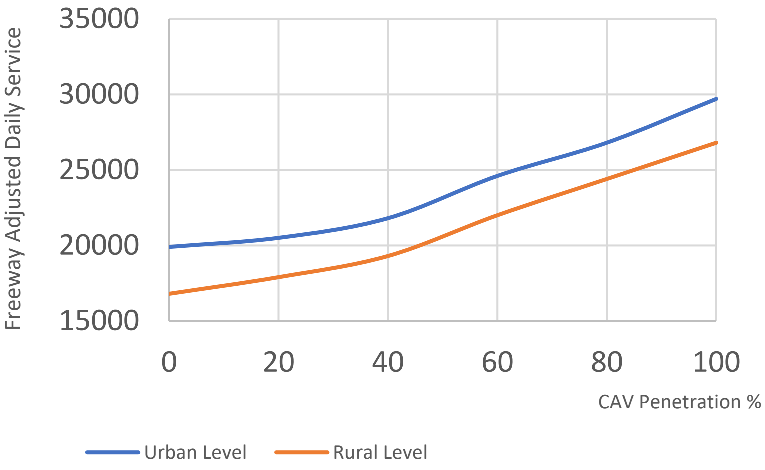


Exhibit 26-18: Daily Maximum Service Volumes for Basic Freeway Segments with CAV Presence (2-way veh/day/ln)

		Proportion of CAVs in Traffic Stream					
Area Type	Terrain	0%	20%	40%	60%	80%	100%
Urban	Level	19,900	20,500	21,800	24,600	26,800	29,700
Urban	Rolling	19,000	19,900	21,400	24,500	26,800	29,700
Rural	Level	16,800	17,900	19,300	22,000	24,400	26,800
Rural	Rolling	15,200	17,200	19,100	21,600	24,400	26,800

Chapter 31 – Signalized Intersections

User Input

- Market Penetration (0% - 100%): What % of the traffic stream is comprised of CAVs?
- Studied Conditions
  - ✓ Thru Movements
  - ✓ Protected Turns
  - ✓ Permitted Left-Turns

FEHR & PEERS

Chapter 31 – Signalized Intersections

Capacity Adjustment

- Due to the reduced headways as a result of CAV presence, the saturation flow rate increases
  - ✓ Thru Movements
  - ✓ Protected Turns
  - ✓ Permitted Left-Turns

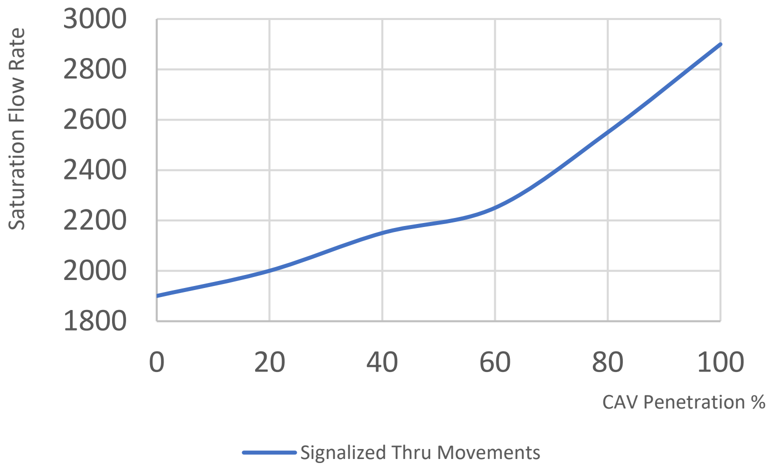


Exhibit 31-64: Base Saturation Flow Rates for CAVs for Through Movements at Signalized Intersections

Proportion of CAVs in Traffic Stream	Base Saturation Flow Rate (pc/h/ln)
0	1,900
20	2,000
40	2,150
60	2,250
80	2,550
100	2,900

Chapter 31 – Signalized Intersections

Service Volume Table

Exhibit 31-67: Illustrative Generalized Service Volume LOS E Thresholds for Signalized Intersections with CAV Presence (veh/h)

Through Movement g/C Ratio	No. of Through Lanes	Proportion of CAVs in Traffic Stream					
		0	20	40	60	80	100
0.40	1	800	840	910	950	1,070	1,220
	2	1,550	1,630	1,750	1,840	2,080	2,370
	3	2,000	2,110	2,260	2,370	2,680	3,050
0.45	1	910	960	1,030	1,080	1,220	1,390
	2	1,740	1,830	1,970	2,060	2,340	2,660
	3	2,250	2,370	2,550	2,660	3,020	3,430
0.50	1	1,020	1,070	1,150	1,210	1,370	1,560
	2	1,930	2,030	2,180	2,290	2,590	2,950
	3	2,500	2,630	2,830	2,960	3,360	3,820

Chapter 33 – Roundabouts

User Input

- Market Penetration (0% - 100%): What % of the traffic stream is comprised of CAVs?
- Studied Conditions
  - ✓ One-lane roundabout
  - ✓ Two-lane roundabout

Exhibit 33-12: Roundabout Entry Lane Capacity Model Parameters (without CAVs)

Entry Lane Type	*A*	*B*
One-lane entry conflicted by one circulating lane	1,380	1.02×10^{-3}
Two-lane entry conflicted by one circulating lane (both entry lanes)	1,420	0.91×10^{-3}
One-lane entry conflicted by two circulating lanes	1,420	0.85×10^{-3}
Two-lane entry conflicting by two circulating lanes (right entry lane)	1,420	0.85×10^{-3}
Two-lane entry conflicting by two circulating lanes (left entry lane)	1,350	0.92×10^{-3}

Equation 33-1:

$$c_{e,pce} = Ae^{-Bv_{c,pce}}$$

$v_{c,pce}$ = conflicting flow rate (pc/h).

	Lane		Lanes[a]		Lane, Both Lanes[a]		Lanes, Left Lane		Lanes, Right Lane	
	f_A	f_B	f_A	f_B	f_A	f_B	f_A	f_B	f_A	f_B
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.05	0.99	1.03	0.99	1.05	0.99	1.03	0.99	1.05	0.96
40	1.12	0.97	1.08	0.96	1.12	0.97	1.08	0.96	1.12	0.93
60	1.22	0.94	1.18	0.92	1.22	0.94	1.18	0.92	1.20	0.87
80	1.29	0.90	1.28	0.89	1.29	0.90	1.28	0.89	1.27	0.84
100	1.35	0.85	1.38	0.85	1.35	0.85	1.38	0.85	1.34	0.80

Equation 33-2:

$$c_{e,adj,pce} = f_A Ae^{-f_B Bv_{c,pce}}$$

$v_{c,pce}$ = conflicting flow rate (pc/h).

Questions to Think About

Given that CAV technology and regulation is still in development, assumptions necessarily have to be made when estimating CAVs' potential capacity benefit.

- Legal or regulatory requirements
- Liability concerns
- Passenger lack of trust concerns
- Mechanical differences

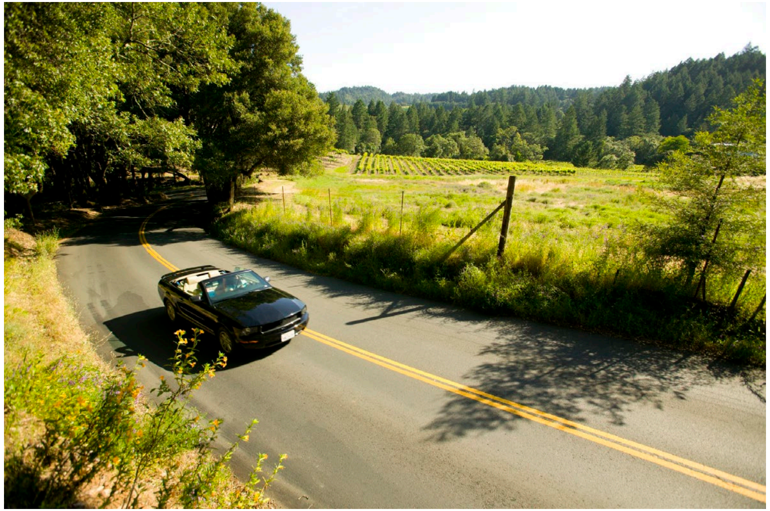
Two-Lane Highway Analysis Revised Procedure

FEHR PEERS

Introduction

Why is two-lane highway analysis important?

- A vast majority of highways in the US are two-lane
- Traffic increases on facilities due to development and shipping
- Widening projects are expensive



General Characteristics

What are key factors to think about for two-lane highways?

- Higher interaction between vehicles traveling in the same direction (Platooning)
- Maintain desired speed passing slower vehicles

Segmentation

HCM 6th Methodology	HCM 7th Methodology
None - % passing zones and length of passing lanes are provided	Segment Types: Passing Constrained, Passing Zone, Passing/Climbing Lane

Segment by – homogeneous traffic demand, grade, lane and shoulder widths, posted speed limit.

Service Measures

HCM 6th Methodology	HCM 7th Methodology
Average Travel Speed (ATS) – mi/h Percent Time Spent Following (PTSF) - % Percent Free Flow Speed (PFFS)- %	Follower Density - followers/mi/ln Number of vehicles in follower state per mile per lane.

LOS	Class I Highways ATS (mi/h)	Class I Highways PTSF (%)	Class II Highways PTSF (%)	Class III Highways PFFS (%)
A	>55	≤35	≤40	>91.7
B	>50–55	>35–50	>40–55	>83.3–91.7
C	>45–50	>50–65	>55–70	>75.0–83.3
D	>40–45	>65–80	>70–85	>66.7–75.0
E	≤40	>80	>85	≤66.7
F	Demand exceeds capacity			

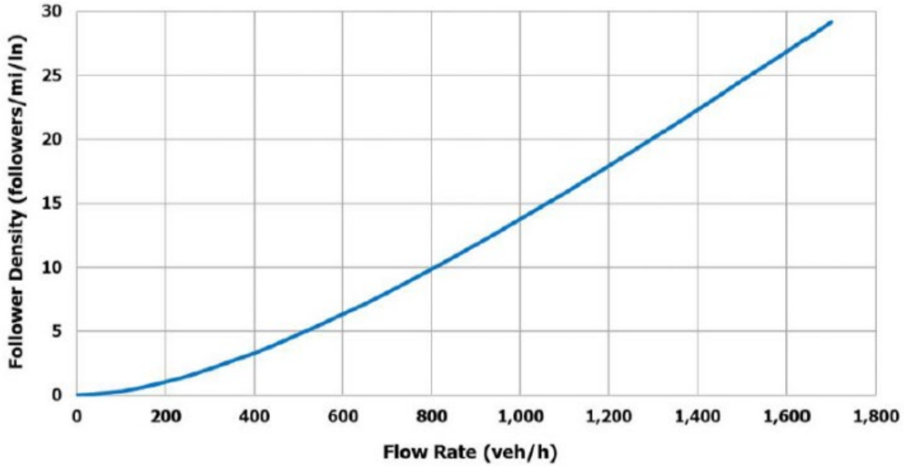
Note: For Class I highways, LOS is determined by the worse of ATS-based LOS and PTSF-based LOS.

LOS	Follower Density (followers/mi/ln) Higher-Speed Highways Posted Speed Limit ≥ 50 mi/h	Follower Density (followers/mi/ln) Lower-Speed Highways Posted Speed Limit < 50 mi/h
A	≤ 2.0	≤ 2.5
B	> 2.0 – 4.0	> 2.5 – 5.0
C	> 4.0 – 8.0	> 5.0 – 10.0
D	> 8.0 – 12.0	> 10.0 – 15.0
E	> 12.0	> 15.0
F	Demand exceeds capacity	

Follower Density

LOS	Follower Density (followers/mi/ln) Higher-Speed Highways Posted Speed Limit ≥ 50 mi/h	Lower-Speed Highways Posted Speed Limit < 50 mi/h
A	≤ 2.0	≤ 2.5
B	> 2.0 – 4.0	> 2.5 – 5.0
C	> 4.0 – 8.0	> 5.0 – 10.0
D	> 8.0 – 12.0	> 10.0 – 15.0
E	> 12.0	> 15.0
F	Demand exceeds capacity	

Exhibit 15-4: Follower Density Versus Directional Flow Rate



Classification

HCM 6th Methodology	HCM 7th Methodology
• Class I, Class II, Class III	• Two different sets of service measure thresholds based on posted speed limit

Class I - High speeds, commuter routes, intercity routes, serves long trips

(a) Examples of Class I Two-Lane Highways

Class II - Not expected to travel high speed, scenic routes, serves shorter trips

(b) Examples of Class II Two-Lane Highways

Class III - Moderately developed area, serves local traffic mixes

(c) Examples of Class III Two-Lane Highways

Percent Followers

Who is a follower?

2.5 s or less headway

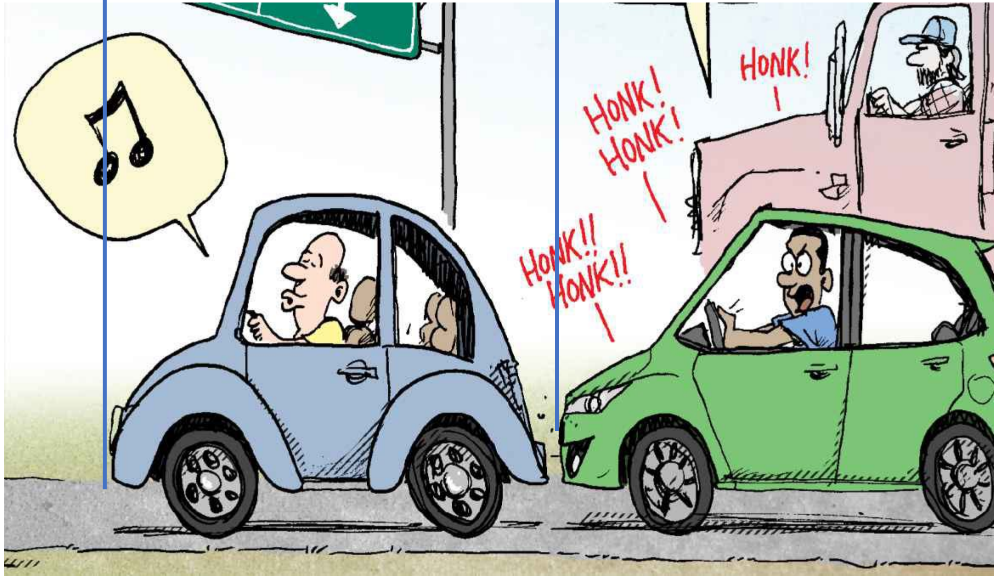
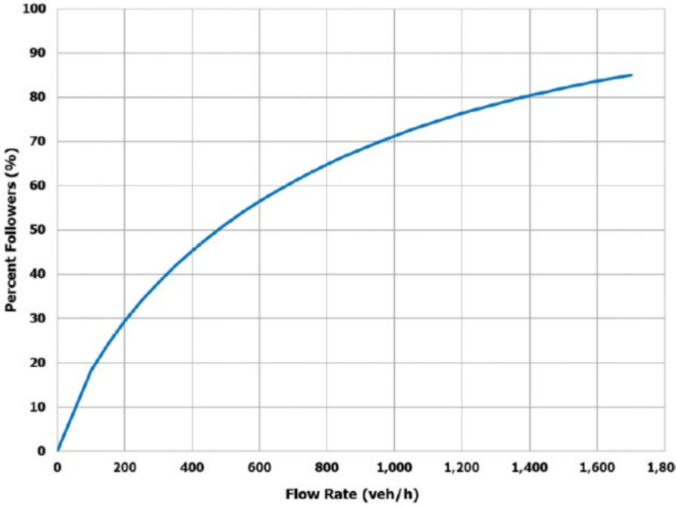
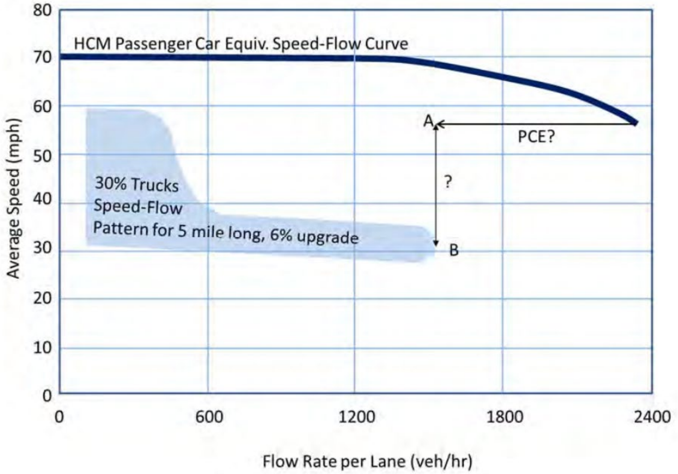


Exhibit 15-3: Percent Followers Versus Directional Flow Rate



Heavy Vehicles

HCM 6th Methodology	HCM 7th Methodology
• Passenger Car Equivalents (PCEs); thus, flow rate in pc/h • PCEs differ by service measure (Speed, PTSF) • Not a function of % trucks • Originally iterative approach due to units • Do not properly account for moderate to steep grades	• % HV as a direct input for performance measures • Flow rate as veh/h



Alignment

	HCM 6th Methodology	HCM 7th Methodology
Vertical	• PCEs for level, rolling, specific • Separate grade adjustment factor for both ATS and PTSF	• 5 vertical classifications on segment length and slope % (both upgrade and downgrade)
Horizontal	• Not considered	• 5 horizontal classifications, based on curve radius and superelevation %

Exhibit 15-11: Classifications for Vertical Alignment (Downgrades in Parentheses)

Segment Length (mi)	Segment Percent Grade (%) ≤1	>1 ≤2	>2 ≤3	>3 ≤4	>4 ≤5	>5 ≤6	>6 ≤7	>7 ≤8	>8 ≤9	>9
≤0.1	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	2 (1)	2 (2)	2 (2)
>0.1 ≤0.2	1 (1)	1 (1)	1 (1)	1 (1)	2 (1)	2 (2)	2 (2)	3 (2)	3 (3)	3 (3)
>0.2 ≤0.3	1 (1)	1 (1)	1 (1)	2 (1)	2 (2)	3 (2)	3 (3)	4 (3)	4 (4)	5 (5)
>0.3 ≤0.4	1 (1)	1 (1)	2 (1)	2 (2)	3 (2)	3 (3)	4 (4)	5 (4)	5 (5)	5 (5)
>0.4 ≤0.5	1 (1)	1 (1)	2 (1)	2 (2)	3 (3)	4 (3)	5 (4)	5 (5)	5 (5)	5 (5)
>0.5 ≤0.6	1 (1)	1 (1)	2 (1)	3 (2)	3 (3)	4 (4)	5 (5)	5 (5)	5 (5)	5 (5)
>0.6 ≤0.7	1 (1)	1 (1)	2 (1)	3 (2)	4 (3)	4 (4)	5 (5)	5 (5)	5 (5)	5 (5)
>0.7 ≤0.8	1 (1)	1 (1)	2 (1)	3 (3)	4 (4)	5 (4)	5 (5)	5 (5)	5 (5)	5 (5)
>0.8 ≤0.9	1 (1)	1 (1)	2 (1)	3 (3)	4 (4)	5 (5)	5 (5)	5 (5)	5 (5)	5 (5)

Exhibit 15-22: Horizontal Alignment Classifications

Radius (ft)	Superelevation (%) <1	≥1 <2	≥2 <3	≥3 <4	≥4 <5	≥5 <6	≥6 <7	≥7 <8	≥8 <9	≥9 <10	≥10
<300	5	5	5	5	5	5	5	5	5	5	5
300–449	4	4	4	4	4	4	4	4	4	4	4
450–599	4	3	3	3	3	3	3	3	3	3	3
600–749	3	3	3	3	3	3	2	2	2	2	2
750–899	2	2	2	2	2	2	2	2	2	2	2
900–1,049	2	2	2	2	2	2	2	2	1	1	1
1,050–1,199	2	2	2	2	1	1	1	1	1	1	1
1,200–1,349	2	2	1	1	1	1	1	1	1	1	1
1,350–1,499	1	1	1	1	1	1	1	1	1	1	—
1,500–1,649	1	1	1	1	1	1	1	1	—	—	—
1,650–1,799	1	1	1	1	1	1	—	—	—	—	—
1,800–1,949	1	1	1	1	1	—	—	—	—	—	—
1,950–2,099	1	1	1	1	—	—	—	—	—	—	—
2,100–2,249	1	1	1	—	—	—	—	—	—	—	—
2,250–2,399	1	1	—	—	—	—	—	—	—	—	—
2,400–2,549	1	—	—	—	—	—	—	—	—	—	—
≥2550	—	—	—	—	—	—	—	—	—	—	—

Note: — means that the curve does not restrict speeds and can be treated as a tangent section.

Capacity

HCM 6th Methodology	HCM 7th Methodology
• 1,700 pc/h	• Passing Zone and Passing Constrained Segments - 1,700 veh/h • Passing Lane Segment - Lower values due to merging friction - Function of %HV and vertical classification

Exhibit 15-5: Maximum Flow Rates for Passing Lane Segments

Heavy Vehicle Percentage (%)	Maximum Flow Rate (veh/h) by Vertical Class				
	1	2	3	4	5
< 5	1,500	1,500	1,500	1,500	1,500
≥ 5 < 10	1,500	1,500	1,500	1,500	1,400
≥ 10 < 15	1,400	1,400	1,400	1,300	1,300
≥ 15 < 20	1,300	1,300	1,300	1,300	1,200
≥ 20 < 25	1,300	1,300	1,300	1,200	1,100
≥ 25	1,100	1,100	1,100	1,100	1,100

Note: Capacity is governed by merge point at end of passing lane segment.

Base Free-Flow Speed

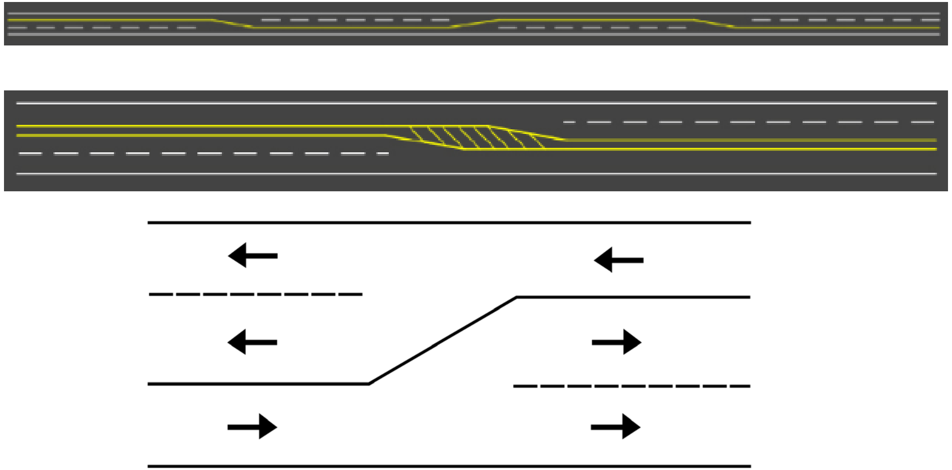
HCM 6th Methodology	HCM 7th Methodology
• No specific guidance	• Can be estimated based on posted speed

Equation 15-2:

$$BFFS = 1.14 \times S_{pl}$$

2+1 Configuration

HCM 6th Methodology	HCM 7th Methodology
• Not considered	• Initial material for estimating performance



Facility Scope

HCM 6th Methodology	HCM 7th Methodology
• Not considered • Essentially single segment analysis, but with additional step for adjusting performance due to upstream passing lane	• Facility LOS based on length-weighted aggregation of segment follower density values

Equation 15-39:

$$FD_F = \frac{\sum_{i=1}^{n} FD_i \times L_i}{\sum_{i=1}^{n} L_i}$$

Methodology Ease of Use Issues

- None of the lookup tables require interpolation: HCM 6th tables, many adjustment factors required interpolation (for some 2-way and 3 way)
- Treating trucks explicitly, rather than through PCE values
- No separate grade adjustment factor, which also varied by service measure
- No '%No-Passing Zones' input; Location and length of passing zones explicitly accounted for
- Elimination of the PTSF measure, which was difficult if not impossible to measure accurately in the field

New Network Analysis Method

FEHR & PEERS

Network Analysis

Objective

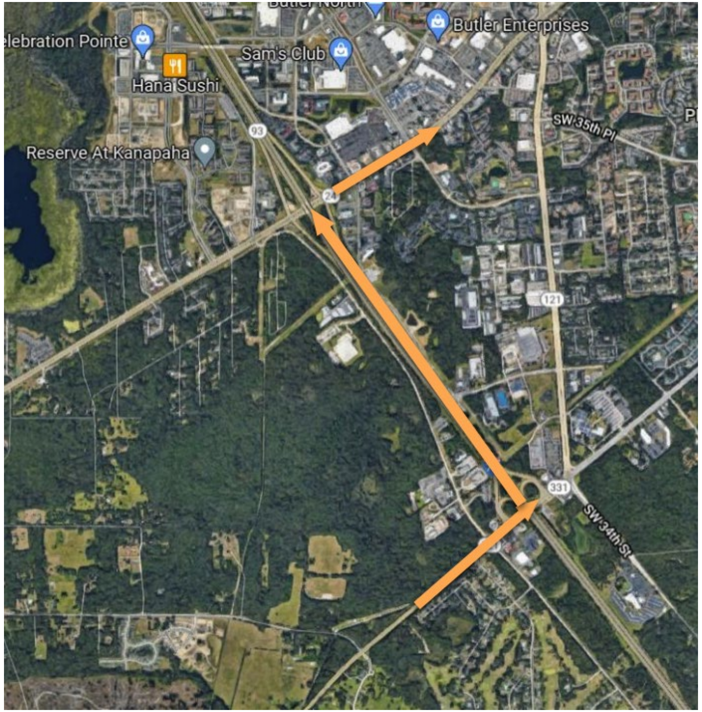
- Evaluate performance measures of corridors with freeways and arterial facilities

Facility	Performance measure
Freeway Segments	Density (pc/mi)
Signalized Intersections	Control delay (s)
Unsignalized Intersections	Control delay (s)
Urban Streets Facilities	Speed (mph)
Interchanges	Experienced travel time (s)

HCM 7th Edition

Chapter 38

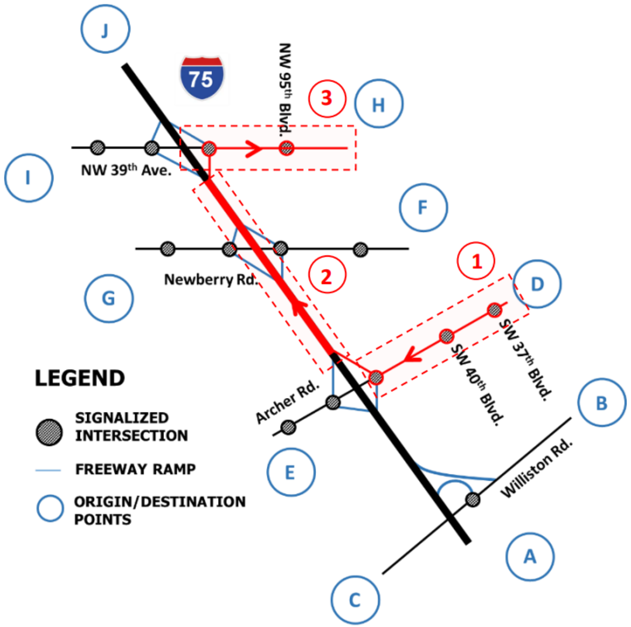
- Evaluate spillback between arterials and freeways
- Estimate travel time across facilities
- Conduct lane-by-lane analysis for freeways



Analyzing Corridor with Freeways and Streets

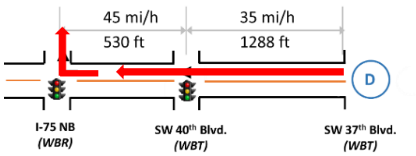
Sample Network Analysis

How to analyze a trip from D to H?

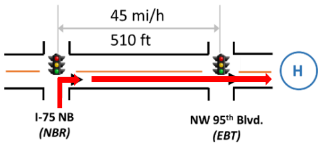


- HCM 6 current method – analyze three different facilities:

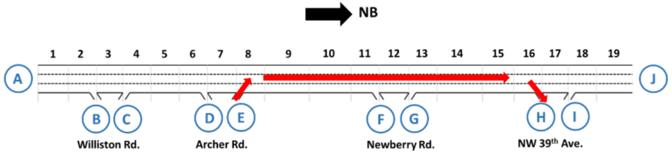
Facility 1: Urban Street



Facility 3: Urban Street



Facility 2: Freeway



Analyzing Corridor with Freeways and Streets

New Method

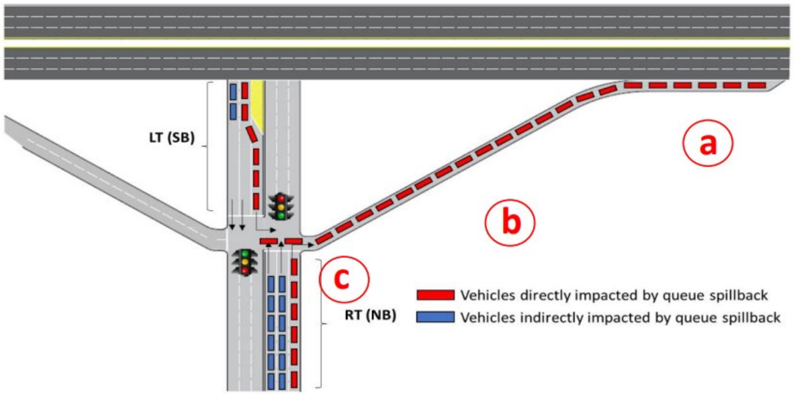
- HCM 7 New Method – Integrates analyses and overcomes limitations:
  - Travel time as common performance measure
  - Congestion propagation at interchanges (queue spillback)
  - Lane selection at freeway depending on O-D
  - Travel time at freeway ramps

Queue Spillback Analysis

Freeway On-ramps

Occurs when:

- Insufficient capacity at:
  - Freeway merge*
  - Ramp meter or
  - Ramp roadway
- Insufficient storage length at the on-ramp;



* Reduced merge capacity only for oversaturated conditions at the freeway (LOS F)

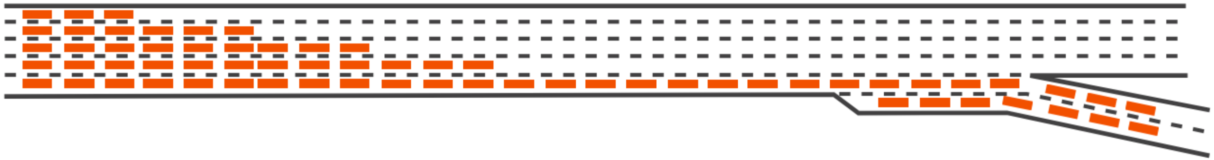
User Inputs:

- Available queue storage at the on-ramp (ft)
- Ramp metering rate, if applicable (veh/h)
- Intersection and freeway inputs per current HCM

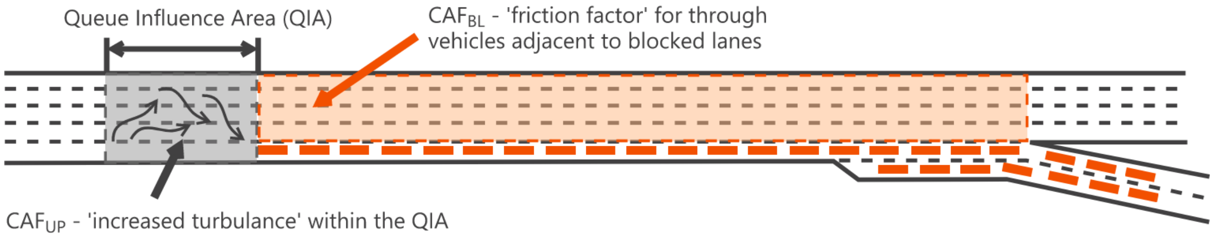
Queue Spillback Analysis

Freeway Off-ramps

Freeway impact is more localized close to exit and spreads further upstream:



Capacity Adjustment Factors – Modeling framework:

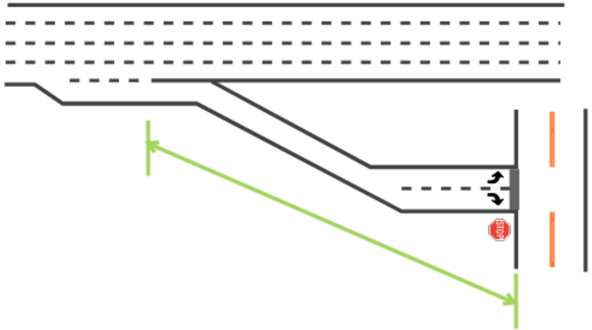


Queue Spillback Analysis

Freeway Off-ramps

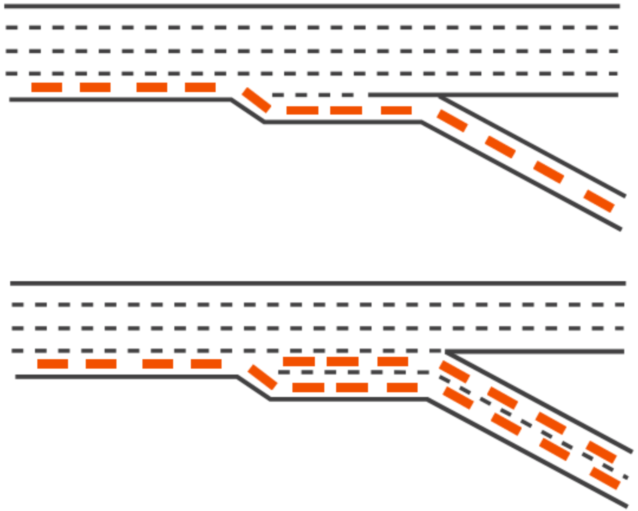
User Inputs:

- Available queue storage at the off-ramp (ft)



- Queue spillback regime

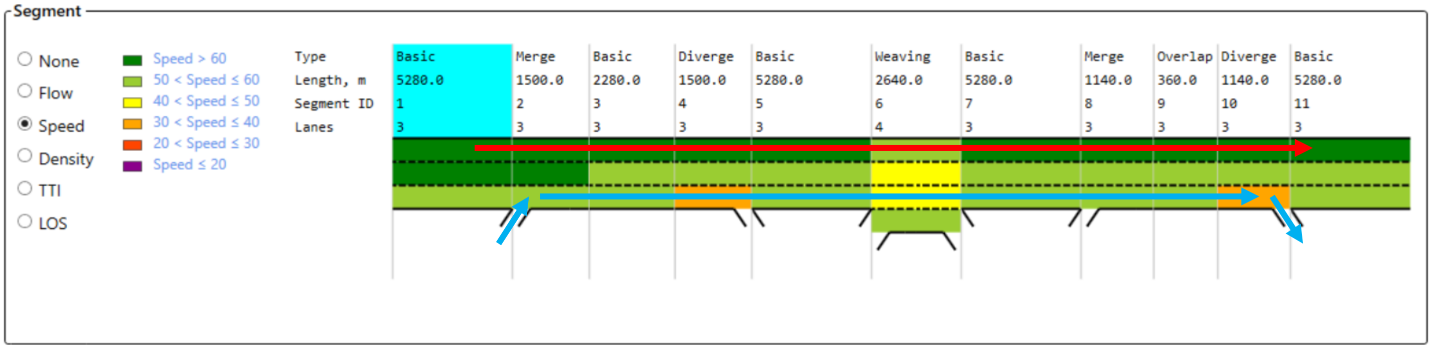
Queue extends through one or two mainline lanes?



New Lane-by-lane Analysis

Freeways

- Instrumental to analyze O-D based travel times – affects lane choice
- Estimation of capacity and speeds for individual lanes
- Flow distribution for individual lanes as function of:
    - Segment and ramp flow rate;
    - Percent grade;
    - Nearby ramps;
    - Number of lanes



Analyzing Corridor with Freeways and Streets

Sample Network Analysis

HCM 6 - Current methods

LOS F

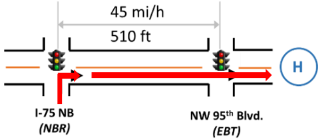
TT = 60 s

Facility 1: Urban Street

LOS E

TT = 45 s

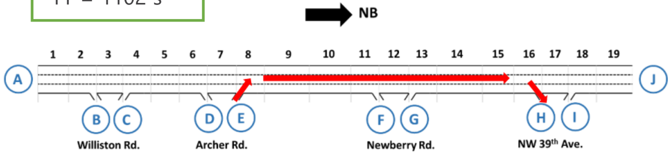
Facility 3: Urban Street



LOS D

TT = 1102 s

Facility 2: Freeway

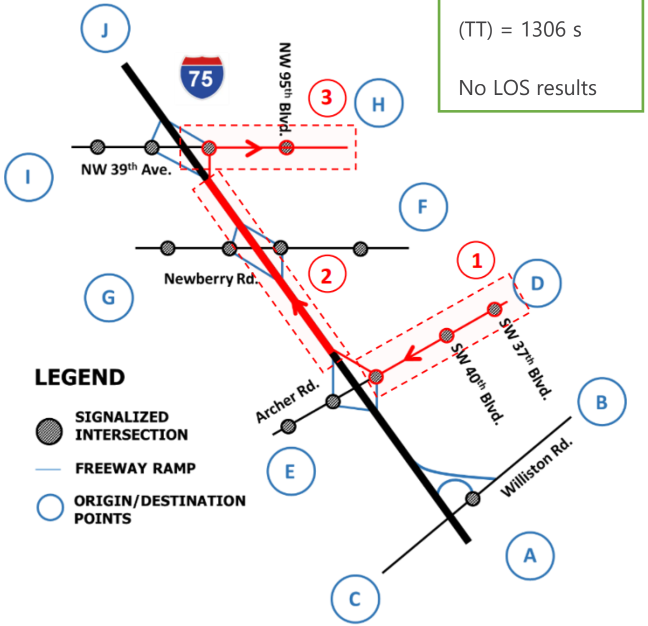


HCM 7 – New method

O-D Travel Time

(TT) = 1306 s

No LOS results



Addressing Long Routes

TT > 15 mins

HCM 6 — Current methods

HCM 7 — New method

Facility Type	Facility Name	Segment ID	HCM 6 Segment Travel time (s) Analysis Period 1	HCM 6 Segment Travel time (s) Analysis Period 2	HCM 6 Cumulative travel time (s)	HCM 7 Segment Travel time (s) Analysis Period 1	HCM 7 Segment Travel time (s) Analysis Period 2	HCM 7 Cumulative travel time (s)
Urban Street	Archer Rd. WB	SW 37th - SW 40th	34	28	34	34	28	34
		SW 40th - I-75 WB	26	29	60	26	29	60
Freeway	I-75 NB	On-ramp	~~73~~	86	133	73	86	133
		8	245	341	378	245	341	378
		9	185	189	563	185	189	563
		10	60	65	623	60	65	623
		11	122	116	745	122	116	745
		12	130	137	875	130	137	875
		13	55	52	930	55	52	930
		14	185	178	1115	185	178	1108
		15	70	68	1185	70	68	1176
		16	50	46	1235	50	46	1222
		Off-ramp	~~26~~	29	1261	26	29	1251
Urban Street	NW 39th Ave. EB	I-75 NB - NW 95th	45	55	1306	45	55	1306
		Total travel time (s):			**1207**			**1306**

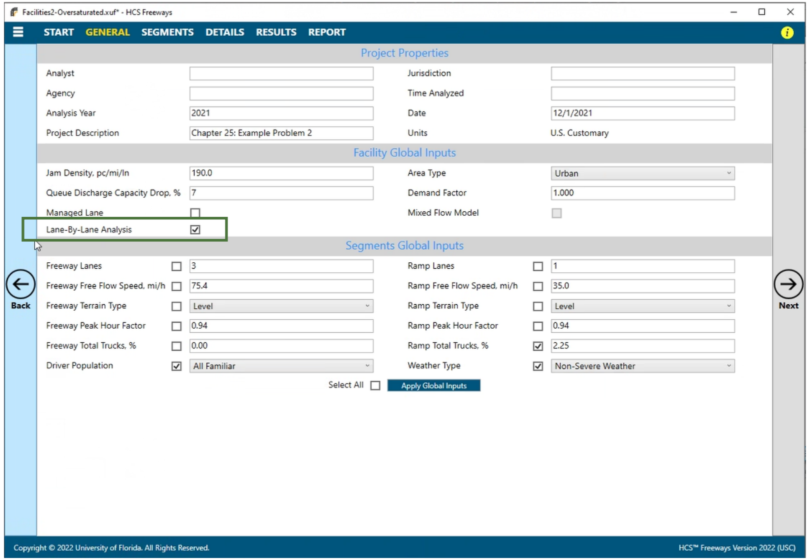
On-ramp travel time

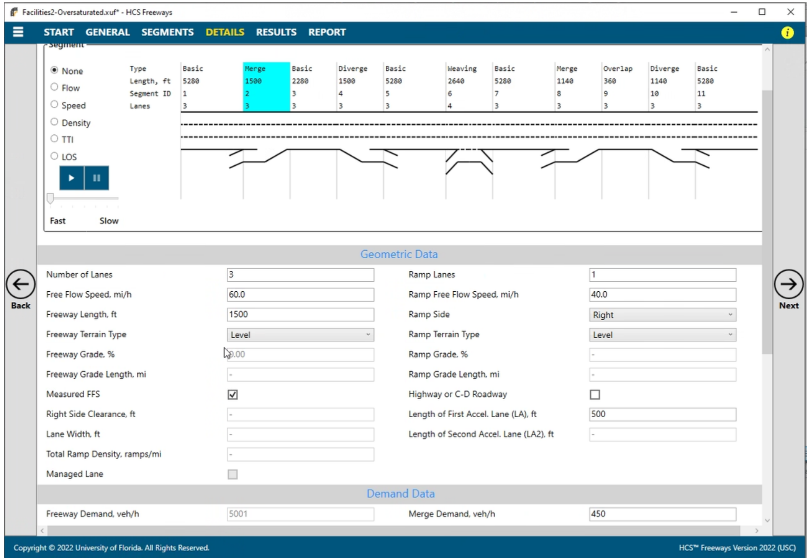
Lane selection

Off-ramp travel time

HCS Tools

Update: Lane-by-lane analysis





Limitation: Doesn't generate the total travel time directly

Resources

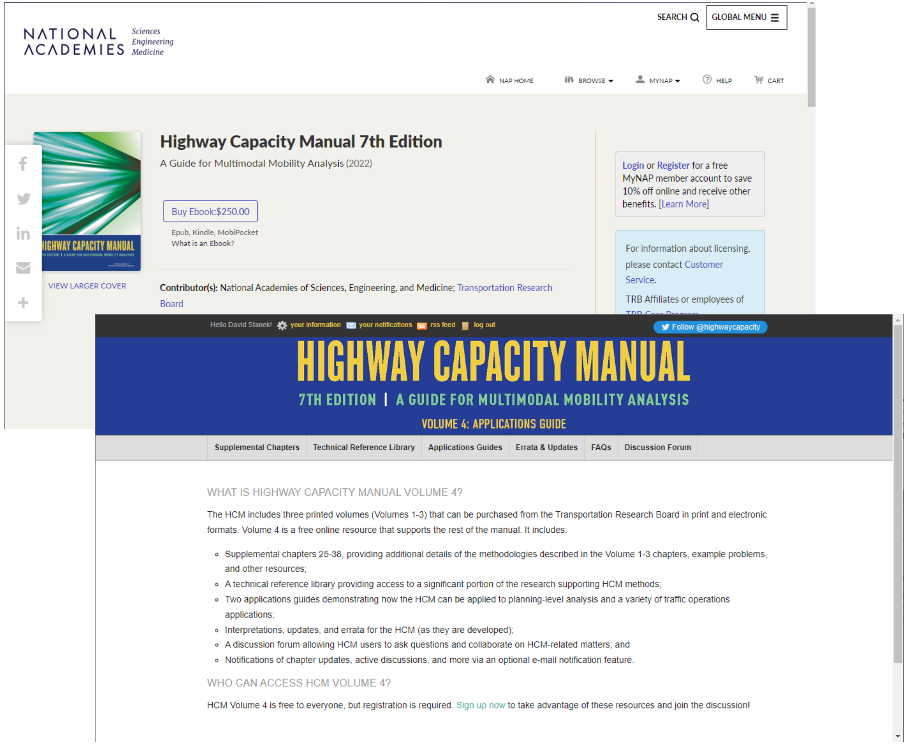
Where can I find it?

HCM 7 can be purchased from TRB

- Electronic and print versions
- Volume 4 is online: hcmvolume4.org
- HCQS TRB Committee: hcqstrb.org

Software applications

- HCS 2022
- Vistro 2022



Q&A

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