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Why use HCM at all?

► Valid results using methods developed through research.
► Various range of applications – Planning, preliminary engineering, design, operations, performance monitoring.
► Some things which cannot be done using simulation.
The Need for a New HCM

► Changes in driver behavior, vehicle fleet mix and capabilities, performance measures.
► Extensive research since the last edition – truck analysis, managed lanes, reliability, planning applications.
► Increasing use of certain roadway features like roundabouts, alternative intersections, and managed lanes.
Presentation Outline

► Introduction to HCM 6
► Major changes in HCM 6
► Methodological changes by System Element – Uninterrupted flow, Interrupted flow
► Examples
► Conclusion
This is the Highway Capacity Manual’s sixth major revision (after 1950, 1965, 1985, 2000, 2010).

Four volumes as in HCM 2010 – Concepts (Volume 1), Uninterrupted Flow (Volume 2), Interrupted Flow (Volume 3), Applications (Volume 4)

Discusses HCM’s ability to measure roadway performance across multiple dimensions and travel modes.

New topics introduced – Travel time reliability, Managed lane, Work zone, Alternative intersection operations.
Major Research Projects Contributing to the Sixth Edition

► NCFRP 41 – Truck Analysis
► NCHRP 03-96 – Managed Lanes
► NCHRP 03-100 – Corridors with Roundabouts
► NCHRP 03-107 – Work Zone Capacity
► NCHRP 03-115 – Update to the 2010 HCM
► NCHRP 07-22 – Planning Guide
► SHRP 2 L08 – Travel Time Reliability
► FHWA-HOP-13-042 – ATDM Strategies
► FHWA TOPR 34 – Roundabout Implementation
► FHWA Saxton Lab TOPR 2 – HCM Chapters
Chapter 11: Freeway Reliability Analysis (Volume 2) and Chapter 17: Urban Street Reliability and ATDM (Volume 3) are two new chapters.

Additional information on input data needs, potential data sources, default values, and interpretation of results have been added to the chapters in Volumes 2 and 3.

New subsections “Concepts” and “Extensions to the Methodology” are added in all the chapters of Volume 2 and Volume 3.

Example problems are now a part of the “Applications” section, instead of a separate section.

Modal methodologies if applicable, are illustrated as individual sections.

Focus on providing the data for users to apply HCM methods in software.
CHAPTER 20
TWO-WAY STOP-CONTROLLED INTERSECTIONS

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NEW!

NEW!

SEPARATE SECTIONS
## Example Input Data Requirement

**Data needs for Freeway Facility Analysis**

<table>
<thead>
<tr>
<th>Required Data and Units</th>
<th>Potential Data Source(s)</th>
<th>Suggested Default Value</th>
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<tr>
<td><strong>Geometric Data</strong></td>
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<tr>
<td>Free-flow speed (mi/h)</td>
<td>Direct speed measurements, estimate from FFS prediction algorithm</td>
<td>Base free-flow speed: speed limit + 5 mi/h (range 55–75 mi/h)</td>
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<tr>
<td>Segment and section length (ft)</td>
<td>Road inventory, aerial photo</td>
<td>Must be provided</td>
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<tr>
<td><strong>Number of mainline freeway lanes (one direction)</strong></td>
<td>Road inventory, aerial photo</td>
<td>At least 2</td>
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<td>Lane width (ft)</td>
<td>Road inventory, aerial photo</td>
<td>12 ft (range 10–12 ft)</td>
</tr>
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<td>Right-side lateral clearance (ft)</td>
<td>Road inventory, aerial photo</td>
<td>6 ft (range 0–6 ft)</td>
</tr>
<tr>
<td>Total ramp density in analysis direction</td>
<td>Road inventory, aerial photo</td>
<td>Must be provided (range 0–6 ramps/mi)</td>
</tr>
<tr>
<td>Area type (urban, rural)</td>
<td>Road inventory, aerial photo</td>
<td>Must be provided</td>
</tr>
<tr>
<td>Terrain type (level, rolling, specific grade)</td>
<td>Design plans, analyst judgment</td>
<td>Must be provided</td>
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<tr>
<td>Ramp number of lanes</td>
<td>Road inventory, aerial photo</td>
<td>1 lane</td>
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<td>Ramp acceleration or deceleration lane length (ft)</td>
<td>Road inventory, aerial photo</td>
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<td>Ramp free-flow speed (mi/h)</td>
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<td><strong>Geometry of managed lanes</strong></td>
<td>Road inventory, aerial photo</td>
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<td><strong>Demand Data</strong></td>
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<tr>
<td>Mainline entry demand volume by time interval (veh/h)</td>
<td>Field data, modeling</td>
<td>Must be provided</td>
</tr>
<tr>
<td>On-ramp and off-ramp demands by time interval (veh/h)</td>
<td>Field data, modeling</td>
<td>Must be provided</td>
</tr>
<tr>
<td>Weaving demands on weaving segments by time interval (veh/h)</td>
<td>Field data, modeling</td>
<td>Must be provided</td>
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<tr>
<td>Heavy vehicle percentage (%)</td>
<td>Field data</td>
<td>5% (urban), 12% (rural)*</td>
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<tr>
<td>Driver population speed and capacity adjustment factors (decimal)</td>
<td>Field data</td>
<td>1.00 (see Chapter 26 for details)</td>
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<tr>
<td>Jam density (pc/mln)</td>
<td>Field data</td>
<td>190 (range 150–270)</td>
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<tr>
<td>Queue discharge capacity drop (%)</td>
<td>Field data</td>
<td>7% (range 0%–20%)</td>
</tr>
<tr>
<td>Managed lane demand volume (veh/h)</td>
<td>Field data, modeling</td>
<td>Must be provided</td>
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</tbody>
</table>

**Source:** HCM 6th Edition, Chapter 10, Freeway Facilities
For the analysis, a new calibration method with adjustment factors is introduced. (DAFcal, SAFcal, CAFcal)

Extension to the 2010 Methodology – Work Zone Analysis. Following variables are introduced:

Lane Closure Severity Index (LCSI), fBr, fAT, fLAT, fDN, fSr, SLwz, TRD (Total Ramp Density)
Managed Lanes Analysis

► Concept of “lane groups” for freeway facilities with managed and general purpose lanes.
► An analyst can now define separate attributes for parallel managed lane and general purpose facility.

Source: HCM 6th Edition, Chapter 10, Freeway Facilities
Components of a freeway system

<table>
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<th>Off</th>
<th>Basic</th>
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</table>
Freeway Weaving Segments

► Method for evaluating managed lane weaving and access segments, cross-weave effects is introduced.

Cross weaving between ramps and managed lane access segment: The impact is handled by using a CAF.

CAF = 1 – CRF

CRF = -0.0897 + 0.0252ln(CW) – 0.00001453L_{cw-min} + 0.002967N_{GP}

Capacity of the general purpose lane is now: \( c_{GPA} = c_{GP} \times CAF \)
Freeway Weaving Segments (contd.)

Weaving within the managed lane segments:

Here, $S_{MAX} = FFS \times SAF$

Source: HCM 6th Edition, Chapter 13, Freeway Weaving Segments

The formula to determine average speed of weaving vehicles includes a speed adjustment factor:

$$s_W = s_{MIN} + \left( \frac{S_{MAX} - S_{MIN}}{1 + W} \right)$$

Here, $S_{MAX} = FFS \times SAF$
Freeway Reliability

- Time based reliability performance measures from the travel time distribution.

Source: HCM 6th Edition, Chapter 12, Freeway Reliability Analysis
Description of the computational steps has been revised for clarity.

Chapter 11 (Basic Freeway Segments) and Chapter 14 (Multilane Highways) from HCM 2010 is merged as one chapter in HCM 6.

New speed flow curves are provided for multilane highways for 65 mi/hr and 70 mi/hr free flow speeds.

Source: HCM 6th Edition, Chapter 12, Basic Freeway and Multilane Highway Segments
Greater emphasis for calibration though CAFs and SAFs for all analyses.

Effects of non-familiar drivers on flow are handled through adjustment factors; driver population factor is removed in calculating service flow rate.
Freeway Merge and Diverge Segments

- Estimating the speed at on-ramp (Merge) and off-ramp (Diverge) junctions, includes adjustment factor for speed. Therefore, the new formula is:

\[
S_R = FFS \times SAF - (FFS \times SAF - 42)M_s \quad \text{(On-ramp)}
\]
\[
S_R = FFS \times SAF - (FFS \times SAF - 42)D_s \quad \text{(Off-ramp)}
\]

where,

- \(S_R\) = average speed of vehicles within the ramp influence area (mi/hr)
- \(M_s\) = speed index for on-ramps
- \(D_s\) = speed index for off-ramps

- The capacity of merge or diverge segment has been adjusted as:

\[
c_{mda} = c_{md} \times CAF
\]
URBAN STREET FACILITIES

► For Level of Service A, travel speed exceeds 80% of the base free flow speed. (85% in HCM 2010)

► Level of Service scores for Pedestrian and Bicycle modes are now weighted by travel time instead of segment length.

\[ I_{p,F} = 0.75 \left[ \frac{\sum_{i=1}^{m} WTT_{p,i}}{\left( \frac{\sum_{i=1}^{m} L_i}{S_{Tp,F}} \right)} \right]^\frac{1}{3} + 0.125 \]

where, \( WTT_{p,i} \) represents the travel time weighted average pedestrian LOS score for a segment \( i \).

► In HCM 6, Chapter 17 (Volume 3) Urban Street Reliability and ATDM is a new chapter.
In urban street segments analysis, the threshold for LOS A has been changed from 85% to 80% of base free flow speed.

The equation to determine the base free flow speed is:

\[ S_{fo} = S_{\text{calib}} + S_o + f_{CS} + f_A + f_{pk} \]

where, \( S_{\text{calib}} \) = base free flow speed calibration factor (mi/hr) and \( f_{pk} \) = adjustment for on-street parking (mi/hr). These two factors were introduced in the sixth edition.

For bicycle mode, unsignalized conflicts factor term considers 20 conflict point per mile as base condition.

The transit vehicle acceleration rate has been changed from 4 ft/s\(^2\) to 3.3 ft/s\(^2\).

Urban Street Segment: Supplemental (Chapter 30), has added \( f_{pa} \), progression adjustment factor. This was included in HCM 2000, but removed in HCM 2010.
Signalized Intersections

► Unsignalized movement delay is now considered in the calculation of approach delay and intersection delay.

► The equation to determine adjusted saturation flow rate has been revised as:

\[ s = s_0 f_w f_{HV} f_p f_{bb} f_L f_{LU} f_{LT} f_{RT} f_{Lp} f_{Rp} f_{wz} f_{ms} f_{sp} \]

► The adjustment factor for heavy vehicles and grade used to be two separate factors.

► \( f_{wz}, f_{ms}, f_{sp}, \) were introduced in HCM 6. They are the adjustment factors for work zone presence, downstream lane blockage, and sustained spillback respectively.
Roundabouts

► Capacity models have been updated on the basis of latest Federal Highway Administration (FHWA) research.
► The procedure for calibration is provided in Chapter 33: Roundabouts (Supplemental)
Ramp Terminals

► Interchange Ramp Terminals (Chapter 22) of HCM 2010 is revised as Ramp Terminals and Alternative Intersections (Chapter 23) in HCM 6.

► The chapter is reorganized into three parts:
  ► Distributed Intersection Concepts
  ► Interchange Ramp Terminal Evaluation
  ► Alternative Interchange Evaluation
Ramp Terminals (Contd.)

Diverging Diamond Interchange

Source: DDI Visualisation, Youtube

Some intersection forms that are now addressed are: **Displaced left turn intersections, diamond interchanges, restricted crossing U turn intersections.**

A new performance measure – **Experienced Travel Time (ETT)** is defined.

\[ ETT = \sum d_i + \sum EDDTT \]

where, \( \sum d_i = \) Control delay experience, and

\( EDDTT = \) Extra Distance Travel Time

Level of Service for Ramp Terminals analysis is defined on the basis of Experienced Travel Time.
1. Restricted Crossing U-Turn
Four-legged RCUT with signals

- Signals on one side of arterial are independent of signals on other side.
- Cross-street right-turn traffic turns right.
- Cross-street left-turn traffic moves through.
- Arterial traffic no different than conventional intersection.
- Cross-street traffic must turn right. Cross-street left-turn and through traffic makes a U-turn in the wide median.

Four-legged RCUT with merges and diverges.
Alternative Intersections (Contd.)

Three-legged RCUT with signals

Four-legged MUT with signals
3. Displaced Left Turn

Full DLT

Partial DLT

DLT
Guidance on applying HCM to a range of engineering applications.
Based on project NCHRP 07-22.
4 parts
- Part 1 – Overview
- Part 2 – Medium-level analysis methods
- Part 3 - High-level analyses
- Part 4 – Case studies
HCM Calc Swashware

► Calculation software
► Uninterrupted flow methodologies of HCM 2010 and HCM 6
► Developed by Dr. Scott Washburn, Professor, Department of Civil and Coastal Engineering, University of Florida
Example – Basic Freeway analysis

HCM 6

HCM 2010
Freeway Segments… Service Volumes

HCM 6

HCM 2010
Weaving Segment Analysis

HCM 6

HCM 2010
### Weaving Segment… Service Volumes

#### HCM 6

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<th>C</th>
<th>D</th>
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#### HCM 2010

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</table>
On-Ramp Segment Analysis

HCM 6

HCM 2010
On-Ramp Segments... Service Volumes

HCM 6

HCM 2010
Off-Ramp Segment Analysis

HCM 6

HCM 2010
Off-Ramp Segments… Service Volumes

<table>
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<th>Lanes</th>
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<th>Hourly Volume (vph/lh) in Both Directions</th>
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HCM 6

HCM 2010
Sources

► Highway Capacity Manual, A Guide for Multimodal Mobility Analysis, presented by Erik Ruehr, VRPA Technologies