Instructors

- Paul Ryus, P.E.
  - Principal Engineer, Kittelson & Associates, Inc.
  - Reston, VA / Svendborg, Denmark
- Radu Nan, P.E.
  - Senior Engineer, Kittelson & Associates, Inc.
  - Boston, MA

Workshop Overview

- Introductions, need for the HCM 6th Edition
- Travel time reliability analysis
- Break
- New freeway analysis methods, freeway case studies
- Alternative intersection and interchange analysis
- Lunch
- Updated urban street analysis methods
- HCM Volume 4
- Break
- Planning & Preliminary Engineering Applications Guide
- Wrap-up, discussion, additional questions, evaluation

Attendee Introductions

- Name
- Organization
- Experience with/common uses of the HCM
- Key questions for today

A Brief History of the HCM

- 1950: focus on capacity
- 1965: LOS concept, bus transit chapter
- 1985: new research, pedestrians, bicycles
  - 1994 & 1997 updates
- 2000: new research, multiple parts
- 2010: new research, multimodal focus, four volumes

The Need for New Research

- Changes in driver behavior
- Changes in vehicle fleet mix & capabilities
- Increasing use of certain roadway features in the U.S.
  - Roundabouts, alternative intersections, managed lanes
- Greater methodological sensitivity to factors influencing roadway performance
- Broader range of performance measures (e.g., reliability)
National Research Since HCM 2010

- NCFRP 41: truck analysis
- NCHRP 03-96: managed lanes
- NCHRP 03-100: roundabouts in corridors
- NCHRP 03-107: work zone capacity
- NCHRP 03-115: HCM production
- NCHRP 07-22: planning guide to HCM
- SHRP 2 L08: travel time reliability
- FHWA: ATDM, roundabouts, alternative intersections


- Published in October 2016

Highway Capacity Manual: A Guide for Multimodal Mobility Analysis

- Providing mobility for people and goods is transportation’s most essential function. It consists of four dimensions:
  - Quantity of travel
  - Quality of travel
  - Accessibility
  - Capacity
- Users of the roadway system include motorists, freight shippers, pedestrians, bicyclists, and passengers in transit vehicles
  - HCM methods address all these modes

HCM 6th Edition

- Previous HCM editions have had a year attached
- Looking forward, it is likely that chapters will continue to be released or updated as new research is completed, rather than waiting for a critical mass to accumulate
  - Two-lane highway update
  - Advances in ATDM
  - Connected and autonomous vehicles
- Each chapter has its own version number, allowing chapters to be updated independently

Growth in HCM Content

- Number of Pages

HCM 6: Not Much Different on the Outside...

- Printed HCM
- Online
  - Volume 1: Concepts
  - Volume 2: Uninterrupted Flow
  - Volume 3: Interrupted Flow
  - Volume 4: Applications Guide
...But Significant Changes on the Inside

- New Chapters 11 and 17 on travel time reliability
- Basic freeway segment and multilane highway methods combined
- Many new and updated methods
  - Managed lanes, work zones, alternative intersections and interchanges, urban street queue spillback, truck effects on freeway operations, and more
- Greater focus on providing the information users need to apply HCM methods in software and to interpret analysis results

The Need for Understanding Hasn’t Changed

- Using software to implement HCM methods doesn’t diminish the analyst’s responsibility to understand how a method works and to interpret its results
- Furthermore, a subset of HCM users still requires step-by-step instructions
  - Researchers, software developers, students
- Changes to how the HCM presents information were required

Presentation Changes in the HCM 2010

- Significant changes were made in the HCM 2010
  - Core information provided in printed chapters
  - Supplemental, detailed information provided in online chapters
  - New material on using the HCM in conjunction with alternative tools such as simulation
  - Research basis for methods provided in Volume 4’s Technical Reference Library

Presentation Changes in the HCM Sixth Edition

- Additional changes have been made for the Sixth Edition
  - Standardized chapter outlines in Volumes 2 and 3
  - Summary tables listing data requirements, potential data sources, suggested default values, and sensitivity of results to inputs
  - Example results in many chapters
  - Example problems moved to Volume 4 and expanded to demonstrate new methods

Standardized Methodological Chapter Outline

- Introduction
- Concepts
- Core Motorized Vehicle Methodology
- Extensions to the Methodology*
- Mode-specific Methodologies*
- Applications

*if provided

Example Summary Data Table

- Required Data and Units
- Potential Data Source(s)
- Suggested Default Value

<table>
<thead>
<tr>
<th>Required Data and Units</th>
<th>Potential Data Source(s)</th>
<th>Suggested Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway class (I, II, III)</td>
<td>Design plans, analyst judgment</td>
<td>Must be provided</td>
</tr>
<tr>
<td>Lane width (ft)</td>
<td>Road inventory, aerial photo</td>
<td>12 ft</td>
</tr>
<tr>
<td>Shoulder width (ft)</td>
<td>Road inventory, aerial photo</td>
<td>6 ft</td>
</tr>
<tr>
<td>Access point density (access points/mi)</td>
<td>Field data, aerial photo</td>
<td>Class I and II: 8/mi, Class III: 16/mi</td>
</tr>
<tr>
<td>Terrain type (level, rolling, specific grade)</td>
<td>Design plans, analyst judgment</td>
<td>Must be provided</td>
</tr>
<tr>
<td>Percent no-passing zone (%)</td>
<td>Road inventory, aerial photo</td>
<td>Level: 20%, Rolling: 40%, More extreme: 80%</td>
</tr>
<tr>
<td>Free-flow speed (mi/h)</td>
<td>Field data, road inventory, aerial photo</td>
<td>Base free-flow speed: Speed limit + 10 mi/h (see discussion in text)</td>
</tr>
<tr>
<td>Passing lane length (mi)</td>
<td>Field data, road inventory, aerial photo</td>
<td>Must be provided</td>
</tr>
<tr>
<td>Average acceleration (ft/s²)</td>
<td>Field data, modeling</td>
<td>Must be provided</td>
</tr>
<tr>
<td>Average deceleration (ft/s²)</td>
<td>Field data, modeling</td>
<td>Must be provided</td>
</tr>
<tr>
<td>Percent peak hour factor (AM/PM)</td>
<td>Field data</td>
<td>0.88</td>
</tr>
<tr>
<td>Average vehicle composition (%)</td>
<td>Field data</td>
<td>70%</td>
</tr>
</tbody>
</table>
Example Results

- Many methodological chapters now provide example results
  - Demonstrate sensitivity of results to important inputs
  - Demonstrate potential range of results
  - Intended to answer many questions about whether a given result makes sense
- Not intended to substitute for an actual analysis

Companion Documents

- Highway Safety Manual
- AASHTO Green Book
- Transit Capacity and Quality of Service Manual
- Manual on Uniform Traffic Control Devices
- Traffic Analysis Toolbox

Why Measure Travel Time Reliability?

- Traditional HCM analyses report average conditions during the analysis hour
- Actual conditions may vary considerably from day to day—why?

TRAVEL TIME RELIABILITY ANALYSIS

Why Measure Travel Time Reliability?

- Traditional HCM performance measures may not fully capture what travelers experience and remember

Why Measure Travel Time Reliability?

- As it becomes more impractical to add capacity, operations techniques are becoming more widely used
  - Ramp metering, road patrols, variable speed limits, etc.
Why Measure Travel Time Reliability?

- Improvements in computing power and automated data collection now make it feasible to measure and forecast reliability
- Measuring reliability addresses the LOS F problem: Quantifying how travelers perceive operations after a facility breaks down

Travel Time Distribution

- A collection of travel time observations on a facility over an extended period of time (e.g., a month, a year)
- Once a travel time distribution has been developed, a variety of useful performance measures can be developed

Example Travel Time Distribution: All of February

Would you say this facility operates reliably?

Example Travel Time Distribution: February Weekdays, 6-9 a.m.

Same facility, shorter time period...
Would you say it operates reliably?

Reliability Reporting Periods

- The HCM uses the concept of reliability reporting periods to define the period of time that reliability performance measures are being reported for
- Examples:
  - All of February
  - All weekday AM peak periods in the year
  - All summer weekends and holidays

Reliability Reporting Periods

- Different reliability reporting periods have different uses
- Examples:
  - All of February or all of the year
  - Determining the free-flow speed (e.g., 5th percentile speed)
  - Freight movement reliability on a rural freeway
  - All weekday AM peak periods in the year
  - Commute trip reliability
  - All summer weekends and holidays
  - Reliability on a recreational route during the time of greatest use
Key Values from the Travel Time Distribution

- Free-flow TT (398 sec) = 5% TT from the all-of-February distribution
- Target TT @ 45 mph (518 sec)
- Mean TT (807 sec)
- 80th percentile TT (1,016 sec)
- 95th percentile TT (1,420 sec) = Planning Time
- Average of highest 5% of TTs (1,580 sec) = Misery Time
- 99th percentile TT (1,753 sec)

Cumulative Travel Time Distribution

Reliability Performance Measure Examples

- **Travel time index (TTI)**
  - The ratio of actual travel time to the free-flow travel time
  - Example: TTI of 2 means that it took twice as long to travel the facility than under free-flow conditions
  - Often reported as a percentile
    - 50th-percentile TTI (50th percentile travel time/free-flow time)
    - Mean TTI
    - 80th-percentile TTI (most sensitive to operations countermeasures)
    - 95th-percentile TTI (planning time index)

- **Level of travel time reliability (LOTTR)**
  - New FHWA measure for performance reporting
  - 80th-percentile travel time / 50th-percentile travel time
  - Value >1.50 indicates unreliable operations

- **Reliability rating**
  - Measure defined by the HCM
  - Percent of trips made at a specified TTI or less
  - Value >1.33 (freeways), >2.50 (urban streets) indicates that the facility has broken down or will likely break down

Reliability Performance Measure Examples

- **Buffer time**
  - Extra time to allow to arrive on time 95% of the time
  - (95th-percentile travel time) – (mean travel time)

- **On-time percentage**
  - Percent of trips made at or above a specified speed

- **Percent trips failing**
  - Percent of trips made below a specified speed

Reliability Performance Measure Examples

- **Vehicle hours of delay**
  - (Volume experiencing a particular travel time) × (experienced travel time in hours – threshold travel time), summed over all travel times exceeding the threshold
  - Threshold could be
    - Free-flow travel time
    - Travel time at the speed limit
    - Travel time at speed producing maximum throughput (capacity)
    - Travel time at a policy speed (e.g., 40 or 45 mph)
Your Turn

- Use the sorted travel times in the handout to determine the LOTTR for each 30-min time period
  - Hint: There are 20 travel time values for each time period, one for each weekday, so each value represents 5%
- For 8:00 a.m., also determine:
  - 95th percentile TTI
  - Buffer time
  - Reliability rating
  - On-time percentage based on 45 mph target (518 seconds)
- When do you think would be the worst time to make a trip on this facility, and why?

Analysis Results

<table>
<thead>
<tr>
<th>Time</th>
<th>6:00</th>
<th>6:30</th>
<th>7:00</th>
<th>7:30</th>
<th>8:00</th>
<th>8:30</th>
<th>9:00</th>
<th>9:30</th>
<th>10:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% TT</td>
<td>421</td>
<td>466</td>
<td>660</td>
<td>861</td>
<td>923</td>
<td>922</td>
<td>788</td>
<td>585</td>
<td>466</td>
</tr>
<tr>
<td>80% TT</td>
<td>427</td>
<td>540</td>
<td>806</td>
<td>1085</td>
<td>1190</td>
<td>1192</td>
<td>1021</td>
<td>727</td>
<td>574</td>
</tr>
<tr>
<td>LOTTR</td>
<td>1.01</td>
<td>1.16</td>
<td>1.22</td>
<td>1.23</td>
<td>1.37</td>
<td>1.44</td>
<td>1.59</td>
<td>1.75</td>
<td>1.80</td>
</tr>
<tr>
<td>95% TT</td>
<td>1.08</td>
<td>1.64</td>
<td>2.11</td>
<td>2.94</td>
<td>4.58</td>
<td>4.06</td>
<td>3.92</td>
<td>2.72</td>
<td>2.30</td>
</tr>
<tr>
<td>Avg TT</td>
<td>426</td>
<td>513</td>
<td>697</td>
<td>938</td>
<td>1080</td>
<td>1066</td>
<td>915</td>
<td>741</td>
<td>580</td>
</tr>
<tr>
<td>Buf Time</td>
<td>-6</td>
<td>142</td>
<td>166</td>
<td>252</td>
<td>770</td>
<td>574</td>
<td>627</td>
<td>385</td>
<td>289</td>
</tr>
<tr>
<td>RR</td>
<td>95%</td>
<td>75%</td>
<td>75%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>30%</td>
<td>35%</td>
<td>60%</td>
</tr>
<tr>
<td>OTP</td>
<td>95%</td>
<td>70%</td>
<td>55%</td>
<td>0%</td>
<td>5%</td>
<td>10%</td>
<td>35%</td>
<td>60%</td>
<td>60%</td>
</tr>
</tbody>
</table>

LOTTR = level of travel time reliability
TT = travel time (seconds)
TTI = travel time index (assumes the free-flow travel time = 398 seconds)
Buf Time = buffer time (seconds)
RR = reliability rating
OTP = on-time percentage (assumes a target 45-mph speed = 518 seconds)

Reliability Forecasting in the HCM

- New Chapter 11 (freeways), Chapter 17 (urban streets)
- Core HCM facility method is applied repeatedly with adjusted demands, capacities, geometry, and free-flow speeds to develop a travel time distribution
- Incorporates demand variation, weather, incident, work zone, and special event effects
- Process is automated in computational engines
  - FREEVAL
  - STREETVAL

Reliability Forecasting in the HCM: Demand Variation

- User inputs:
  - All inputs normally required for a facility analysis (seed file)
  - Reliability reporting period start/end times, days
  - Demand patterns expressed as demand multipliers relative to the seed file demands
    - Number of patterns determined by the user (e.g., by season, by month, with or without day-of-week variations)
    - Can be developed from local data or can use national defaults
- For each scenario (day) in the reliability reporting period, the method adjusts the seed file demand according to the pattern
Reliability Forecasting in the HCM: Severe Weather

- User inputs:
  - Nearest metropolitan area to study location
  - 10-year weather data available for 103 metro areas specifying frequency and duration by month of 10 types of severe weather
  - User can also provide a custom weather event distribution

- Method specifies capacity and free-flow speed reductions for each severe weather type

- For each scenario (day) in the reliability reporting period, the method randomly assigns the weather type and (if needed) a start time and duration

Reliability Forecasting in the HCM: Incidents

- User inputs:
  - Incident frequency and duration by type
    - Derived from complete crash/incident log data (ideal)
    - Facility-specific crash rate and incident-to-crash ratio (next best)
    - HERS model AADT-based crash rate and default ICR (also an option)

- Method specifies capacity, free-flow speed, and lane reductions for each incident type

- The method randomly assigns incidents, along with severity, start time, duration, and location along the facility

Reliability Forecasting in the HCM: Work Zones

- User inputs:
  - Scheduled work zone start/end times and days
  - Capacity, free-flow speed, demand, lane adjustments during work zone hours

- Method substitutes work zone conditions for normal conditions during work zone hours

- Non-scheduled work zones (e.g., pothole filling) best treated as incidents

- Special events input and modelled similarly to work zones

Reliability Forecasting in the HCM: ATDM

- Advanced traffic demand management (ATDM) strategies are modeled with respect to their impact on
  - Demand
  - Capacity and lane use
  - Free-flow speed
  - Incident frequency
  - Incident duration

Travel Time Reliability in the HCM: Summary

- The HCM 6th Edition defines a variety of useful performance measures for quantifying existing and forecasted travel time reliability

- Travel time reliability analysis can be used to forecast the effects of ATDM strategies on operations

- The HCM’s computational engines automate the reliability forecasting process
  - Once a core facility analysis is set up, not much additional effort required to perform a reliability analysis
Workshop Overview

- Introductions, need for the HCM 6th Edition
- Travel time reliability analysis
- Break
- New freeway analysis methods, freeway case studies
- Alternative intersection and interchange analysis
- Lunch
- Updated urban street analysis methods
- HCM Volume 4
- Break
- Planning & Preliminary Engineering Applications Guide
- Wrap-up, discussion, additional questions

HCM 6th Edition: New Freeway Analysis Capabilities

- Travel time reliability
- Unified speed–flow equation
- Work zone analysis
- Managed lane analysis
- New truck methodology
- New planning method
- ATDM effects
- Calibration guidance

HCM 6th Edition: Uninterrupted Flow Chapters

- Chapter 10: Freeway Facilities
- Chapter 11: Freeway Reliability Analysis
- Chapter 12: Basic Freeway and Multilane Highway Segments
- Chapter 13: Freeway Weaving Segments
- Chapter 14: Freeway Merge and Diverge Segments
- Chapter 15: Two-Lane Highways
- Chapter 25: Freeway Facilities: Supplemental
- Chapter 26: Freeway and Highway Segments: Supplemental
- Chapter 27: Freeway Weaving: Supplemental
- Chapter 28: Freeway Merges and Diverges: Supplemental

New Generic Speed–Flow Model

- One equation represents the relationship between speed and flow, regardless of the free flow speed (FFS)
  - No longer necessary to specify FFS in 5-mph increments
  - Facilitates reliability evaluation and model calibration through speed and capacity adjustment factors
  - Facilitates application of the method in software
- Speed–flow curve defined by
  - Free-flow speed
  - Breakpoint
  - Density at capacity
Speed–Flow Model

\[ S = \frac{FFS_{adj}}{(1 - \alpha_{wz})} \]

where

- \( S \) is the free-flow speed
- \( FFS_{adj} \) is the adjusted free-flow speed
- \( \alpha_{wz} \) is the percentage drop in pre-breakdown capacity under queuing conditions

Free-flow speed and capacity adjustment factors (CAF, SAF) used to reflect:
- Managed lane operations
- Work zone operations
- Severe weather conditions
- Effects of incidents
- Truck influences
- Driver population

Freeflow speed

Capacity and speed adjustment factors (CAF, SAF)

\[ c_{adj} = c \times CAF \]

\[ FFS_{adj} = FFS \times SAF \]

Freeway Work Zone Analysis

- Work zones can reduce the freeway’s capacity, FFS, or both, which in turn affects the speed–flow relationship
- HCM method calculates speed and capacity adjustment factors that are then used with the generic speed–flow curve

Lane Closure Severity Index (LCSI)

Considers both the percentage reduction in the number of lanes and the absolute number of lanes closed:

\[ \text{LCSI} = \frac{1}{(\text{Open Ratio} \times \text{number of open lanes})} \]

<table>
<thead>
<tr>
<th>Number of Total Lane(s)</th>
<th>Number of Open Lane(s)</th>
<th>Open Ratio</th>
<th>LCSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>1.00</td>
<td>0.33</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0.75</td>
<td>0.44</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0.67</td>
<td>0.75</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0.50</td>
<td>2.00</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0.33</td>
<td>3.00</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0.25</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Use for shoulder closures, lane shifts, and crossovers with no lane reduction

Work Zone Queue Discharge Rate

\[ QDR_{wz} = 2.093 - 154 \times LCSI - 194 \times f_{BR} - 179 \times f_{AT} + 9 \times f_{LAT} - 59 \times f_{DN} \]

- \( QDR_{wz} \) is the 15-min queue discharge rate (pc/h/ln)
- \( LCSI \) is the lane closure severity index
- \( f_{BR} \) is the barrier factor (hard = 0, drums/cones = 1)
- \( f_{AT} \) is the area type (urban = 0, rural = 1)
- \( f_{LAT} \) is the lateral distance from edge of travel lane to barrier (ft)
- \( f_{DN} \) is lighting (day = 0, night = 1)

Work Zone Capacity Adjustment Factor

\[ c = \frac{QDR_{wz} \times 100}{100 - \alpha_{wz}} \]

- \( c_{adj} \) is the pre-breakdown work zone capacity (pc/h/ln)
- \( \alpha_{wz} \) is the percentage drop in pre-breakdown capacity under queuing conditions (default = 13.4)

\[ CAR_{adj} = \frac{c_{adj}}{c} \]
Work Zone Free-Flow Speed

\[ FFS_{wz} = 9.95 + 33.49 \times f_D + 0.53 \times SL_{wz} - 5.60 \times LCSI - 3.84 \times f_{SR} - 1.71 \times f_{SR} - 8.7 \times TRD \]

- \( FFS_{wz} \) = work zone free-flow speed (mph)
- \( f_D \) = speed ratio (ratio of non-WZ speed limit to WZ speed limit)
- \( SL_{wz} \) = work zone speed limit (mph)
- \( TRD \) = total ramp density (ramps/mi), counted 3 mi upstream and 3 mi downstream from WZ center

\[ SA_{wz} = \frac{FFS_{wz}}{FFS} \]

Your Turn

- Paving project on rural freeway
  - Nighttime work
  - 2 lanes reduced to 1
  - 65-mph speed limit reduced to 50 mph
  - Plastic drums placed adjacent to lane stripe
  - Diamond interchange 2 miles downstream from WZ center
  - Free-flow speed = 70 mph (pre-construction)
  - Base capacity = 2,400 pc/h/ln

What is the CAF and SAF for this work zone?

Work Zone Queue Discharge Rate & CAF

\[ QDR_{wz} = 2,093 - 154 \times LCSI - 194 \times f_{SR} - 179 \times f_{SR} + 9 \times f_{SR} - 59 \times f_{SR} \]

\[ QDR_{wz} = 2,093 - 154 \times (2) - 194 \times (1) - 179 \times (1) + 9 \times (0) - 59 \times (1) \]

\[ QDR_{wz} = 1,353 \text{ pc/h/ln} \]

\[ c = \frac{QDR_{wz}}{100 - \alpha_{wz}} \times 100 = \frac{1,353}{100 - 13.4} \times 100 = 1,562 \text{ pc/h/ln} \]

<table>
<thead>
<tr>
<th>Number of Total Lane(s)</th>
<th>Number of Open Lane(s)</th>
<th>Open Ratio LCSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0.75</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0.75</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0.33</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0.25</td>
</tr>
</tbody>
</table>

\[ CA_{wz} = \frac{c_{wz}}{C} = \frac{1,562}{2,400} = 0.651 \]

\[ FFS_{wz} = 50.4 \text{ mph} \]

\[ CAF_{wz} = \frac{FFS_{wz}}{FFS} = \frac{50.4}{70} = 0.720 \]

Work Zone Analysis: Final Comments

- Example reflects a basic freeway segment
  - Chapter 25 (Freeway Facilities: Supplemental) provides guidance for merge, diverge, crossover, and weaving segments
- CAFs and SAFs can be combined
  - For example, work zone on a steep upgrade, with heavy rain and unfamiliar drivers
- Chapter 26 presents a method for two-lane highway work zones with alternating traffic
Managed Lanes

- The HCM 6th Edition can be used to analyze five types of managed lanes
  - Continuous access
  - Buffer (paint stripe) separation, 1 or 2 lanes
  - Barrier separation, 1 or 2 lanes

Managed Lane Segment Types

- Basic ML segments
  - Accounts for single-lane operation
  - Accounts for friction between managed and general-purpose lanes (Continuous access, Buffer 1)
- ML merge/diverge/weaving segments
  - Direct entries/exits to managed lanes
- ML access segments
  - Access/egress from/to GP lanes
  - Weaving to/from GP exits/entrances

Adjacent GP Lane Friction Effect

Managed Lane Capacities

- Managed lane capacities (or maximum observed flows) for different separation types

<table>
<thead>
<tr>
<th>FBS (mi/h)</th>
<th>Continuous Access</th>
<th>Buffer 1</th>
<th>Buffer 2</th>
<th>Barrier 1</th>
<th>Barrier 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>1,800</td>
<td>1,800</td>
<td>1,750</td>
<td>2,100</td>
<td>2,050</td>
</tr>
<tr>
<td>70</td>
<td>1,750</td>
<td>1,700</td>
<td>1,650</td>
<td>1,800</td>
<td>1,900</td>
</tr>
<tr>
<td>65</td>
<td>1,700</td>
<td>1,600</td>
<td>1,550</td>
<td>1,700</td>
<td>1,850</td>
</tr>
<tr>
<td>60</td>
<td>1,650</td>
<td>1,500</td>
<td>1,450</td>
<td>1,600</td>
<td>1,750</td>
</tr>
<tr>
<td>55</td>
<td>1,600</td>
<td>1,400</td>
<td>1,350</td>
<td>1,500</td>
<td>1,600</td>
</tr>
</tbody>
</table>

Why Analyze Freeways as Facilities?

Freeway Facilities (Chapter 10)

- New freeway work zone method
- New managed lanes method
- New research on truck effects on freeway operations
- Guidance on evaluating ATDM strategies (effects on average day operations)
- Improved guidance on segmenting freeways
- Guidance on matching section data from external databases to HCM segments
Freeway Facilities: Supplemental (Chapter 25)

- Calibrating core methodology to existing conditions using CAFs & SAFs
- Truck performance on composite grades
- Planning-level method for estimating freeway facility performance
- New example problems that demonstrate the new freeway facility capabilities

Freeway Reliability Analysis (Chapter 11)

- New chapter presenting travel time reliability performance measures and forecasting methods
- Extension to method allows analysis of individual ATDM strategies and packages of strategies
- Chapter 25 describes calibration procedure
- Chapter 37 provides guidance on evaluating specific ATDM strategies

FREEVAL Computational Engine

- Available on online HCM Volume 4
  - "Research grade" software
  - User guide available
  - Java-based: runs on any operating system
- Implements core freeway facility, reliability, and ATDM methods

FREEVAL Screenshot

Basic Freeway & Multilane Highway Segments (Ch. 12)

- Merges previous individual chapters on basic freeway segments and multilane highways
- Uses one unified speed–flow equation applicable to both freeway and multilane highway segments, but the forms of the curves are different

Freeway and Multilane Highway Segments

- Other changes include:
  - Revised truck PCE tables
  - Increased emphasis on calibration through capacity and speed adjustment factors (CAF and SAFs)
  - Driver population effects now handled by CAF and SAFs
- For multilane highways:
  - Density at capacity = 45 pc/mi/ln
  - Revised LOS E–F range to reflect revised density
  - New speed–flow curves for 65 and 70 mi/h highways
Freeway and Multilane Highway Segments

- Chapter 26 provides additional details:
  - Truck performance on extended (long and/or steep) grades
  - New method for measuring capacity in the field
  - Updated example problems

- Users guided to bicycle method in Chapter 15, Two-Lane Highways, for evaluating bicycle operations on multilane highways

Freeway Weaving (Chapter 13)

- Covers traditional weaving sections, managed lane weaving sections, and cross-weave effects in the general-purpose lanes

- Emphasis on the use of CAFs and SAFs for calibration

- Chapter 27 provides new example problems demonstrating the new capabilities

Freeway Merges and Diverges (Chapter 14)

- Addresses merges and diverges in both general purpose lanes and managed lanes

- New guidance on aggregating densities in segments with 3+ lanes

- Emphasis on the use of CAFs and SAFs for calibration

- Chapter 28 provides new example problems demonstrating the new capabilities

Case Study Overview

1. Major freeway work zone
   - Queuing impacts
   - Lane closure requirements
   - Identifying diversion targets

2. Work zone lane closure sensitivity
   - Setting allowable work hours
   - Queuing impacts

3. Ramp metering feasibility
   - Quantifying freeway congestion and whole-year reliability
   - Evaluating the temporal operation of ramp metering

Case Study 1: Major Freeway Work Zone—Raleigh, NC
Case Study 3: Ramp Metering Feasibility

- How does ramp metering affect the freeway congestion and whole-year reliability?
- How does the temporal operation of ramp metering impact congestion?

Impact on Representative Single-day Operations (AM Peak)

- Before
- After

Whole-Year Reliability Analysis

Impact of Temporal Operation of Ramp Meters on Reliability

Alternative Intersections and Interchanges (Chapter 23)

- Alternative Intersections
  - Characterized by redirecting one or more movements to another at-grade path to improve efficiency and/or safety
  - Creates a system of interlinked, closely spaced intersections (“junctions”)
- Interchanges
  - Characterized by grade-separating (vertically) one or more movements
  - Ramp terminal intersections (if present) can be closely spaced and interlinked
- Intersections are operationally inter-dependent and best analyzed as a single unit
(Primary) Types of Alternative Intersections

- Displaced Left-Turn Intersection (DLT)
  - Continuous Flow Intersection (CFI)
  - Crossover Displaced Left-Turn Intersection
- Median U-Turn Intersection (MUT)
  - Median U-turn Crossover
  - Boulevard Turnaround
  - Michigan Left
  - Thru U-Turn Intersection
- Restricted Crossing U-Turn (RCUT)
  - Superstreet Intersection
  - J-turn Intersection
  - Synchronized Street Intersection
- Diverging Diamond Interchange (DDI)
  - Double Crossover Diamond (DCD)

Unique Signal Control Attribute → Demand Starvation

Lane Utilization Adjustments

Saturation Flow Rate Adjustments

Yield-Controlled Movements
Chapter 23 Adjustments: Beyond Standard Intersection Analysis

New Capabilities in HCM 6th Edition

- LOS framework
- Ramp terminals
  - Diverging diamond interchange (DDI) evaluation
- Alternative intersections
  - RCUT and MUT computational steps
  - Displaced left turn (DLT) computational steps

New LOS Framework

- New service measure: experienced travel time
  - Sum of control delays at each node and extra distance travel time experienced by rerouted movements

LOS Measures and Thresholds

- Service measure is extra travel time (ETT)
  - ETT = control delay + extra distance travel time (EDTT)
- Interchanges with signalized ramp terminals
  - No change in LOS thresholds from HCM 2010
  - signalized intersection control delay thresholds × 1.5
- Interchanges with roundabouts at ramp terminals
  - No change from HCM 2010, slightly higher LOS thresholds than for isolated roundabouts
- Alternative intersections
  - Same LOS thresholds as signalized intersections

New LOS Framework

- New input data
  - Extra travel distance relative to the centerline
  - Travel speed for extra travel distance
    - Default value estimated from speed limit

Extra travel distance for O4 to O1

\[ V_{	ext{max}, LT} \]
Diverging Diamond Interchanges

- Saturation flow adjustment factor
  \[ f_{DDI} = 0.913 \]
- Lane utilization
- Additional lost time
- Yield-controlled movements

Lane Utilization at DDIs

- Significant differences in lane volumes
- Equation provided to predict lane volumes
- Five lane configurations addressed

Additional Lost Time due to Downstream Internal Queues

- Back of downstream queue does not start moving until several seconds after start of green
- If internal storage is filled and the upstream phase starts before the back of downstream queue is moving, then additional lost time is incurred by upstream phase

Additional Lost Time due to Clearance Lost Time (1)

- Long clear time needed after through phase before ramp can discharge safely
- Modeled as lost time since overlap cannot be modeled using signalized intersection method

Additional Lost Time due to Clearance Lost Time (2)

Phase 7: WB thru clears ramp, EB thru green

Phase 8: EB thru & ramp green
Yield-Controlled Movements at DDIs

- Ramp left-turn or right-turn can be yield-controlled

Capacity of Yield-Controlled Movements at DDIs

- Capacity dictated by three flow regimes
- Equations provided for estimating capacity of each regime
- Overall turn capacity is computed as probability-weighted average of three regime capacities

RCUTs, MUTs: Additional Input Data

- Volume of U-turns on red at a signalized crossover
- Median width at a signalized U-turn crossover
- Distance from the U-turn crossover to main junction
- Free-flow speed along major street

RCUT & MUT Analysis Differences

- Weaving delay
  - Estimated using freeway weaving methodology
- U-turn saturation flow rate adjustment factors
  - Narrow median (< 35 ft): 0.80
  - Typical median (35-80 ft): 0.85
  - Wide median (>80 ft): 0.95
- U-turn gap acceptance parameters
  - Critical headway: 4.4 s
  - Follow-up headway: 2.6 s

Partial Displaced Left Turn (DLT) Intersections

- Three signalized intersections are analyzed using
  - Urban Street Segments method and
  - Signalized Intersections method

DLT Analysis Differences

- Guidance
  - Signals are timed properly such that displaced left-turns have zero delay when turning onto cross street
- Saturation flow rate adjustments
  - Left turns at supplemental intersections
    - Recommend using right-turn saturation flow rate adjustment factor when computing left-turn saturation flow rate
- Offset adjustment
  - Guidance provided to compute signal offset needed to allow displaced lefts to proceed across the cross street without stopping
Full DLT Intersections

- Five signalized intersections
- Analysis approach
  - Analyze as two DLT intersections
    - DLT on N-S street
    - DLT on E-W street
  - Aggregate the results

Workshop Overview

- Introductions, need for the HCM 6th Edition
- Travel time reliability analysis
- Break
- New freeway analysis methods, freeway case studies
- Alternative intersection and interchange analysis
- Lunch
- Updated urban street analysis methods
- HCM Volume 4
- Break
- Planning & Preliminary Engineering Applications Guide
- Wrap-up, discussion, additional questions

HCM 6th Edition: New Urban Street Analysis Capabilities

- Travel time reliability
- Work zone analysis
- New truck methodology
- Updated roundabout capacity values
- Roundabout corridors
- New planning methods
- Alternative intersections and interchanges

Volume 3: Interrupted Flow Chapters

Printed Chapters
16. Urban Street Facilities
17. Urban Street Reliability and ATDM
18. Urban Street Segments
19. Signalized Intersections
20. Two-Way Stop-Controlled Intersections
21. All-Way Stop-Controlled Intersections
22. Roundabouts
23. Ramp Terminals and Alternative Intersections
24. Off-Street Pedestrian and Bicycle Facilities
Volume 3: Hierarchical View

17 Reliability = Facility operations aggregated temporally
16 Facility = Segment operations aggregated spatially
18 Segment = Operations of link plus boundary intersection
24 Off-Street Pedestrian and Bicycle Facilities

Urban Street Facilities (Chapter 16)

- Service measure changes
  - Measure changed to average travel speed (before: ATS as percent of free-flow speed)
  - LOS A/B threshold lowered to equivalent of 80% of FFS
- New method for evaluating queue spillback
- Pedestrian and bicycle LOS now weighted by travel time instead of length

Urban Street Reliability and ATDM (Chapter 17)

- New chapter
- Reliability calculation process similar to that used for freeways
  - Repetitive application of Chapter 16 core method with varying inputs
- New guidance on analyzing ATDM strategies
- STREETVAL computational engine available online in HCM Volume 4

Urban Street Segments (Chapter 18): Key Changes (1)

- Same service measure changes as for facilities
- New method for evaluating segments with midsegment lane blockage
- Improved procedure for predicting segment queue spillback time
- New adjustment factor for parking activity that affects free-flow speed estimation

Urban Street Segments (Chapter 18): Key Changes (2)

- Procedure can now evaluate segments with roundabouts at one or both ends
- Right-turn-on-red vehicles incorporated into volume-balancing method for flows into/out of a segment
- Pedestrian and bicycle LOS scores now use time-based weighting

Urban Street Segments (Chapter 18): Key Changes (3)

- Pedestrian and bicycle link LOS thresholds changed for consistency with original research

<table>
<thead>
<tr>
<th>LOS</th>
<th>Link LOS Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≥2.00</td>
</tr>
<tr>
<td>B</td>
<td>&gt;2.00–2.75</td>
</tr>
<tr>
<td>C</td>
<td>&gt;2.75–3.50</td>
</tr>
<tr>
<td>D</td>
<td>&gt;3.50–4.25</td>
</tr>
<tr>
<td>E</td>
<td>&gt;4.25–5.00</td>
</tr>
<tr>
<td>F</td>
<td>&gt;5.00</td>
</tr>
</tbody>
</table>
Performance Measures: Urban Street Segments

<table>
<thead>
<tr>
<th>Mode</th>
<th>Travel Speed</th>
<th>Perception Score</th>
<th>LOS Letter</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>stop rate, downstream int. v/c ratio</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>pedestrian space</td>
</tr>
<tr>
<td>Bicycle</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>segment wait-ride score</td>
</tr>
</tbody>
</table>

Green indicates measures used to determine level of service (LOS)

HCM Multimodal Philosophy

- Allow trade-offs in the use of the right-of-way by different modes to be evaluated

<table>
<thead>
<tr>
<th>Mode Affected</th>
<th>Impacting Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Turning patterns</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Lane configurations</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Driver yielding</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Min. green time</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Turn conflicts</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Traffic separation</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Sidewalk crowding</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Crosswalk crowding</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Cross-flows</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Mid-block xings</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Heavy vehicle blocking delay stops</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Signal priority</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Transit stop queues</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Bus stop cross-flows</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Vehicle yielding</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Auto volumes</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Signal timing</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Min. green time</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Turn conflicts</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Traffic separation</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Mid-block xings</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Pedestrian space</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Bike volumes</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Heavy vehicle blocking delay stops</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Bike environment quality</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Bike volumes</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Heavy vehicle blocking delay stops</td>
</tr>
<tr>
<td>Auto &amp; HV volumes</td>
<td>Bus volumes</td>
</tr>
</tbody>
</table>

Roundabouts (Chapter 22)

- Modified capacity equations
  - Calibrated to recently collected data
  - Predicted capacity tends to be higher
  - Guidance provided on local calibration

<table>
<thead>
<tr>
<th>Entry Lanes</th>
<th>Opposing Lanes</th>
<th>Capacity by HCM Version and Conflicting Volume, vph</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>HCM 2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( V_c = 0 ) vph</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1,130</td>
</tr>
<tr>
<td>Right</td>
<td>2</td>
<td>1,130</td>
</tr>
<tr>
<td>Left</td>
<td>2</td>
<td>1,130</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1,130</td>
</tr>
<tr>
<td>R or L</td>
<td>1</td>
<td>1,130</td>
</tr>
</tbody>
</table>

Roundabout Segments

- New to the HCM 6th Edition
- Based largely on NCHRP Report 772: Evaluating the Performance of Corridors with Roundabouts
- Incorporated into Chapter 18 urban street segment methodology

Roundabout Segment Methodology: Input Data

- Data needed for urban street segment methodology also needed for roundabout segment evaluation
  - Exception: signal data not needed
- Required data
  - Inscribed circle diameter
  - Number of circulating lanes
  - Average width of circulating lanes
  - Control delay by lane at boundary roundabout
  - Capacity by lane at boundary roundabout

Roundabout Segment Methodology: Influence Areas

- Influence area measured from roundabout yield line to a point along the segment
- Defined as distance over which the geometric features of the roundabout influence travel speed
- Computed for upstream roundabout and downstream roundabout
Signalized Intersections (Chapter 19)

- Combined saturation flow adjustment factor for heavy vehicles and grade
- New saturation flow adjustment factors for intersection work zone presence, midsegment lane blockage, and downstream spillback
- Delay of unsignalized turning movements can now be considered (user-supplied input)

Signalized Intersections: Combined Truck & Grade Saturation Flow Rate Adjustment Factor

HCM 2010: solid lines
HCM 6th Edition: dashed lines

Signalized Intersection Planning Method

- Two-part procedure
  - First part (steps 1–5) produces estimate of "sufficiency"
    - "Under", "near", or "over" capacity
  - Optional second part (steps 6–9) generates performance measures
    - Delay by lane group and intersection-wide
    - LOS
    - Queues
- Can be performed by hand; spreadsheet-based computational engine available on HCM Volume 4

Signalized Intersection Planning Method: Applications

- Conduct planning-level (back-of-envelope) capacity analyses
- Predict intersection’s critical v/c ratio
- Assess lane geometry sufficiency
- Quickly compare capacity improvement alternatives
- Estimate signal phasing and timing
- Check for software results for reasonableness
- Screen large number of intersections for long-range plan
- Educate about traffic signal operations fundamentals

Signalized Intersection Planning Method: Limitations

- Only applicable to motorized vehicles
- Based on pre-timed operations
- Does not analyze all potential combinations of left-turn operation
- Does not account for upstream or downstream impedances and effects of short lanes
- Does not directly consider the effects of grade, lane width, bus activity, bicycle conflicts, and other “fine tuning” aspects of the HCM operations method

Planning Method: Input Data

- Required
  - Volumes by turning movement
  - Lane geometry
- Also used, but can be defaulted
  - Heavy vehicle %
  - Peak hour factor
  - Pedestrian activity (low, moderate, high, extreme)
  - On-street parking presence
- Used for delay/LOS, but can be estimated or defaulted
  - Cycle length, effective green time, progression quality
Evaluation Steps: Operational Sufficiency

1. Determine left-turn phasing
2. Identify lane groups
3. Convert turning movements to the equivalent volume of through passenger cars
4. Identify critical lane groups and their volumes
5. Compute intersection volume-to-capacity (v/c) ratio

Step 1: Determine Left-Turn Phasing

- If the left-turn phasing is already known, use it and proceed to Step 2
  - Planning method can use
    - Permitted left turns
    - Protected left turns
    - Split phasing
    - Protected-permitted left turns
- If the roadway agency has policies specifying when certain types of left-turn phasing should be used, follow them and proceed to Step 2
- Otherwise, follow the general rules on the next slide
  - Will assume either permitted or protected LT operation

Step 1: Left-Turn Phasing Guidance

- Protected left-turn phase (arrow) assumed if any of these occur:
  - Left-turn volume exceeds 240 veh/h
  - (Left-turn volume) × (opposing through volume) > 50,000 (one opposing through lane)
  - > 90,000 (two opposing through lanes)
  - > 110,000 (3+ opposing through lanes)
  - Two or more left-turn lanes provided
  - Approach has an exclusive left-turn lane and the opposing approach meets any of the above criteria
- Otherwise, permitted left-turn phasing assumed

Step 2: Identify Lane Groups

- Lane group: lane or set of lanes designated for separate analysis
- If a traffic movement uses only an exclusive lane, it is analyzed as an exclusive lane group
- If two or more traffic movements share a lane, all lanes which convey those movements are analyzed as a mixed lane group
- Check mixed lane groups to see if a de facto turn lane exists

Your Turn: Left-Turn Phasing

<table>
<thead>
<tr>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Left-Turn Phasing Results

<table>
<thead>
<tr>
<th>Check 1</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 2</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 3</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 4</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 5</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 6</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 7</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 8</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 9</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 10</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 11</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 12</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 13</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 14</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Check 15</th>
<th>Approach</th>
<th>NB</th>
<th>SB</th>
<th>WB</th>
<th>EB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Your Turn: Identify Lane Groups

<table>
<thead>
<tr>
<th>Lane Group Results</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak hour volume (veh/h)</td>
<td>152</td>
<td>676</td>
<td>531</td>
<td>22</td>
</tr>
<tr>
<td>Number of lanes</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>De facto exclusive lane?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Lane group type</td>
<td>Ex. Mixed</td>
<td>Ex. Mixed</td>
<td>Ex. Mixed</td>
<td>Ex. Mixed</td>
</tr>
</tbody>
</table>

Step 3: Convert Turning Movements to Through PCEs

- **Mixed-traffic volumes making each turning movement are converted to the equivalent number of through-movement passenger cars**
- **Six types of adjustment factors**
  - Heavy vehicles, $E_{HV}$
  - Peak hour factor, $E_{PHF}$
  - Turn impedance, $E_{LT}$ & $E_{RT}$
  - Parking activity, $E_{P}$
  - Lane utilization, $E_{LU}$
  - Other, user-specified (uncommon) effects, $E_{other}$

Volume Adjustment Factors (1)

- **Heavy vehicles**: Equation 31-158
  - Converts mixed-traffic volume to passenger car equivalents (PCEs)
  - $E_{HVadj} = 1 + P_{HV}(E_{HV} - 1)$
  - Default $E_{HV} = 2$, $P_{HV}$ = proportion heavy vehicles (decimal)

- **Peak hour factor**: Equation 31-159
  - Adjusts hourly traffic volume to reflect peak 15-minute conditions
  - $E_{PHF} = \frac{1}{\text{PHF}}$

Volume Adjustment Factors (2)

- **Turn impedance factor**
  - Adjusts left- and right-turning volumes to the equivalent number of through vehicles
  - How many through vehicles could be served in the same time as one average turning vehicle?
    - Permitted left turns: Exhibit 31-33
    - Protected left turns: $E_{LT} = 1.05$
    - Protected-permitted left turns: $E_{PT} = 1.00$
    - Permitted right turns: Exhibit 31-34
    - Protected right turns: $E_{RT} = 1.00$
    - Through movements: $E_{TL} + E_{TR} = 1.00$

Volume Adjustment Factors (3)

- **Parking factor**: Exhibit 31-35
  - Parking activity near the intersection will sometimes delay traffic in the adjacent travel lane
  - $E_{P} = 1.00$ if the lane group has no adjacent parking (e.g., a left-turn lane with another lane group to the right)
Volume Adjustment Factors (5)

- Lane utilization factor: Exhibit 31-36
  - When a lane group has more than one lane, traffic typically is not evenly distributed across the lanes
  - Factor increases volumes to reflect time required to serve traffic in the busiest lane

<table>
<thead>
<tr>
<th>Lane Group Movements</th>
<th>No. of Lanes in Lane Group</th>
<th>EVf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through or shared</td>
<td>2</td>
<td>1.05</td>
</tr>
<tr>
<td>Exclusive LT</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td>Exclusive RT</td>
<td>1</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Volume Adjustment Factors (6)

- “Other effects” adjustment factor
  - Optional
  - Can be used to account for other situations identified in the HCM that affect traffic flow (e.g., mid-segment lane blockage, queue spillback)
  - Default = 1.00

Equivalent Through Passenger Car Flow Rate

- Equivalent through PC flow rate for a movement (tpc/h) = movement volume \( \times \) the adjustment factors
  - \( V_{\text{adj,net}} = V_{\text{adj,net}} E_{\text{HVadj}} E_{\text{PHF}} E_{\Delta L} E_{\Delta R} E_{\text{other}} \)

- Divide the result by the number of lanes to get a per-lane value (tpc/h/ln)

Through Passenger Car Flow Rate Results

<table>
<thead>
<tr>
<th>Movement volume (veh/h)</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHF adj., EPHF</td>
<td>1.09</td>
<td>1.09</td>
<td>1.09</td>
<td>1.09</td>
</tr>
<tr>
<td>Left turn impedance adj., ELT</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Right turn impedance adj., ER</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Parking adj., EP</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Other effects adj., Eother</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Equivalent flow rate (tpc/h)</td>
<td>100</td>
<td>862</td>
<td>340</td>
<td>641</td>
</tr>
<tr>
<td>Number of Lanes</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Lane group type</td>
<td>Ex. Mixed</td>
<td>Ex. Mixed</td>
<td>Ex. Mixed</td>
<td>Ex. Mixed</td>
</tr>
<tr>
<td>Lane group flow rate (tpc/h)</td>
<td>100</td>
<td>862</td>
<td>340</td>
<td>641</td>
</tr>
<tr>
<td>Equivalent flow rate (tpc/h/ln)</td>
<td>100</td>
<td>404</td>
<td>162</td>
<td>515</td>
</tr>
</tbody>
</table>

Your Turn: Through Passenger Car Flow Rates

- No parking NB/SB, parking EB/WB
- For all approaches:
  - PHF = 0.92
  - 5% heavy vehicles
  - “Medium” pedestrian activity

Step 4: Calculate Critical Lane Group Volumes

- Critical lane groups are the ones that require the most time to serve during the traffic signal cycle
- They are the conflicting lane groups from opposing approaches that have the highest total demand, measured on a per-lane basis
- East–west and north–south approaches are assessed independently
- The specific movements that form the critical lane groups depends on the signal phasing
Determining Critical Lane Group Volumes:
Protected Left-Turn Phasing

- Add the LT flow rate on one approach to the through* lane group flow rate on the opposing approach
- Do the same for the opposite approach
- The higher of the two values is the critical volume for that pair of approaches

*Or the exclusive RT lane group flow rate, if higher

---

Determining Critical Lane Group Volumes:
Other Types of Left-Turn Phasing

- Permitted phasing
  - The highest lane group volume of any lane group on the pair of approaches is the critical volume
- Split phasing
  - The highest lane group volume on one approach plus the highest lane group volume on the opposite approach is the critical volume
- Protected–permitted phasing
  - See guidance in Chapter 31

---

Critical Lane Group Volumes: Intersection Results

- Critical E-W lane groups are the EB LT and WB TH, with a total volume of 622 tpc/h/ln
- Critical N-S lane groups are the SB LT and NB TH, with a total volume of 1,202 tpc/h/ln
- The sum of critical lane group volumes is 1,824 tpc/h/ln

---

Step 5: Intersection Volume-to-Capacity Ratio

- Use a default capacity value of 1,650 tpc/h/ln in the absence of local data
  - This value will be refined in Step 6 if the analysis proceeds to estimate delay
- Divide the critical intersection volume by 1,650 and compare to Exhibit 31-37

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.85</td>
</tr>
<tr>
<td>0.85–0.98</td>
</tr>
<tr>
<td>&gt;0.98</td>
</tr>
</tbody>
</table>

---

Volume-to-Capacity Ratio Results

- For the example intersection, the v/c ratio is 1,824 / 1,650 = 1.11
- Conclusion: The intersection will likely operate over capacity
- Next steps for an actual project:
  - Option 1: Proceed to calculate delay
  - Option 2: Repeat the planning-level analysis with alternative lane configurations
  - Option 3: Conduct an operations-level analysis, using more site-specific data to confirm the result and test alternatives

---

Evaluation Steps: Delay, LOS, and Queuing

6. Calculate capacity
   a. Estimate cycle length (if not already known or estimated in previous steps)
   b. Estimate effective green times (if not already known)
   c. Calculate capacity and v/c ratio (by lane group and for the intersection)
7. Estimate delay
8. Determine LOS
9. Estimate queue lengths
   - Optional queue lengths

Optional step provided in HCM Planning Guide
HCM VOLUME 4

Methodological Details

- This tab provides access to supplemental Chapters 25–37
- Chapters can be viewed online or printed out

Technical Reference Library

- Provides access to many of the research reports and papers referenced in the HCM
- FREEVAL, STREETVAL computational engines

Applications Guides

- Planning & Preliminary Engineering Applications Guide to the HCM
  - Guidance on back-of-the-envelope analysis methods for planning applications
  - Guidance on incorporating HCM methods into planning tools
- HCM Applications Guidebook
  - Examples of how the HCM can be applied to a project as it evolves from concept to design to implementation

HCM Volume 4: Applications Guide

- Available online at hcmvolume4.org
- Open to all, including those who don’t have a personal copy of the HCM
  - Must sign up for a free user account to get access
- Old hcm2010.org site is still available to support the HCM 2010

Interpretations and Errata

- Will be updated as needed in the future
- Provides a link for submitting questions to the committee (but try the discussion forum first)
Other Volume 4 Sections and Features

- Frequently asked questions
- Discussion forum
  - Ask other HCM users questions about applying the manual
  - The Highway Capacity Committee monitors posts and responds as needed to questions specific to the manual
- E-mail notifications
  - Errata and chapter updates (opt-out)
  - New Volume 4 material by chapter (opt-in)
  - New discussion forum posts (opt-in)

Workshop Overview

- Introductions, need for the HCM 6th Edition
- Travel time reliability analysis
- Break
- New freeway analysis methods, freeway case studies
- Alternative intersection and interchange analysis
- Lunch
- Updated urban street analysis methods
- HCM Volume 4
- Break
- Planning & Preliminary Engineering Applications Guide
- Wrap-up, discussion, evaluation

Defining “Planning Analysis” in an HCM Context

- Planning analyses are generally directed toward broad issues
  - May include some combination of
    - Large study areas
    - Distant horizon years
    - Limited data availability
    - Uncertainty about data accuracy (e.g., future volume forecasts)
    - Analysis result will not be used to make final decisions about project scope

Defining “Preliminary Engineering” in an HCM Context

- Preliminary engineering analyses support moderately detailed issues
  - May include some combination of
    - Smaller study areas
    - Shorter-term horizon years
    - Some, but not all, data needed for a full HCM (“operations”) analysis available
    - Higher degree of confidence in available data
    - Analysis will support planning decisions to advance specific projects or policies
### HCM Operations and Design Analyses

- Operations and design analyses apply the full analysis methods given in the HCM
  - May include some combination of
    - Smaller study areas
    - Existing conditions or near-term horizon year
    - All data needed to apply an HCM method available
  - Highest degree of confidence in available data
- Analysis results used to
  - Make final determinations about roadway geometry and traffic control,
  - Support final project approval, and/or
  - Require mitigation actions

### Examples of Planning & Preliminary Engineering Applications

- Evaluating predicted or forecasted conditions for various roadway facility types
- Applying HCM methods using combinations of actual data, default values, and/or simplifying assumptions
- Providing generalized answers (e.g., “Is this sufficient?”) over broader areas & longer timeframes
- Performing quick back-of-the-envelope calculations
- Prioritizing projects being considered for funding
- Monitoring roadway performance

### 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

### Levels of Roadway Operations 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
Guide's Relationship to 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’s Relationship to the Project Life Cycle Example Use of the Guide Over the Project Life Cycle

Guide’s Relationship to the Project Life Cycle

Example Use of the Guide Over the Project Life Cycle

Part 1: Overview

- **Navigation**
  A. Introduction
  B. Medium-Level (Facility-Specific) Analyses
  C. High-Level Analyses
- **Cross-cutting Material**
  D. Working with Traffic Demand Data
  E. Predicting Intersection Traffic Control
  F. Default Values
  G. Service Volume Tables

Organization of the Guide

- **Guide is not intended**
  to be read cover-to-cover
- **Four parts**
  1. Overview
  2. Medium-level analysis
  3. High-level analysis
  4. Case studies
- **Guide uses lettered sections**
  A–V to contrast with numbered HCM chapters 1–37

Example Use of the Guide Over the Project Life Cycle

Guide’s Relationship to the Project Life Cycle

Example Use of the Guide Over the Project Life Cycle

Part 1: Overview

- **Navigation**
  A. Introduction
  B. Medium-Level (Facility-Specific) Analyses
  C. High-Level Analyses
- **Cross-cutting Material**
  D. Working with Traffic Demand Data
  E. Predicting Intersection Traffic Control
  F. Default Values
  G. Service Volume Tables

Organization of the Guide

- **Guide is not intended**
  to be read cover-to-cover
- **Four parts**
  1. Overview
  2. Medium-level analysis
  3. High-level analysis
  4. Case studies
- **Guide uses lettered sections**
  A–V to contrast with numbered HCM chapters 1–37
Part 2: Medium-Level Analysis

- **HCM System Elements**
  - H. Freeways
  - I. Multilane Highways
  - J. Two-Lane Highways
  - K. Urban Streets
  - L. Signalized Intersections
  - M. Stop-Controlled Intersections
  - N. Roundabouts
- **HCM Non-auto Modes**
  - O. Pedestrians, Bicyclists, and Public Transit
  - P. Truck Level of Service

Part 3: High-Level Analysis

- **Q. Corridor Quick Estimation Screenline Analysis**
- **R. Areas and Systems**
- **S. Roadway System Monitoring**
  - Screenline analysis (Q)
  - Roadway link speed estimation (R)
  - Roadway link capacity estimation (R)
  - Performance measures from system monitoring data (S)
  - System monitoring data collection & archiving (S)

Freeway Case Study Background

- Freeway 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

Part 4: Case Studies

- **T. Freeway Master Plan**
- **U. Arterial Bus Rapid Transit Planning**
- **V. Long-Range Transportation Planning**

Study Area and Facility Overview

- 4–6 lane interurban corridor
- 70 miles long, mostly freeway, but some multilane highway
- Passes through 5 urban areas
- 7% grade over Cuesta Pass
- AADT between 20,000 and 74,000 trips per day
- Truck traffic between 8% and 10% of AADT
- Recurring congestion in the afternoon between San Luis Obispo and Pismo Beach
### Evaluation Approach

- Divide the facility into “supersections” with similar characteristics
- Use service volume tables to quickly screen out portions of the corridor unlikely to have capacity problems
- Apply simplified version of the HCM freeway method to evaluate remaining sections

### Use of Service Volume Tables for Screening

- Service volume tables give the maximum daily or hourly volume that achieves a given LOS, for an assumed set of conditions
- Created by applying the HCM method multiple times with different volume inputs
- In this example, supersections with AADTs exceeding the LOS C service volume will be flagged for further analysis

### Example Service Volume Table

<table>
<thead>
<tr>
<th>Area Type</th>
<th>Terrain</th>
<th>Multilane highway AADT (2-way veh/day/ln)</th>
<th>Freeway AADT (2-way veh/day/ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Level</td>
<td>LOS A-C</td>
<td>LOS D (capacity)</td>
<td>LOS E (capacity)</td>
</tr>
<tr>
<td>Urban Rolling</td>
<td>11,800</td>
<td>14,600</td>
<td>16,700</td>
</tr>
<tr>
<td>Rural Level</td>
<td>10,200</td>
<td>12,600</td>
<td>14,400</td>
</tr>
<tr>
<td>Rural Rolling</td>
<td>9,200</td>
<td>11,400</td>
<td>13,000</td>
</tr>
<tr>
<td>Rural Mountain</td>
<td>7,700</td>
<td>9,500</td>
<td>10,800</td>
</tr>
</tbody>
</table>

- Default values used for free-flow speed, % trucks, PHF, ramp density, lane width, K, and D for each combination of area type and terrain
- Case Study 1 in the Guide shows how to customize the tables when some of these data are available

### Your Turn

- The following data are available for each supersection:

<table>
<thead>
<tr>
<th>Lanes, 2-dir</th>
<th>Facility type</th>
<th>Area type</th>
<th>Terrain</th>
<th>AADT, 2-dir</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freeway</td>
<td>Urban</td>
<td>Level</td>
<td>7,700</td>
</tr>
<tr>
<td></td>
<td>Freeway</td>
<td>Rural</td>
<td>Level</td>
<td>5,700</td>
</tr>
<tr>
<td></td>
<td>Freeway</td>
<td>Urban</td>
<td>Level</td>
<td>7,700</td>
</tr>
<tr>
<td></td>
<td>Freeway</td>
<td>Rural</td>
<td>Level</td>
<td>5,700</td>
</tr>
<tr>
<td></td>
<td>Freeway</td>
<td>Urban</td>
<td>Level</td>
<td>7,700</td>
</tr>
<tr>
<td></td>
<td>Freeway</td>
<td>Rural</td>
<td>Level</td>
<td>5,700</td>
</tr>
</tbody>
</table>

- Which supersections will operate at LOS A–C and can be screened out of further analysis?

### Analysis Results

- Two-thirds of the supersections are not expected to have operational problems and do not need to be evaluated further
More Detailed Analysis: Focus on Supersection C

Sectioning and Volume-to-Capacity Ratio

- Supersection C is split into 7 sections between ramps
- Each section’s per-lane capacity is determined
- Per-lane demand volumes are compared to per-lane capacity
- Bottlenecks where demand exceeds capacity
  meter demand to the downstream section
- Bottlenecks can be flagged for further analysis
  (e.g., analyzing mitigation options)

Section Speed and Travel Time

- Speeds and travel times are determined for each section within the supersection
- The only input required for estimating speed is the demand-to-capacity ratio
- Travel times also require knowing the section length
- Average speed and overall travel time can be determined for the supersection as a whole
- Results can be tabulated or shown in a diagram

Speed Contour for Supersection C

Level of Service

- LOS is determined for each section
- Freeway LOS is based on density
  - Density = demand / speed
  - Demand must be adjusted from vehicles per hour to passenger cars per hour to account for the effects of trucks in the traffic stream
- Supersection generally operates at LOS E or F throughout the peak hour

Queuing

- Queues are estimated for each section
- If the queue length exceeds the section length, the section is considered to be 100% in queue
  - Queues are not propagated upstream in the planning method
  - More detailed analysis is required if a section is 100% in queue
Travel Time Reliability

- Measures of the section’s reliability can be estimated
  - Compute vehicle miles traveled (VMT)
  - Compute vehicle hours traveled (VHT)
  - Compute average facility speed = VMT / VHT
  - Identify maximum facility demand-to-capacity ratio
  - Compute the recurring delay rate
  - Estimate the incident delay rate
  - Estimate the mean travel time index
  - Estimate the 95th percentile index
  - Estimate percent trips under 45 mph

Alternatives Evaluation

- The effect of adding an auxiliary lane to the bottleneck section is evaluated
- Previous calculations are repeated
- Auxiliary lane removes the bottleneck in Section C-4, but sends more demand downstream
- LOS F in either scenario, but facility speed, density, queuing, and maximum demand-to-capacity ratio improve with the auxiliary lane

<table>
<thead>
<tr>
<th>Maximum d/c Ratio by Scenario</th>
<th>C-1</th>
<th>C-2</th>
<th>C-3</th>
<th>C-4</th>
<th>C-5</th>
<th>C-6</th>
<th>C-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Nothing</td>
<td>0.82</td>
<td>1.04</td>
<td>0.94</td>
<td>1.28</td>
<td>0.96</td>
<td>0.96</td>
<td>0.89</td>
</tr>
<tr>
<td>Add Lane</td>
<td>0.82</td>
<td>1.04</td>
<td>0.94</td>
<td>0.74</td>
<td>0.97</td>
<td>1.09</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Summary (1)

- The HCM 6th Edition provides a more robust tool set than ever before
  - Travel time reliability forecasting
  - Managed lanes
  - Truck analysis
  - Operational effects of work zones and ATDM strategies
  - Roundabout analysis based on latest US research
  - Multimodal performance measures
- Methods have been thoroughly researched, tested, validated, and peer reviewed

Summary (2)

- The HCM 6th Edition supports a variety of applications
  - Back-of-the-envelope methods in the Planning & Preliminary Engineering Applications Guide
  - Macoroscopic traffic analysis at levels ranging from planning to design to detailed operations
  - Performance monitoring
  - Guidance on using the HCM in conjunction with simulation
- Some applications, such as forecasting travel time reliability, cannot be practically performed with simulation
Summary (3)

- The HCM 6th Edition and its resources help support the modern practitioner
  - Concepts and guidance needed for a practitioner to properly apply the HCM through software, calibrate methods to local conditions, and interpret analysis results
  - Computational engines for freeway and urban street analysis
  - Applications guides demonstrating how the HCM can be applied to actual projects
  - Online Volume 4 with background and supplemental information and ability to ask questions of other users

Contact Information

- Paul Ryus
  - pryus@kittelson.com
  - (503) 535-7410
- Radu Nan
  - rnan@kittelson.com
  - (857) 265-2153 x2504
Exercise Material for Travel Time Reliability

The following are travel times (in seconds) over the length of a 6.5-mile freeway facility for the 20 weekdays in February 2017, measured during the 5-minute period at the start of each half-hour. The times have been sorted for you in increasing order of length. For example, for trips made at 6:30 a.m. in February 2017, one could travel the facility in 439 seconds on the fastest day and in 843 seconds on the slowest day. Because there are 20 observations for each half-hour, each observation equals 5%. Thus, the 95th percentile travel time at 6:30 a.m. was 651 seconds.

For each time period, determine the level of travel time reliability (LOTTR). For the 8:00 time period, also calculate the other travel time reliability measures shown in the table below. If you have extra time, feel free to calculate the additional reliability measures for the other time periods. The free-flow travel time is 398 seconds. The target travel time to make a trip at 45 mph or better is 518 seconds.

<table>
<thead>
<tr>
<th>6:00</th>
<th>6:30</th>
<th>7:00</th>
<th>7:30</th>
<th>8:00</th>
<th>8:30</th>
<th>9:00</th>
<th>9:30</th>
<th>10:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>394</td>
<td>439</td>
<td>461</td>
<td>660</td>
<td>519</td>
<td>434</td>
<td>444</td>
<td>418</td>
<td>413</td>
</tr>
<tr>
<td>407</td>
<td>444</td>
<td>506</td>
<td>714</td>
<td>669</td>
<td>608</td>
<td>445</td>
<td>431</td>
<td>423</td>
</tr>
<tr>
<td>411</td>
<td>447</td>
<td>516</td>
<td>760</td>
<td>738</td>
<td>774</td>
<td>547</td>
<td>434</td>
<td>424</td>
</tr>
<tr>
<td>413</td>
<td>452</td>
<td>545</td>
<td>776</td>
<td>839</td>
<td>829</td>
<td>605</td>
<td>444</td>
<td>427</td>
</tr>
<tr>
<td>416</td>
<td>452</td>
<td>580</td>
<td>789</td>
<td>855</td>
<td>842</td>
<td>621</td>
<td>449</td>
<td>431</td>
</tr>
<tr>
<td>418</td>
<td>453</td>
<td>584</td>
<td>825</td>
<td>862</td>
<td>850</td>
<td>672</td>
<td>450</td>
<td>441</td>
</tr>
<tr>
<td>419</td>
<td>455</td>
<td>613</td>
<td>834</td>
<td>882</td>
<td>865</td>
<td>685</td>
<td>518</td>
<td>452</td>
</tr>
<tr>
<td>421</td>
<td>459</td>
<td>626</td>
<td>838</td>
<td>885</td>
<td>865</td>
<td>710</td>
<td>575</td>
<td>453</td>
</tr>
<tr>
<td>421</td>
<td>459</td>
<td>626</td>
<td>845</td>
<td>904</td>
<td>889</td>
<td>768</td>
<td>580</td>
<td>453</td>
</tr>
<tr>
<td>422</td>
<td>466</td>
<td>660</td>
<td>861</td>
<td>923</td>
<td>922</td>
<td>788</td>
<td>585</td>
<td>466</td>
</tr>
<tr>
<td>421</td>
<td>472</td>
<td>679</td>
<td>862</td>
<td>929</td>
<td>923</td>
<td>807</td>
<td>626</td>
<td>478</td>
</tr>
<tr>
<td>422</td>
<td>488</td>
<td>684</td>
<td>917</td>
<td>942</td>
<td>941</td>
<td>918</td>
<td>645</td>
<td>506</td>
</tr>
<tr>
<td>424</td>
<td>491</td>
<td>717</td>
<td>922</td>
<td>1005</td>
<td>1038</td>
<td>1058</td>
<td>660</td>
<td>542</td>
</tr>
<tr>
<td>425</td>
<td>514</td>
<td>735</td>
<td>943</td>
<td>1010</td>
<td>1055</td>
<td>1074</td>
<td>786</td>
<td>568</td>
</tr>
<tr>
<td>427</td>
<td>523</td>
<td>794</td>
<td>1042</td>
<td>1093</td>
<td>1310</td>
<td>1135</td>
<td>998</td>
<td>804</td>
</tr>
<tr>
<td>427</td>
<td>540</td>
<td>806</td>
<td>1055</td>
<td>1265</td>
<td>1327</td>
<td>1252</td>
<td>1021</td>
<td>837</td>
</tr>
<tr>
<td>429</td>
<td>564</td>
<td>814</td>
<td>1096</td>
<td>1267</td>
<td>1392</td>
<td>1268</td>
<td>1028</td>
<td>849</td>
</tr>
<tr>
<td>432</td>
<td>567</td>
<td>833</td>
<td>1158</td>
<td>1368</td>
<td>1511</td>
<td>1493</td>
<td>1049</td>
<td>863</td>
</tr>
<tr>
<td>432</td>
<td>651</td>
<td>893</td>
<td>1170</td>
<td>1808</td>
<td>1617</td>
<td>1559</td>
<td>1081</td>
<td>875</td>
</tr>
<tr>
<td>788</td>
<td>843</td>
<td>840</td>
<td>1298</td>
<td>2001</td>
<td>1862</td>
<td>1801</td>
<td>1141</td>
<td>1019</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>6:00</th>
<th>6:30</th>
<th>7:00</th>
<th>7:30</th>
<th>8:00</th>
<th>8:30</th>
<th>9:00</th>
<th>9:30</th>
<th>10:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOTTR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% travel time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80% travel time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>95% travel time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>95% TTI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean travel time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buffer time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliability rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-time %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LOTTR = (80th percentile travel time) / (50th percentile travel time)
TTI = (actual travel time) / (free-flow travel time)
Buffer time = (95th percentile travel time – mean travel time)
Reliability rating = % of freeway trips made at a TTI of 1.33 or less
On-time percentage = % of freeway trips made at the target speed (in this case, 45 mph) or better
Exercise Material for Freeway Work Zones

A nighttime paving project is planned for a rural freeway. The following information about the project is available:

- Nighttime work
- 2 lanes reduced to 1
- 65-mph speed limit reduced to 50 mph
- Plastic drums placed adjacent to lane stripe
- Diamond interchange 2 miles downstream from WZ center
- Free-flow speed = 70 mph (pre-construction)
- Base capacity = 2,400 pc/h/ln

Determine the CAF and SAF for this work zone.

\[
CAF_{WZ} = \frac{c_{WZ}}{c}
\]

\[
c_{WZ} = \frac{QDR_{WZ}}{100 - \alpha_{WZ}} \times 100
\]

\[
QDR_{WZ} = 2,093 - 154 \times LCSI - 194 \times f_{Br} - 179 \times f_{AT} + 9 \times f_{LAT} - 59 \times f_{DN}
\]

<table>
<thead>
<tr>
<th>Number of Total Lane(s)</th>
<th>Number of Open Lane(s)</th>
<th>Open Ratio</th>
<th>LCSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>1.00</td>
<td>0.33</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0.75</td>
<td>0.44</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0.67</td>
<td>0.75</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0.50</td>
<td>2.00</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0.33</td>
<td>3.00</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0.25</td>
<td>4.00</td>
</tr>
</tbody>
</table>

\(CAF_{WZ}\) = work zone capacity adjustment factor
\(c_{WZ}\) = work zone capacity (pc/h/ln)
\(c\) = base capacity without work zone (pc/h/ln)
\(QDR_{WZ}\) = work zone queue discharge rate (pc/h/ln)
\(\alpha_{WZ}\) = percentage drop in pre-breakdown capacity under queuing conditions (default = 13.4)
\(LCSI\) = lane closure severity index, from table
\(f_{Br}\) = barrier factor (hard barrier = 0, drums or cones = 1)
\(f_{AT}\) = area type (urban = 0, rural = 1)
\(f_{LAT}\) = lateral distance from edge of travel lane to barrier (ft)
\(f_{DN}\) = lighting factor (day = 0, night = 1)
\[ SAF_{wz} = \frac{FFS_{wz}}{FFS} \]

\[ FFS_{wz} = 9.95 + 33.49 \times f_{Sr} + 0.53 \times SL_{wz} - 5.60 \times LCSI - 3.84 \times f_{Br} - 1.71 \times f_{DN} - 8.7 \times TRD \]

- \( SAF_{wz} \) = work zone speed adjustment factor
- \( FFS_{wz} \) = work zone free-flow speed (mph)
- \( FFS \) = free-flow speed without work zone (mph)
- \( f_{Sr} \) = speed ratio = (speed limit without work zone) / (speed limit with work zone)
- \( SL_{wz} \) = work zone speed limit
- \( LCSI \) = lane closure severity index, from table on previous page
- \( f_{Br} \) = barrier factor (hard barrier = 0, drums or cones = 1)
- \( f_{DN} \) = lighting factor (day = 0, night = 1)
- \( TRD \) = total ramp density (ramps/mi), counted 3 miles upstream and 3 miles downstream from the center of the work zone
Exercise Material for Signalized Intersection Planning Method

For each step of the process, pick one pair of approaches (north/south or east/west) to work on. If you have extra time, feel free to work on the other pair of approaches.

Turning movement volumes (veh/h) and lane configurations are shown in the bubble to the right. North is up.

No parking on north- and southbound approaches, on-street parking on other approaches. PHF = 0.92, “medium” pedestrian activity, and 5% heavy vehicles on all approaches.

### Left-Turn Phasing

<table>
<thead>
<tr>
<th>Check</th>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Left-turn volume (veh/h)</td>
<td>Is the left-turn volume &gt; 240 veh/h?</td>
</tr>
<tr>
<td>2</td>
<td>Opposing through volume (veh/h)</td>
<td>Left-turn volume * opposing volume</td>
</tr>
<tr>
<td></td>
<td>Threshold* for Check 2</td>
<td>Number of opposing through lanes</td>
</tr>
<tr>
<td>3</td>
<td>Left-turn lanes</td>
<td>Is product &gt; threshold?</td>
</tr>
<tr>
<td>4</td>
<td>Opposing through volume</td>
<td>Left-turn lanes</td>
</tr>
</tbody>
</table>

*Thresholds: 1 opposing lane: >50,000; 2 opposing lanes: >90,000; 3+ opposing lanes: >110,000

### Lane Groups

<table>
<thead>
<tr>
<th>Lane Group</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
<tr>
<td>Peak hour volume (veh/h)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of lanes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>De facto exclusive lane?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane group type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Critical Flow Rate and Intersection Sufficiency

\[ E_{HVadj} = 1 + P_{HV}(E_{HV} - 1) \]

\[ E_{HV} = \text{heavy vehicle equivalency factor (default} = 2) \]

\[ P_{HV} = \text{proportion of heavy vehicles (decimal)} \]

\[ E_{PHF} = \frac{1}{PHF} \]

**Left-turn impedance factor:**

- Protected left turns: \( E_{LT} = 1.05 \)
- Permitted left turns: see table to right

<table>
<thead>
<tr>
<th>Opposing Through and Right-Turn Volumes (veh/h)</th>
<th>( E_{LT} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;200</td>
<td>1.10</td>
</tr>
<tr>
<td>200–599</td>
<td>2.00</td>
</tr>
<tr>
<td>600–799</td>
<td>3.00</td>
</tr>
<tr>
<td>800–999</td>
<td>4.00</td>
</tr>
<tr>
<td>≥1,000</td>
<td>5.00</td>
</tr>
</tbody>
</table>
**Right-turn impedance factor:**
Protected right turns: $E_{RT} = 1.05$
Permitted right turns: see table below

**Pedestrian Activity $E_{RT}$**
- None or low: 1.20
- Medium: 1.30
- High: 1.50
- Very high: 2.10

**Lane utilization factor, $E_{LU}$:** see table to right

$$v_{adj} = V E_{HV adj} E_{PHF} E_{LT} E_{RT} E_{p} E_{LU} E_{other}$$

**Parking factor, $E_{p}$:** see table below

<table>
<thead>
<tr>
<th>Parking Activity</th>
<th>Number of Lanes in Lane Group</th>
<th>$E_{p}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No parking lane</td>
<td>All</td>
<td>1.00</td>
</tr>
<tr>
<td>Adjacent parking</td>
<td>1</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lane Group Movements</th>
<th>No. of Lanes in Lane Group</th>
<th>$E_{LU}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through or shared</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>$\geq 3$</td>
<td>1.10</td>
</tr>
<tr>
<td>Exclusive LT</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>$\geq 2$</td>
<td>1.03</td>
</tr>
<tr>
<td>Exclusive RT</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>$\geq 2$</td>
<td>1.13</td>
</tr>
</tbody>
</table>

### Table

<table>
<thead>
<tr>
<th>Movement volume (veh/h)</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heavy vehicle adj., $E_{HV adj}$</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PHF adj., $E_{PHF}$</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Left turn impedance adj., $E_{LT}$</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Right turn impedance adj., $E_{RT}$</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parking adj., $E_{p}$</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lane utilization adj., $E_{LU}$</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other effects adj., $E_{other}$</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equivalent flow rate (tpc/h)</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of lanes</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lane group type</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lane group flow rate (tpc/h)</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equivalent flow rate (tpc/h/ln)</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Critical lane group?</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sum of critical lane group flows</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intersection capacity</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>v/c ratio</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intersection sufficiency</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

### Intersection sufficiency:
- $v/c < 0.85$ = under capacity
- $0.85 \leq v/c \leq 0.98$ = near capacity
- $v/c > 0.98$ = over capacity
Exercise Material for Freeway Screening Method

Given the facility data provided below, use the service volume table to determine which supersections will operate at LOS A–C and can therefore be screened out of further analysis.

**Service Volume Table**

<table>
<thead>
<tr>
<th>Area Type</th>
<th>Terrain</th>
<th>Multilane Highway AADT (2-way veh/day/ln)</th>
<th>Freeway AADT (2-way veh/day/ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LOS A-C</td>
<td>LOS D</td>
</tr>
<tr>
<td>Urban</td>
<td>Level</td>
<td>12,600</td>
<td>15,700</td>
</tr>
<tr>
<td>Urban</td>
<td>Rolling</td>
<td>11,800</td>
<td>14,600</td>
</tr>
<tr>
<td>Rural</td>
<td>Level</td>
<td>10,200</td>
<td>12,600</td>
</tr>
<tr>
<td>Rural</td>
<td>Rolling</td>
<td>9,200</td>
<td>11,400</td>
</tr>
<tr>
<td>Rural</td>
<td>Mountain</td>
<td>7,700</td>
<td>9,500</td>
</tr>
</tbody>
</table>

**Facility Data and Worksheet**

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Lanes, 2-dir</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facility type</td>
<td>Highway</td>
<td>Freeway</td>
<td>Freeway</td>
<td>Freeway</td>
<td>Highway</td>
<td>Freeway</td>
<td>Freeway</td>
<td>Freeway</td>
</tr>
<tr>
<td>Area type</td>
<td>Urban</td>
<td>Urban</td>
<td>Rural</td>
<td>Urban</td>
<td>Rural</td>
<td>Urban</td>
<td>Urban</td>
<td>Urban</td>
</tr>
<tr>
<td>Terrain</td>
<td>Level</td>
<td>Level</td>
<td>Level</td>
<td>Level</td>
<td>Mtn</td>
<td>Level</td>
<td>Rolling</td>
<td>Level</td>
</tr>
<tr>
<td>AADT, 2-dir</td>
<td>57,600</td>
<td>63,500</td>
<td>70,100</td>
<td>55,800</td>
<td>44,500</td>
<td>54,700</td>
<td>52,800</td>
<td>32,400</td>
</tr>
</tbody>
</table>

AADT/lane

LOS C service volume

Screen out?