Highway Capacity Manual - 6th Edition Overview

Course No: C03-065
Credit: 3 PDH

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COURSE DESCRIPTION:

The 6th Edition of the Highway Capacity Manual (HCM) was released in 2016 and is now the standard for both the Fundamentals of Engineering (FE) exam and Principles and Practice of Engineering (PE) exam. The title of this new HCM is "HCM 6th Edition: A Guide for Multimodal Mobility Analysis". This edition of the HCM provides methods for evaluating multimodal operations of freeways, highways, and arterial streets. The focus of this course is on providing a general overview of the content and organization of the HCM 6th edition and highlighting revisions/updates from the previous edition of the HCM (HCM 2010). The course does not provide detailed coverage of analysis methodology elements. Due to the volume of material covered in the HCM, some general knowledge of the document(s) may be helpful to completing this course, but it is not required.
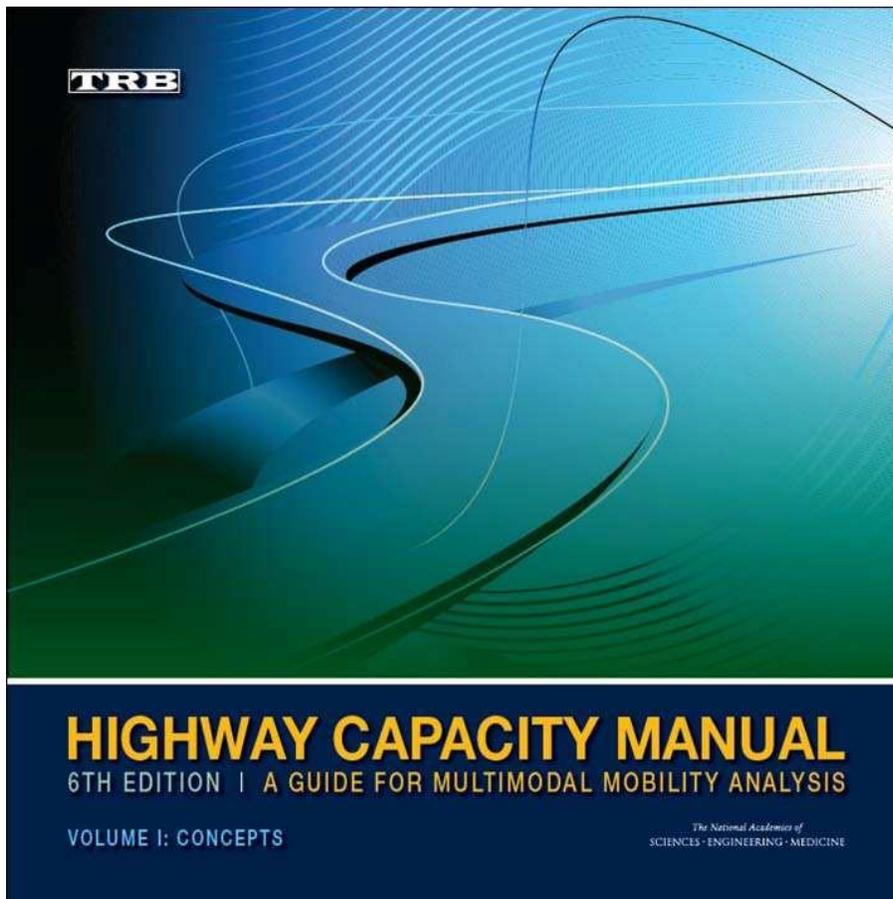

Figure 1. Highway Capacity Manual 6th Edition Cover
Source: Transportation Research Board

In this course, you will learn about:

- HCM edition history
- Why the HCM title was changed
- Why the need for a new HCM edition
- HCM 6th edition structure – revised chapter layout design to help practitioners use the manual
- New HCM analysis methodology capabilities
- Future directions/updates to the HCM

Source of figure is Scott or Leslie Washburn, unless noted otherwise.

Table of Contents

List of Figures

List of Tables

INTRODUCTION AND HISTORY

"The *Highway Capacity Manual, Sixth Edition: A Guide for Multimodal Mobility Analysis* (HCM) continues the manual's evolution from its original objective— providing methods for quantifying highway capacity—to its current form as a fundamental reference on concepts, performance measures, and analysis techniques for evaluating the multimodal operation of streets, highways, freeways, and off-street pathways. The Sixth Edition incorporates the latest research on highway capacity, quality of service, and travel time reliability, and improves the HCM's chapter outlines to help practitioners better understand basic concepts, computational steps, and outputs when applying HCM methods. These changes are designed to keep the manual in step with its users' needs and present times."

The Transportation Research Board's Highway Capacity and Quality of Service (HCQS) committee is responsible for development and maintenance of the HCM. The HCQS committee is comprised of the following subcommittees:

- freeways/multilane highways,
- two-lane highways,
- signalized intersections,
- unsignalized intersections,
- simulation applications,
- performance measures,
- user liaison,
- planning and preliminary engineering, and
- active transportation and demand management.

The first HCM was published in 1950. Since that time, new editions of the HCM have been published every 10-20 years. Previous HCM editions have had a year in the title, although they have also been referred to with an "edition" number. The previous HCM editions are listed in Figures 2-4.
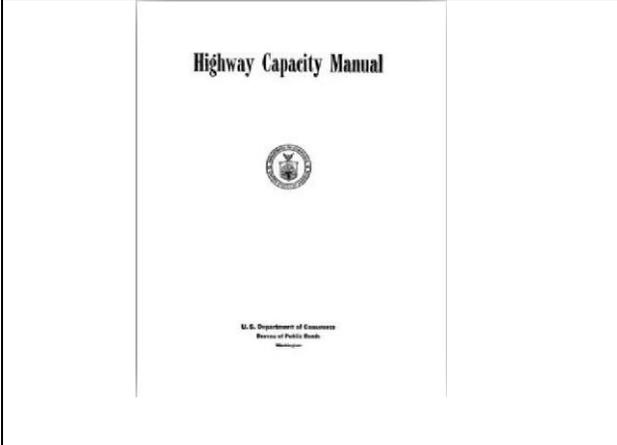
Highway Capacity Manual U.S. Department of Commerce Bureau of Public Roads Washington	HIGHWAY CAPACITY MANUAL 1965 National Academy of Sciences National Research Council
1950: Only 160 pages long, and focused on capacity related to the U.S. roadway network expansion after World War II.	1965: Introduction of the level of service (LOS) concept and bus transit chapter.

Figure 2. HCM Covers for 1950 and 1965 editions

Starting with the 1985 edition, results of new research on highway capacity and quality of service were presented for measuring roadway performance.
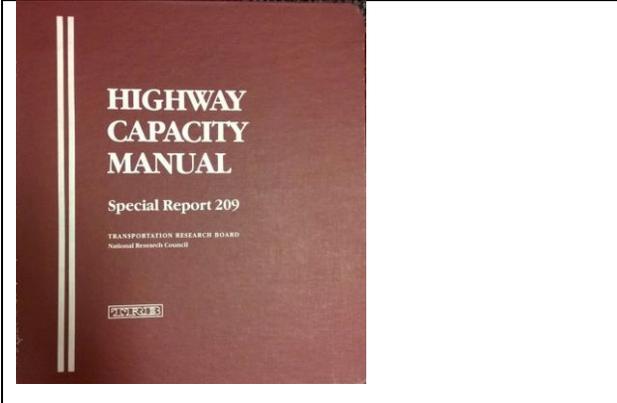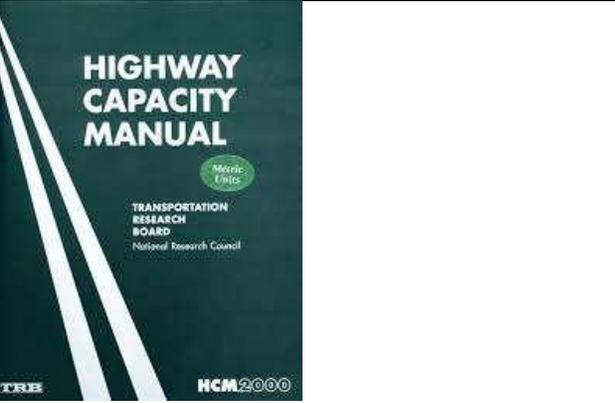
HIGHWAY CAPACITY MANUAL Special Report 209 TRANSPORTATION RESEARCH BOARD National Research Council	HIGHWAY CAPACITY MANUAL Metric Units TRANSPORTATION RESEARCH BOARD National Research Council TRB HCM2000
1985: Significant research incorporated adding pedestrians and bicycles chapters. Updates to this edition were made in 1992, 1994, and 1997	2000: Added new research with increase in volume and breadth.

Figure 3. HCM Covers for 1985 and 2000 editions

In order to make the material in the HCM 2000 easier to understand and follow, the HCM 2010 was reorganized with new material added from research projects. A broader range of performance measures were introduced for assessing the performance of transportation facilities and allroadway users.
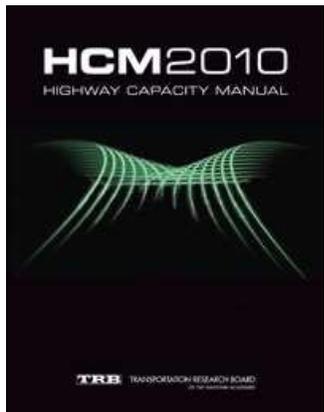
HCM2010 HIGHWAY CAPACITY MANUAL	2010: New research added, additional focus on non-automobile modes, four volumes. Reorganized to make it more clear and understandable.

Figure 4. HCM Cover for 2010 edition

The four volumes of the HCM 2010 include:
- Volume 1: Concepts,
- Volume 2: Uninterrupted Flow,
- Volume 3: Interrupted Flow, and
- Volume 4, Applications Guide.

Volume 4 was introduced online to facilitate issuing new and updated chapters.

NEED FOR A NEW EDITION

The interim chapters and soon-to-be-completed research needed to be integrated into the HCM in an organized manner for users to follow. New methodologies require complicated and rigorous calculations, where computer software is needed in order for practitioners to realistically implement the new methods. The new methods needed to be outlined and explained in detail in order for software developers to replicate the methods in software programs and so practitioners understand the calculations.

The content of the HCM has changed and evolved from simply highway capacity to include many facility type performance measures and multimodal analysis. Transportation professionals and decision-makers have not always been aware of these additional features. The analysis needs of transportation professionals changed, but the HCM title remained the same since 1950. Providing mobility for people and goods is transportation's most essential function. Thus, "A Guide for

Multimodal Mobility Analysis" captures the HCM's ability to quantify roadway performance across multiple dimensions and travel modes.

Also, in order for research to become implemented, it needs to be usable by practitioners. This now often means that methods need to be implemented in software. In order for software to be developed, the new methods need to be integrated with existing material and explained in sufficient detail that software developers can accurately replicate the method(s). At the same time, the need exists to explain the methods clearly to end users. As a result, a new edition of the HCM was necessary.

The new HCM consists of four dimensions:

- *Quantity of travel, the magnitude of use of a transportation facility or service;*
- *Quality of travel, users' perceptions of travel on a transportation facility or service with respect to their expectations;*
- *Accessibility, the ease with which travelers can engage in desired activities; and*
- *Capacity, the ability of a transportation facility or service to meet the quantity of travel demanded of it.*
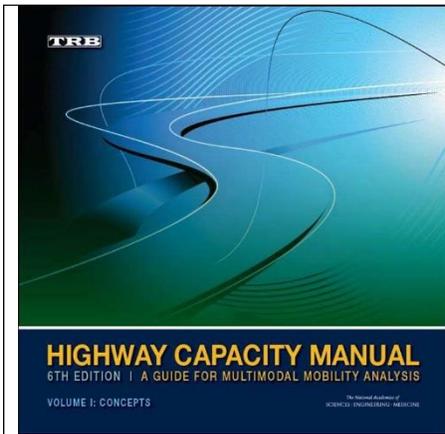
HCM 6th Edition revisions includes:

- *New title, to reflect how HCM content has expanded considerably beyond simply "highway capacity"*
- *Multiple performance measures*
- *Many facility types*
- *Multimodal analysis (autos, trucks, peds, bikes, buses)*
- *Added travel time reliability, and managed lane, work zone, and alternative intersection operations.*

Several million dollars in new research has been performed since the HCM 2010 was published. Some of these projects introduce new capabilities to the HCM:

- analyzing managed lane and work zone operations,
- measuring and predicting travel time reliability,
- analyzing alternative intersection forms, and
- evaluating roadway corridors incorporating a series of roundabouts.

Some projects update previous research to account for driver behavior and vehicle technology changes:

- truck analysis,
- roundabouts, and
- Active Traffic and Demand Management (ATDM).

Finally, some projects have focused on enhancing how all of this new and existing information can be effectively communicated to HCM users.

> ***New 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*
> - *SHRP2-L08: Travel time reliability*
> - *FHWA: ATDM, roundabouts, alternative intersections*

HCM 6TH EDITION ORGANIZATION

Overview

The HCM 2010 reorganized the manual to better serve its users. Basic information about each chapter's methods was provided in the printed chapters. Depending on the complexity of the method, this information could range from full step-by-step instructions to a higher-level overview of a method's inputs and flow of calculations. Supplemental online chapters, provide calculation details for the more complex methods and other information primarily of interest to a subset of HCM users. For some methods requiring iterative calculations, computational engine code listings provided in the online technical reference library offered the greatest level of detail. The online library also provides access to many of the research reports that document the development of HCM methods.

The HCM 6th Edition continues the evolution of how HCM information is presented to better serve the needs of today's users. As will be described in detail, methodological

> **Additional changes made for the HCM 6th Edition**
> - *Standardized chapter outlines*
> - *Presentation of the core chapter methodology, followed by extensions*
> - *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*

chapter outlines have been standardized. Summary tables are provided that list data requirements, potential data sources, suggested default values, and the sensitivity of results to particular inputs.

Many Volume 2 and 3 chapters now provide example results to help analysts determine the reasonableness of the results they obtain from software, to highlight a method's sensitivity to particular inputs, and to highlight possible methodological quirks (e.g., step-function behavior). They are not intended to substitute for an actual analysis, as the results depend on the assumptions used for other inputs, and are therefore deliberately printed at a size large enough to indicate trends but too small to pick out specific results.

Example problems have been moved to the supplemental chapters in online Volume 4 to free up space for new material in the printed HCM and allow access to all, including students who do not yet own an HCM. The creation of online Volume 4 allows the HCM to be updated more quickly after research is completed, compared to the typical multi-year wait for a new edition. Four such chapters; Active Traffic and Demand Management (ATDM) update (Chapter 35), Travel time reliability (Chapters 36, 37), and Managed lanes (Chapter 38) were released online in 2014. Each chapter was stand-alone and could not be used in conjunction with other new material (e.g., reliability of managed lanes).

Structure

The HCM is divided into four volumes: three printed and one online, just as for the HCM2010. Volume 1 houses concepts material, Volume 2 describes the methodologies for freeways and highways, while Volume 3 describes the methodologies for urban streets and off-street pedestrian and bicycle facilities. Volume 4 provides additional resources that support the material in the printed HCM.

General highway capacity and quality of service concepts were addressed in Volume 1. The typical Volumes 2 and 3 section layout consists of:

- Detailed chapter-specific concepts, such as service volume tables, have been added.
- Methodological chapters begin with a short introduction describing the purpose of the chapter, the information found within it, and cross-references to related material in other chapters.
- The core motorized vehicle methodology (e.g., two-lane highway analysis for motor vehicles) is presented next, including the method's strengths and limitations, circumstances when alternative tools might be considered, the method's required input data (and potential sources), and a description of the flow of calculations.
- Mode-specific methodologies (e.g., bicycle travel on two-lane highways), to better highlight the existence of these methods, are provided after the motorized vehicle methodology
- An applications section provides information about applying the chapter's method to planning and preliminary engineering, operations, and design analyses; often provides example results; and discusses the use of the method in conjunction with alternative tools, when available.
- A reference section for each chapter is provided.

Volume 1 - Concepts

Volume 1 introduces concepts that all HCM users should be familiar with before applying the manual. The chapter structure of Volume 1 is the same as the HCM 2010. Chapter 36 in online Volume 4 provides supplemental information that supports Volume 1; new information in this chapter includes guidance on measuring travel time reliability in the field and listings of reliability values for selected U.S. facilities.

Printed Chapters	*Online Chapters (Volume 4)*
1. HCM User's Guide	36. Concepts: Supplemental
2. Applications	
3. Modal Characteristics	
4. Traffic Operations and Capacity Concepts	
5. Quality-of-Service Concepts	
6. HCM and Alternative Analysis Tools	
7. Interpreting HCM and Alternative Tool Results	
8. HCM Primer	
9. Glossary and Symbols	

Volume 2 – Uninterrupted Flow

HCM Volume 2 provides concepts, performance measures, and analysis methodologies specific to uninterrupted-flow facilities such as freeways. Chapter 11 on freeway reliability analysis is new. In addition, the HCM 2010 chapters on basic freeway segments and multilane highways have been merged into a single chapter (Chapter 12), as these roadways share many similar characteristics. Chapters 25-28 in online Volume 4 provide material that supplements the Volume 2 chapters. In particular, the example problems for uninterrupted-flow facilities have been moved into the Volume 4 chapters.

Printed Chapters	*Online Chapters (Volume 4)*
10. Freeway Facilities Core Methodology	25. Freeway Facilities: Supplemental
11. Freeway Reliability Analysis (New)	26. Freeway and Highway Segments: Supplemental
12. Basic Freeway and Multilane Highway Segments	27. Freeway Weaving: Supplemental
13. Freeway Weaving Segments	28. Freeway Merges and Diverges: Supplemental
14. Freeway Merge and Diverge Segments	
15. Two-Lane Highways	

Volume 3 – Interrupted Flow

HCM Volume 3 provides concepts, performance measures, and analysis methodologies specific to interrupted-flow facilities such as urban streets and the intersections found along them.

Chapter 17, presenting methods for evaluating travel time reliability on urban streets and analyzing the effects of ATDM strategies, is new in the sixth edition. In addition, Chapter 23 has been expanded to cover alternative intersection and interchange types, such as diverging diamond interchanges and median U-turn intersections. Chapters 29-35 in online Volume 4 provide supplemental information, including example problems.

Printed Chapters

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

Online Chapters (Volume 4)

29. Urban Street Facilities: Supplemental
30. Urban Street Segments: Supplemental
31. Signalized Int.: Supplemental
32. Stop-Controlled Intersections: Supplemental
33. Roundabouts: Supplemental
34. Interchange Ramp Terminals: Supplemental
35. Pedestrian & Bikes: Supplemental
37. ATDM: Supplemental

Volume 4 (Online) – Concepts Supplemental

Volume 4 provides more than just access to supplemental chapters. Unlike the 2010 version, Volume 4 is open to all, including those who do not have a personal copy of the HCM. A free user account is required for access. It is available online at http://www.hcmvolume4.org/.

Figure 5. HCM 6th Edition, Volume 4: Application Guide
Source: Transportation Research Board

TRB's HCQS Committee periodically issues interpretations and errata for the HCM that result from user questions and feedback. These errata are posted in Volume 4. The technical reference library provides access to many of the source research reports that form the basis for the HCM analysis methods, including:

- The HCM Applications Guidebook: This is an online tool that demonstrates how the HCM can be applied to a project as it evolves from concept to design to implementation.
- The Planning and Preliminary Engineering Applications Guide: This demonstrates how HCM concepts and methods can be incorporated into planning-level evaluations.
- Discussion Forum: This allows HCM users to ask questions of the broader HCM community on proper application of the HCM methodologies, technical interpretations,

provide feedback about the HCM, etc. Committee members monitor and respond to the forum.

NEW METHODOLOGY CAPABILITIES: UNINTERRUPTED FLOW

Freeway Facilities (Chapters 10/25)

A number of new capabilities have been added to Chapter 10 as a result of new research, including core methods to analyze freeway work zones and managed lanes, including interactions between managed lanes and general-purpose lanes. Truck effects are discussed in Chapter 12 in the context of freeway segments, but carry over into a facilities analysis. Similarly, ATDM strategy evaluation is discussed in Chapter 11 in the context of a reliability analysis, but Chapter 10 provides guidance on evaluating the effects of these strategies on typical-day (average) freeway operations.

Finally, in light of the increasing availability of freeway travel time data from commercial providers, Chapter 10 provides guidance on matching those databases' sections to HCM segments.
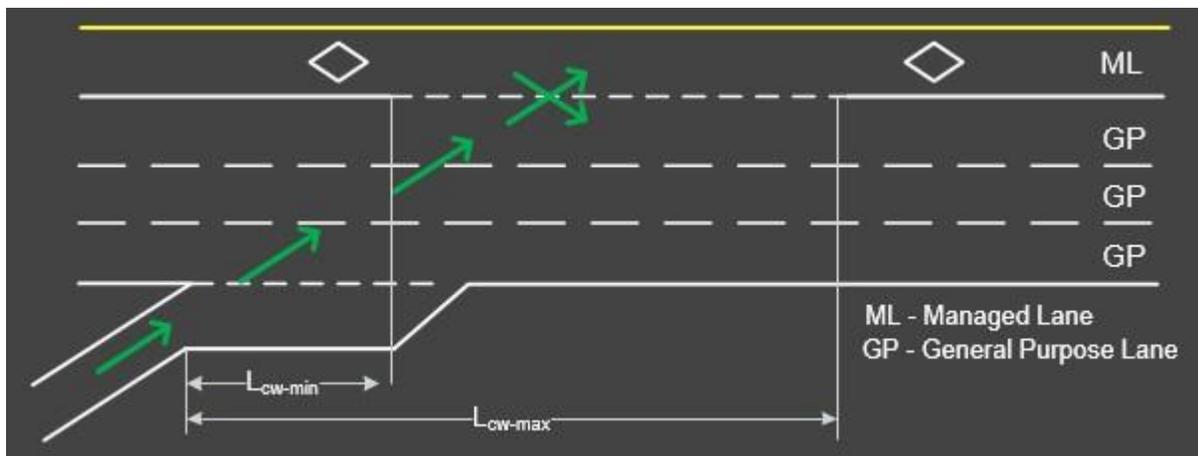
Figure 6. Freeway managed lanes and general-purpose lanes interaction

Chapter 25, Freeway Facilities: Supplemental, provides additional details related to the freeway facilities method. It describes how the method can be calibrated to match existing conditions through the application of capacity and speed adjustment factors. It also provides a method for evaluating truck performance on composite grades—that is, a series of consecutive grades with differing gradients. A new planning-level method, compatible with the Chapter 10 operational method, is presented. Finally, new example problems have been developed that demonstrate the new capabilities.

Freeway Reliability Analysis (Chapter 11)

A new Chapter 11, Freeway Reliability Analysis, integrates material from the former interim Chapters 36 and 37 with the other enhancements to the freeway facility methodology. Rather than evaluating only an "average" or "typical" day with good weather and no incidents, a reliability analysis looks at the effects of various things (for example, severe weather and incidents) that temporarily reduce a freeway's performance over the course of year or other long-term timeframe.

Each combination of demand level, weather condition, and incident and work zone effects during a given day is called a "scenario". A set of scenarios is randomly generated in software based on the probability of a particular condition occurring; one scenario is generated for each day within the "reliability reporting period" (for example, each non-holiday weekday throughout the year). The facility travel time is evaluated for each 15-minute analysis period within each scenario by repeatedly applying the Chapter 10 method, resulting in a distribution of travel times that can be used to generate a variety of useful reliability-related performance measures.

- Significant extension of material on travel time reliability and ATDM
- Applies HCM Chapter 10 method repeatedly with adjusted demands, capacities, lanes, and free-flow speeds to develop a travel time distribution
- Incorporates demand variation, weather, incident, work zone, and special event effects
- Produces a variety of reliability-related performance measures

Chapter 11 also describes how the effects of ATDM strategies on freeway reliability can be evaluated, including the process for developing reliability "scenarios" and for accounting for weather and incident effects, which has been improved. Supplemental Chapter 25 provides computational details and describes how the reliability method can be calibrated to existing conditions.

Freeway and Multilane Highway Segments (Chapters 12/26)

Figure 7. Freeway

Because the basic methods for evaluating freeway and multilane highway segments are very similar, they have been merged into one chapter for ease of presentation. Factors that distinguish multilane highway operation from freeway operation are still accounted for. To facilitate the integration of the new reliability, managed lanes, and work zone methods, a unified speed-flow equation has been developed applicable to both freeway and multilane highway segments, but the forms of the curves are different.

Other notable changes in Chapter 12 include updated truck passenger car equivalency tables, based on new research. Capacity and free-flow speed adjustment factors (CAFs and SAFs) are now the primary way of making adjustments to the speed-flow relationship. Changes to the multilane highway methodology include making the density at capacity value no longer dependent on free-flow speed and setting this value consistent with that for basic freeway segments (i.e., 45 pc/mi/ln) and providing speed-flow curves for 65 and 70 mi/h free-flow speeds.

The performance measure for level of service (i.e., service measure) remains unchanged (i.e., density). Thus, the equation for basic freeway and multilane highway segment remains.

$$D = \frac{v_p}{S}$$

where:

D = Density, in pc/mi/ln

v_p = Analysis flow rate in pc/h/ln, and

S = Average speed, in mi/h.

Unified speed-flow equation

Previous editions of the HCM defined separate equations for basic freeway segments and multilane highway segments, although they were largely similar. In the 6th edition of the HCM, a single equation has been defined for both basic freeway and multilane highway segments, with parameters whose values can vary by segment type. This new equation is referred to as the unified speed-flow equation, and is as follows:

$$S = FFS_{adj} \qquad\qquad\qquad v_p \leq BP$$

where:

FFS_{adj} = Adjusted free-flow speed, in mi/h, and is calculated as follows:

$FFS_{adj} = FFS \times SAF$ for basic freeway segments
$FFS_{adj} = FFS$ for multilane highway segments

$$S = FFS_{adj} - \frac{\left(FFS_{adj} - \dfrac{c_{adj}}{D_c}\right)\left(v_p - BP\right)^a}{\left(c_{adj} - BP\right)^a} \qquad BP < v_p \leq c_{adj}$$

where:

c_{adj} = Adjusted capacity, in pc/h/ln, and is calculated as follows:

$c_{adj} = c \times CAF$ for basic freeway segments
$c_{adj} = c$ for multilane highway segments

v_p = 15-min passenger car equivalent flow rate, in pc/h/ln,
BP = Linear to curvilinear flow rate breakpoint value in pc/h/ln,
D_c = Density at capacity (45 pc/mi/ln), and
a = Exponent value.

The unified speed–flow equation defines a region where the speeds are equal to the free-flow speed and a region where speeds drop until capacity is reached, which is defined as occurring at a density of 45 pc/mi/ln for both freeways and multilane highways. A breakpoint flow rate marks the boundary between the two regions. The exponent *a*, which defines the shape of the curve beyond the breakpoint flow rate, is different for freeways and multilane highways. The capacity for a given free-flow speed is also different for freeways and multilane highways. Both free-flow speeds and capacities can be adjusted to reflect the effects of severe weather, incidents, work zones, and special events, or to calibrate the HCM speed-flow curves to local conditions. An example illustration of the unified speed-flow equation is shown in Figure 8.
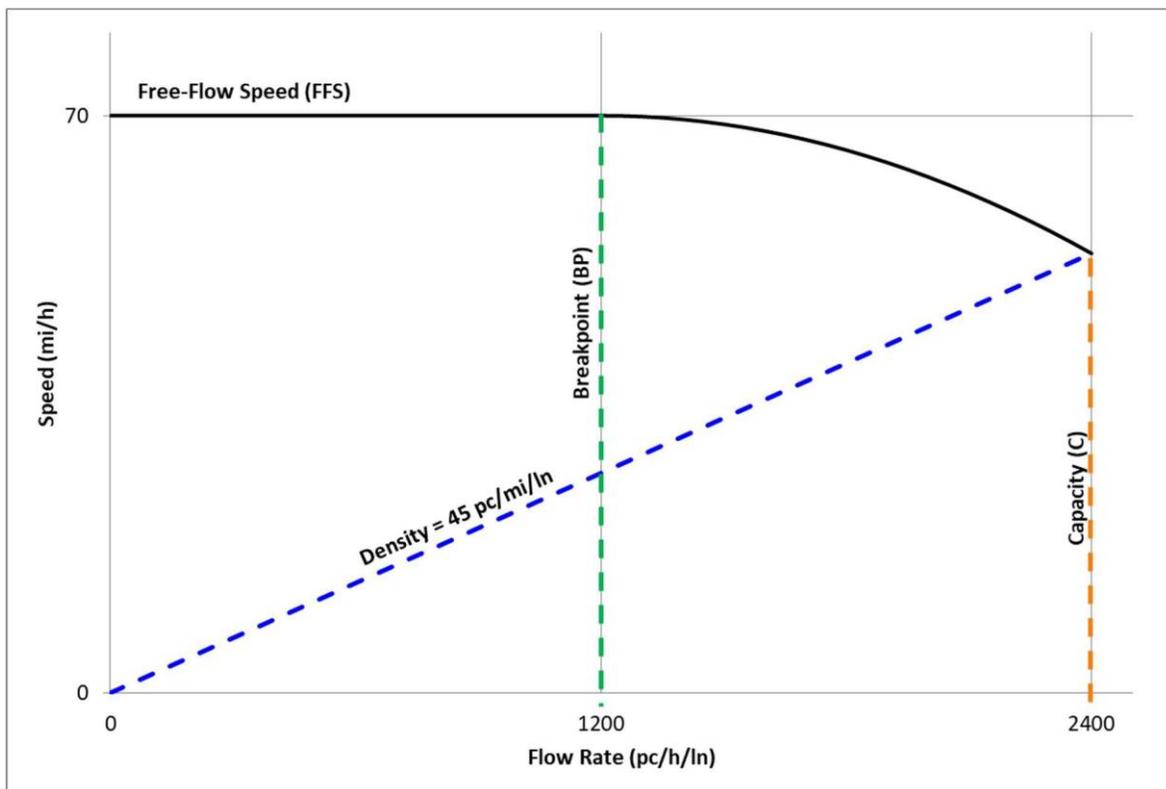
Figure 8. Unified speed-flow equation

The calculation or assignment of the parameter values, specific to each segment type are as follows:

Capacity (*c*)

For freeway segments:

$$c = \text{Min}\left[2200 + 10\left(FFS - 50\right), 2400\right] \qquad 55 \leq FFS \leq 75$$

For multilane highway segments:

$$c = \text{Min}\left[1900 + 20\left(FFS - 45\right), 2300\right] \qquad 45 \leq FFS \leq 70$$

Breakpoint (*BP*)

For freeway segments:

$$BP = \left[1000 + 40\left(75 - FFS_{adj}\right)\right] \times CAF^2 \qquad 55 \leq FFS \leq 75$$

For multilane highway segments:
1400 pc/h/ln

Exponent *a*

For freeway segments: 2.0
For multilane highway segments: 1.31

Roadway base conditions for a basic freeway segment are defined by the HCM as 12-ft minimum lane widths, 6-ft minimum right-shoulder clearance, only passenger cars, 6 miles or greater interchange ramp spacing and level terrain (2% grade or less). The following figure shows some example speed-flow relationships based on the unified speed-flow equation and the parameter values for basic freeway segments.
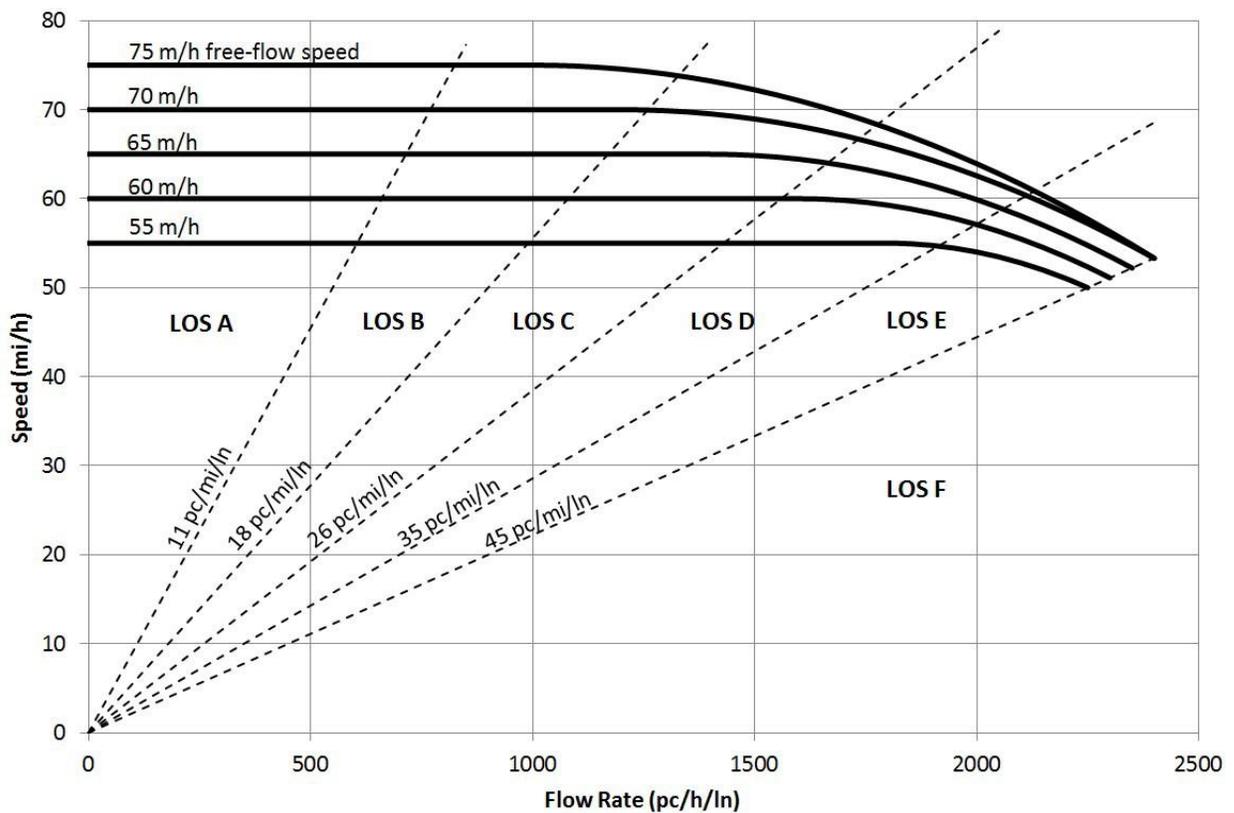
Figure 9. Basic Freeway Segment Speed-Flow Curves

Roadway base conditions for a multilane highway are defined by the HCM as 12-ft minimum lane widths, 12-ft minimum total lateral clearance, only passenger cars, no access points, divided highway, free-flow speed of 60 mi/h or more and level terrain (2% grade or less). The LOS E–F density threshold has been revised to use 45 pc/mi/ln for all free-flow speeds (the same value for basic freeway segments), rather than varying by free-flow speed as in the HCM 2010. The unified equation parameter calculations also allow speed-flow curves to be developed for free-flow speeds up to 70 mi/h, versus a maximum free-flow speed of 60 mi/h for the HCM 2010. The following figure shows some example speed-flow relationships based on the new unified speed-flowequation and the parameter values for multilane highway segments.
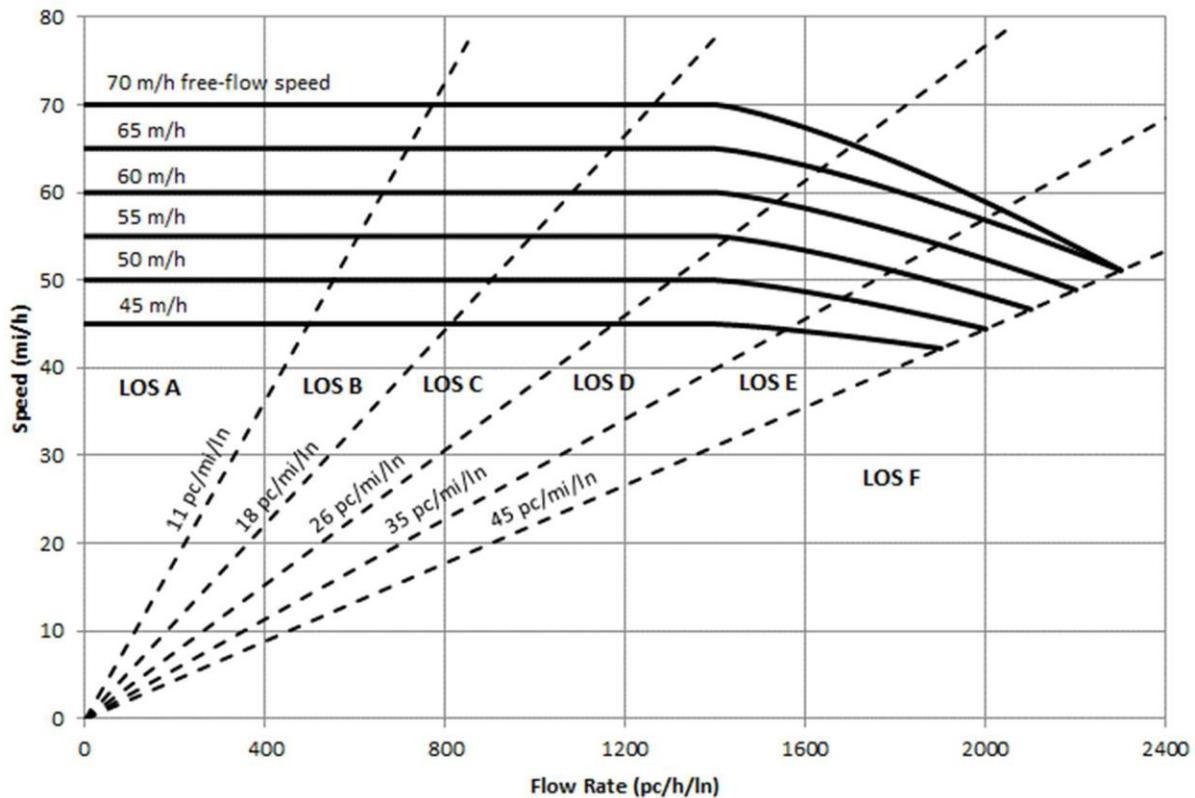
Figure 10. Multilane Highway Segment Speed-Flow Curves

The bicycle analysis methodology for multilane highways is identical to the method for two-lane highways, and users are referred to Chapter 15 for the details of that method.

Analysis Flow Rate

The analysis flow rate equation no longer includes the driver population factor (f_p). The impact to the traffic stream density due to driver population is now handled by revising the speed-flow relationship, by applying adjustments to the free flow speed (through the SAF) and the capacity (through the CAF). More information on this topic is provided in Chapter 26, exhibit 26-9.

$$v_p = \frac{V}{PHF \times N \times f_{HV}}$$

where:

v_p = 15-min passenger car equivalent flow rate in pc/h/ln,

V = hourly volume in veh/h,

PHF = peak-hour factor,

N = number of lanes, and

f_{HV} = heavy-vehicle adjustment factor.

Passenger Car Equivalents (PCE) for Heavy Vehicles (E_T)

The categorization of heavy vehicles changed. In the HCM 2010, heavy vehicles were categorized as either large trucks or buses (the "Trucks" category) or as recreational vehicles (the "RV's" category). Likewise, there were separate passenger car equivalent (PCE) values for each category, E_T and E_{RV}, for the Trucks and RV's categories respectively. In the HCM 6th edition, the categories for heavy vehicles now consist of single-unit trucks (SUTs) and tractor-trailers (TTs). Buses and RV's are considered to be in the SUT category (generally, FHWA classes 4 and 5). Single-unit trucks with three or more axles and tractor + semi-trailer combinations are considered to be in the TT category (generally, FHWA classes 6 and above). There is no longer separate PCE values for the different heavy vehicle categories; thus, the new equation for calculating the heavy vehicle adjustment factor only includes an E_T parameter, rather than E_T and E_{RV} parameters, as follows:

$$f_{HV} = \frac{1}{1 + P_T \left(E_T - 1 \right)}$$

f_{HV} = heavy-vehicle adjustment factor,

P_T = proportion of heavy vehicles in the traffic stream, and

E_T = passenger car equivalent for heavy vehicles.

Considering the heavy vehicle category, either SUT or TT, in determining a single PCE value (E_T) depends on the terrain classification used for analysis. If a general terrain classification is used (i.e., level or rolling terrain), only the overall percentage of heavy vehicles in the traffic stream is considered and not the specific SUT/TT split. The PCE values for a general terrain classification (HCM Exhibit 12-25) analysis are as follows:

E_T for level terrain is 2.0 (formerly 1.5 in HCM 2010)

E_T for rolling terrain is 3.0 (formerly 2.5 in HCM 2010)

It should also be noted that the "mountainous" general terrain classification in the HCM 2010 has been removed. For this situation, where trucks are likely to operate at crawl speed for significant distances or frequent intervals, a new analysis approach is included, referred to as the "mixed-flow model". This approach, detailed in Chapters 25 and 26, is the recommended approach for analyzing such conditions. However, such terrain conditions can be analyzed using the specific-terrain component of the methodology, albeit with likely less accuracy than the mixed-flow model. For terrain that is not considered level or rolling, but trucks will operate at speeds higher than crawl speed, the specific terrain methodology, described as follows, should provide reasonably accurate results.

- Basic freeway segments and multilane highways merged into one HCM Chapter, 12
- One unified speed–flow equation applicable to both freeway and multilane highway segments, but the forms of the curves are different
- Revised truck PCE values
- Increased emphasis on calibration through capacity and speed adjustment factors (CAFs and SAFs)
- Driver population effects now handled by CAFs and SAFs

When the analysis segment consists of terrain that cannot be classified as general terrain (i.e., level or rolling), it should be analyzed with its specific terrain characteristics, which consider the slope and length of segment. Additionally, the percentage split between the SUT and TT categories of heavy vehicles in the traffic stream must be considered. PCE tables are provided in the HCM 6th edition for three different truck category splits: Exhibit 12.6 for 30% SUTs/70% TTs, Exhibit 12.7 for 50% SUTs/50 TTs, and Exhibit 12.8 for 70% SUTs/30% TTs. For splits less than 30/70 (e.g., 20/80) the values in Exhibit 12.6 should be used. For splits greater than 70/30 (e.g., 75/25), the values in Exhibit 12.8 should be used. For other splits (and not 50/50), PCE values should be interpolated linearly between the relevant tables.

Additionally, a new method for estimating capacity from field measurements and updated example problems can be found in supplemental Chapter 26.

Other Freeway Segments

Weaving (Chapter 13/27)

The core methodology from the HCM 2010 and HCM 6th Edition (Chapter 13) is unchanged. The new edition includes guidance on how to apply the weaving analysis procedure for segments that provide access to/from managed lanes adjacent to general purpose lanes, such as illustrated in Figure 10. It also includes guidance on how to apply the weaving analysis procedure to a managed lane weaving segment, such as illustrated in Figure 11.
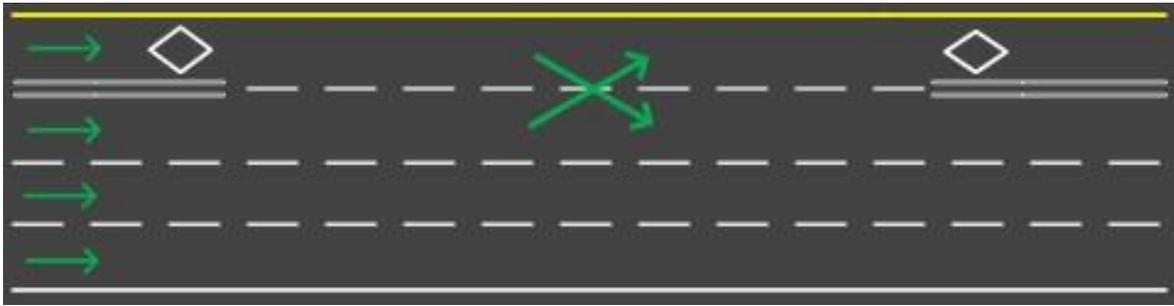
Figure 11. Weaving in a Managed Lane Access Segment
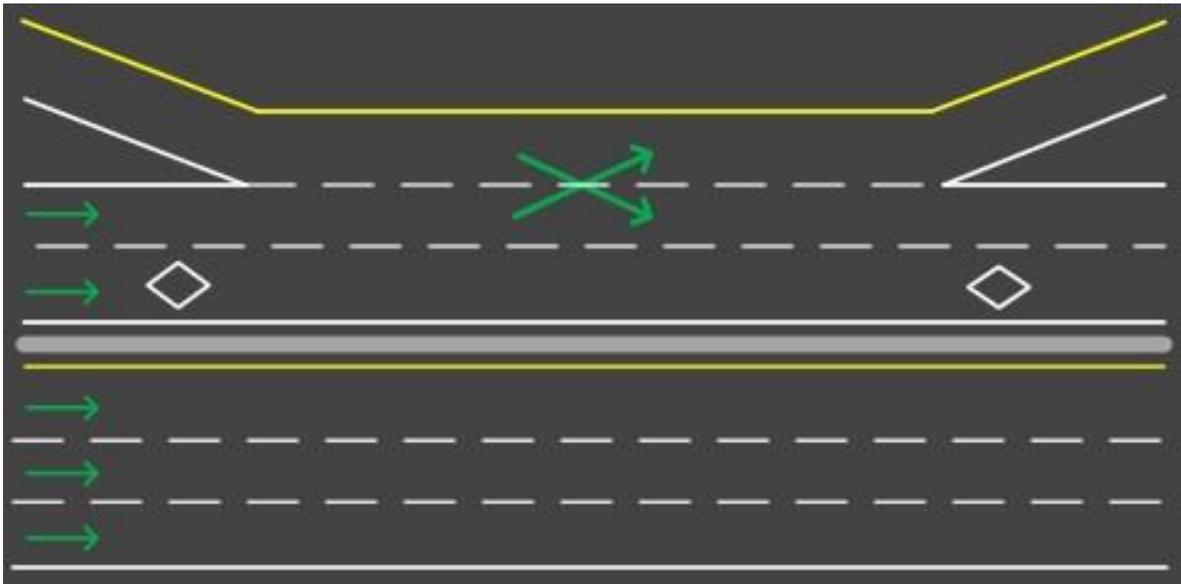
Figure 12. Managed Lane Weaving Segment

There is an emphasis on the use of CAFs and SAFs for calibration. Chapter 27 provides new example problems demonstrating the new capabilities.

Merge/Diverge (Chapter 14/28)

The core methodology from the HCM 2010 and HCM 6th Edition (Chapter 14) is unchanged. The chapter provides new formalized guidance for aggregating merge and diverge segment densities for segments with three or more lanes The new edition includes guidance on how to apply the merge/diverge analysis procedures to merges and diverges on managed lanes, such as illustrated in Figures 12 and 13.
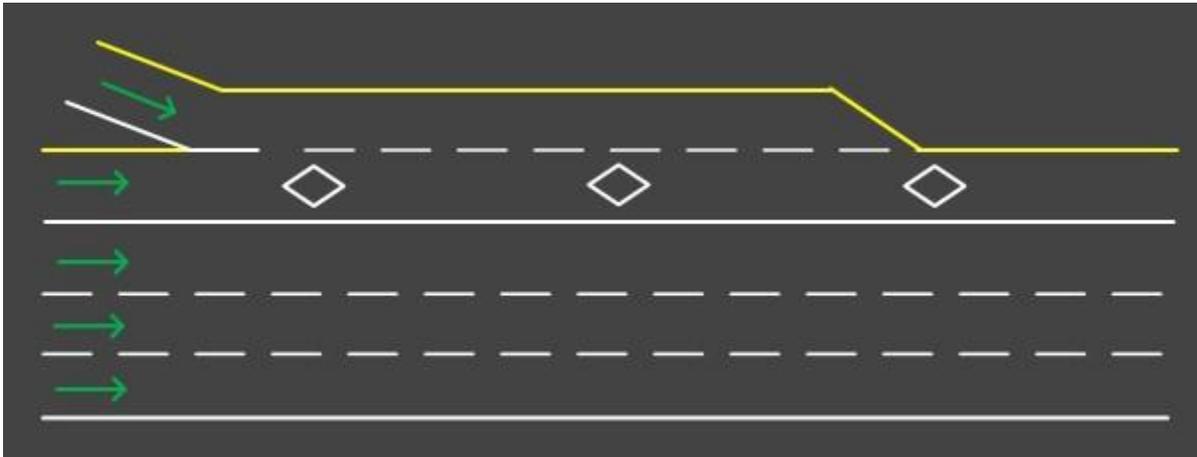
Figure 13. Managed Lane Merge Example
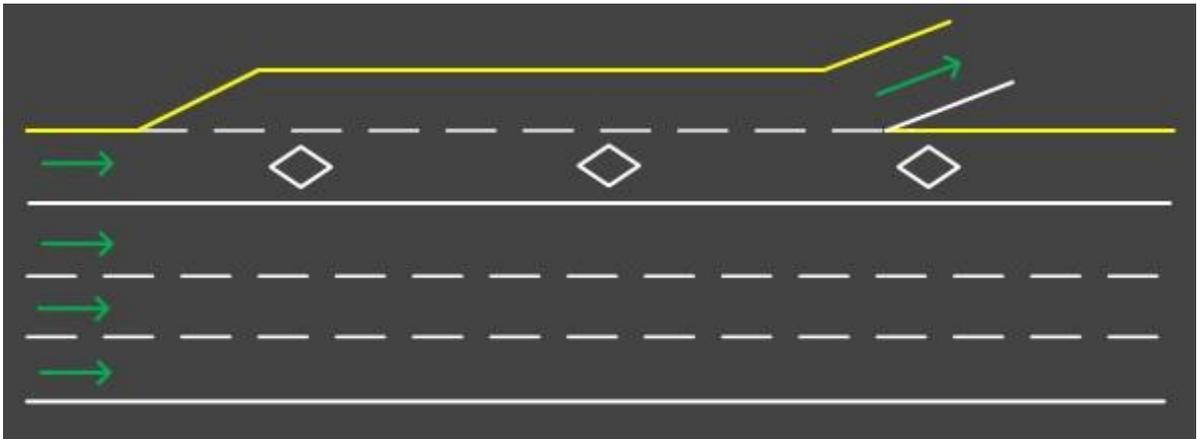
Figure 14. Managed Lane Diverge Example

Again, emphasis on the use of CAFs and SAFs for calibration is provided. Chapter 28 provides new example problems demonstrating the new capabilities.

Two-Lane Highways (Chapter 15/26)

Figure 15. Two-Lane Highway Segment

No significant changes have been made to the method. Some calculation steps that previously were always skipped (because they were not needed to calculate LOS for a particular two-lane highway class) have been made optional, to clarify that they can be applied if the user is interested in determining the performance measure calculated by that step. This chapter's example problems now appear in Chapter 26.

It should be pointed out that NCHRP Project 17-65 (Washburn et al., 2018) developed a new two-lane highway analysis methodology. This project was completed in March 2018 and is currently going through the review process with the Highway Capacity and Quality of Service Committee for potential adoption and inclusion in the HCM.

NEW METHODOLOGY CAPABILITIES: INTERRUPTED FLOW

Urban Street Facilities (Chapters 16/29)

The service measure has been changed from 'average travel speed as a percent of free-flow speed' to just 'average travel speed'. This was done to make the service measure more intuitive to practitioners and because the previous service measure resulted in LOS results that were more sensitive to rounding effects in the calculations. LOS F, in addition to the average speed thresholds, also applies anytime the d/c ratio exceeds 1.0. Table 1 provides the new service measurethresholds. Example problems have been moved to Chapter 29.

Table 1. Travel Speed Threshold by Base Free-Flow Speed (mi/h)

LOS	Travel Speed Threshold by Base Free-Flow Speed (mi/h)						
	55	**50**	**45**	**40**	**35**	**30**	**25**
A	> 44	> 40	> 36	> 32	> 28	> 24	> 20
B	> 37	> 34	> 30	> 27	> 23	> 20	> 17
C	> 28	> 25	> 23	> 20	> 18	> 15	> 13
D	> 22	> 20	> 18	> 16	> 14	> 12	> 10
E	> 17	> 15	> 14	> 12	> 11	> 9	> 8
F	≤ 17	≤ 15	≤ 14	≤ 12	≤ 11	≤ 9	≤ 8

Source: HCM

Urban Street Reliability and ATDM (Chapter 17/37)

Chapter 17 is a new chapter that integrates the ATDM material previously found in Chapter 35 and the urban street travel time reliability material previously found in interim HCM Chapters 36 and 37. Similar to freeway reliability analysis, the urban street reliability method repeatedly applies the core Chapter 16 facility method with varying demands, capacities, free-flow speeds, and number of lanes that reflect the variations in demand and the effects of severe weather, incidents, work zones, and special events over a long timeframe (up to a year). Due to complexity in the analysis for the urban street reliability method can only practically be implemented through software. New conceptual information for ATDM and techniques for evaluating ATDM strategies can be found in Chapter 17.

Urban Street Segments (Chapters 18/30)

The urban street segment service measure has been changed to average travel speed, and the LOS A/B threshold has been reduced to the equivalent of 80% of free-flow speed, same as urban street facilities. New and improved methods include the capability to evaluate segments with midsegment lane blockage.
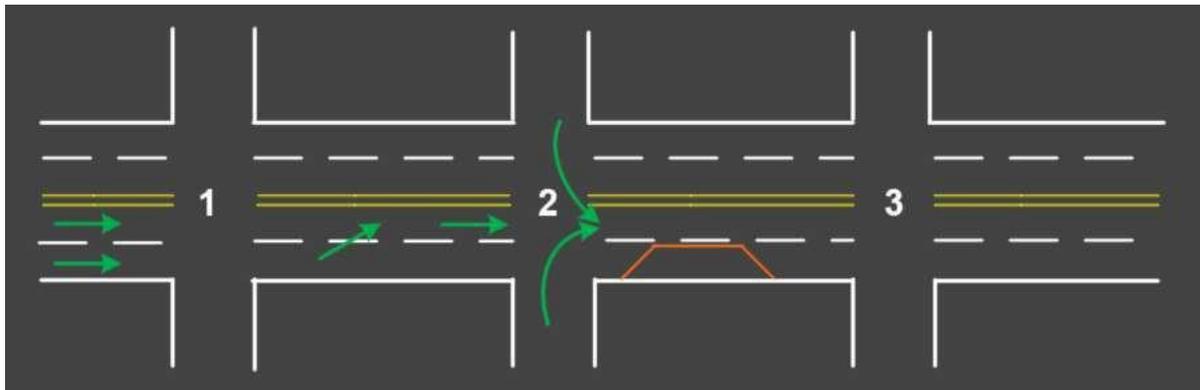
Figure 16. Midsegment Lane Blockage Depiction

Urban street segments also includes an improved procedure for predicting segment queue spillback time, and a new adjustment factor for parking activity that affects free-flow speed estimation as well as procedures for evaluating segments with roundabouts at one or both directions.
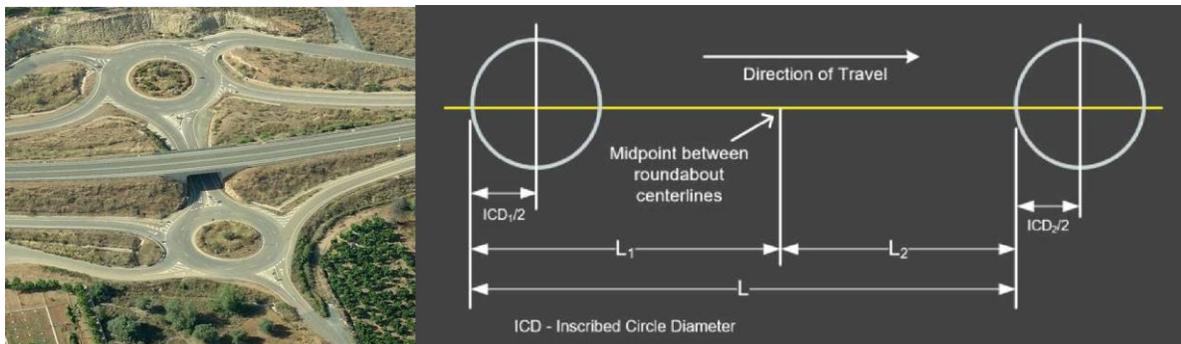

Figure 17. Roundabout in both directions

Supplemental Chapter 30 provides calculation details for estimating segment travel time when roundabouts are located at one or both ends of the segment.

Pedestrian and bicycle LOS scores are now weighted by link travel time instead of link length, to reflect the amount of time these modes experience conditions on the link. There are also some changes to the bicycle and bus default values.

The unsignalized conflicts factor term for the bicycle mode has been revised to consider 20 conflict points per mile as the base (no-effect) condition, rather than 0 conflict points per mile. Default transit vehicle acceleration and deceleration rates have been added.

Right-turn-on-red vehicles are incorporated into the volume-balancing method for flows into and out of a segment.
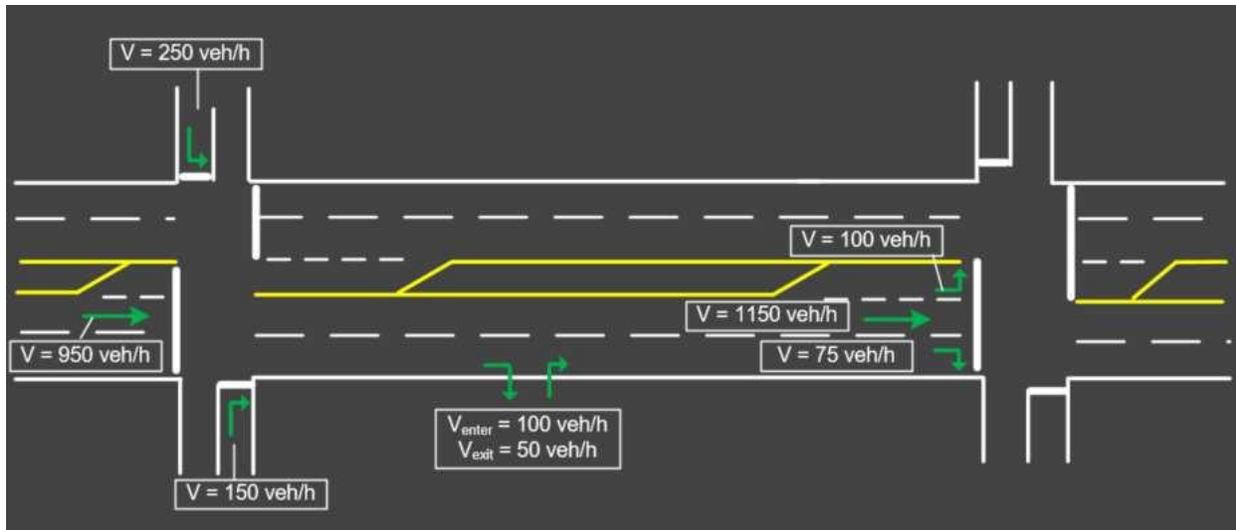

Figure 18. Right-turn-on-red vehicles incorporated into volume-balancing method

Supplemental Chapter 30 provides calculation details, a planning method for urban street segments, and updated example problems.

Signalized Intersections (Chapters 19/31)

Figure 19. Signalized Intersection

The saturation flow adjustment factors for heavy vehicles and grade are now combined into a single factor. The delay of unsignalized movements at a signalized intersection are now considered when calculating approach and intersection delay where the user must supply these delay values. New saturation flow adjustment factors are provided for intersection work zone presence, midsegment lane blockage, and downstream spillback.
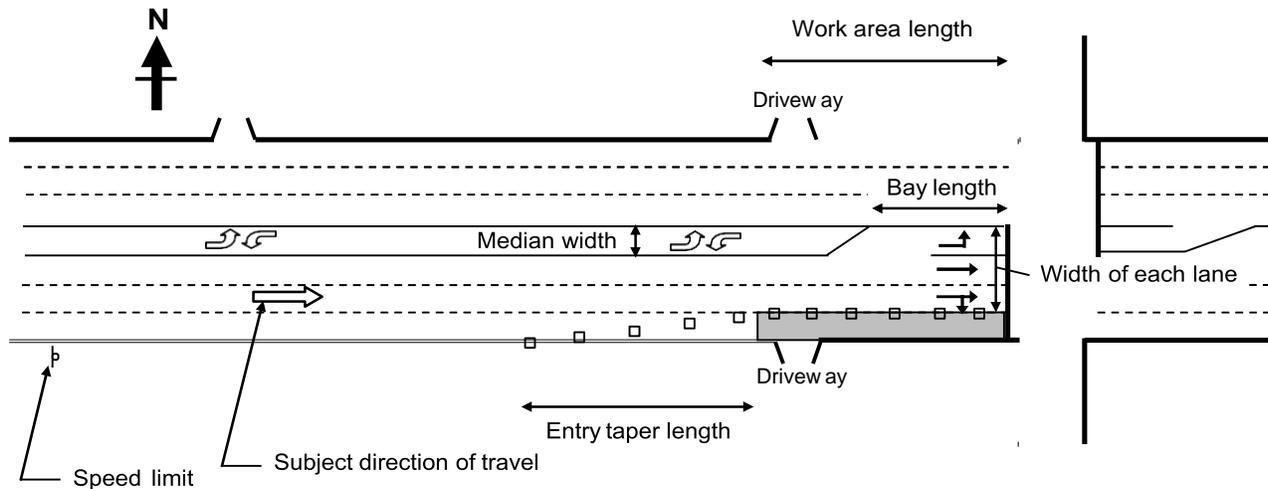
Figure 20. Work zone presence at approach to signalized intersection
Source: HCM

Chapter 31 provides an improved planning method with reduced input data requirements outlined in a worksheet. The simplified calculations are demonstrated in example problems.

Two-Way Stop-Controlled Intersections (Chapters 20/32)

There are no significant changes in the two-way stop control methods, but how the peak hour factor (PHF) should be applied is clarified. Example problems have been moved to Chapter 32.

All-Way Stop-Controlled Intersections (Chapters 21/32)

There are no significant changes in the all-way stop control methods, but how the peak hour factor (PHF) should be applied is clarified. Example problems have been moved to Chapter 32.
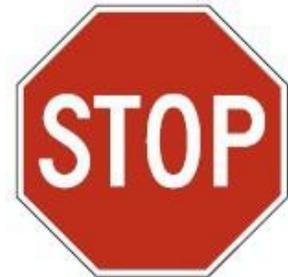
Roundabouts (Chapters 22/33)

Roundabout capacity models have been updated as a result of new research in *NCHRP 03-100: Roundabouts in corridors* as well as a new calibration procedure is provided. Additionally, clarification of how the peak hour factor (PHF) should be applied. Example problems have been moved to Chapter 33.
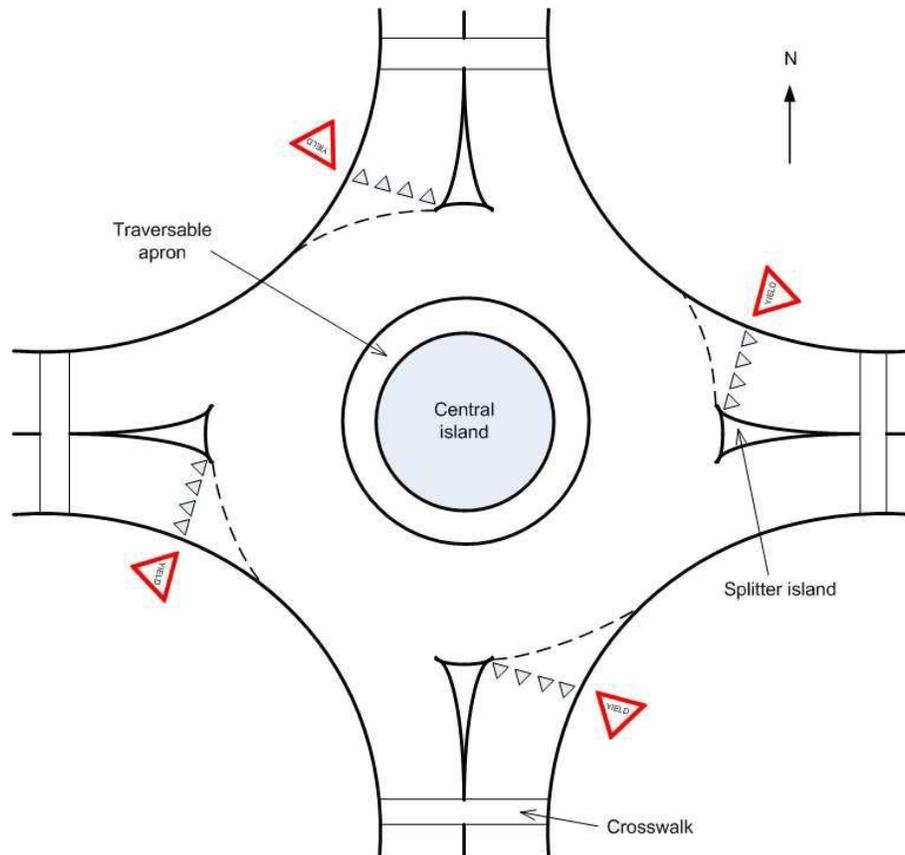
Figure 21. Roundabout Example

Ramp Terminals and Alternative Intersections (Chapter 23/34)

The former Interchange Ramp Terminals chapter has been expanded to include a greater variety of distributed intersections. Distributed intersections include those with two or more intersections with close spacing and displaced or distributed traffic movements that are operationally interdependent and are best analyzed as a single unit.

Chapter 23 now covers both interchange ramp terminals and alternative intersection forms. It is divided into three parts: distributed intersection concepts, interchange ramp terminal evaluation, and alternative intersection evaluation. The interchange ramp terminal forms addressed in Chapter 23 are the different varieties of partial cloverleaf, diamond, single point urban, and diverging diamond interchanges.

| Partial Cloverleaf	Diamond
Single Point Urban Interchange (SPUI)	Diverging Diamond Interchange (DDI)
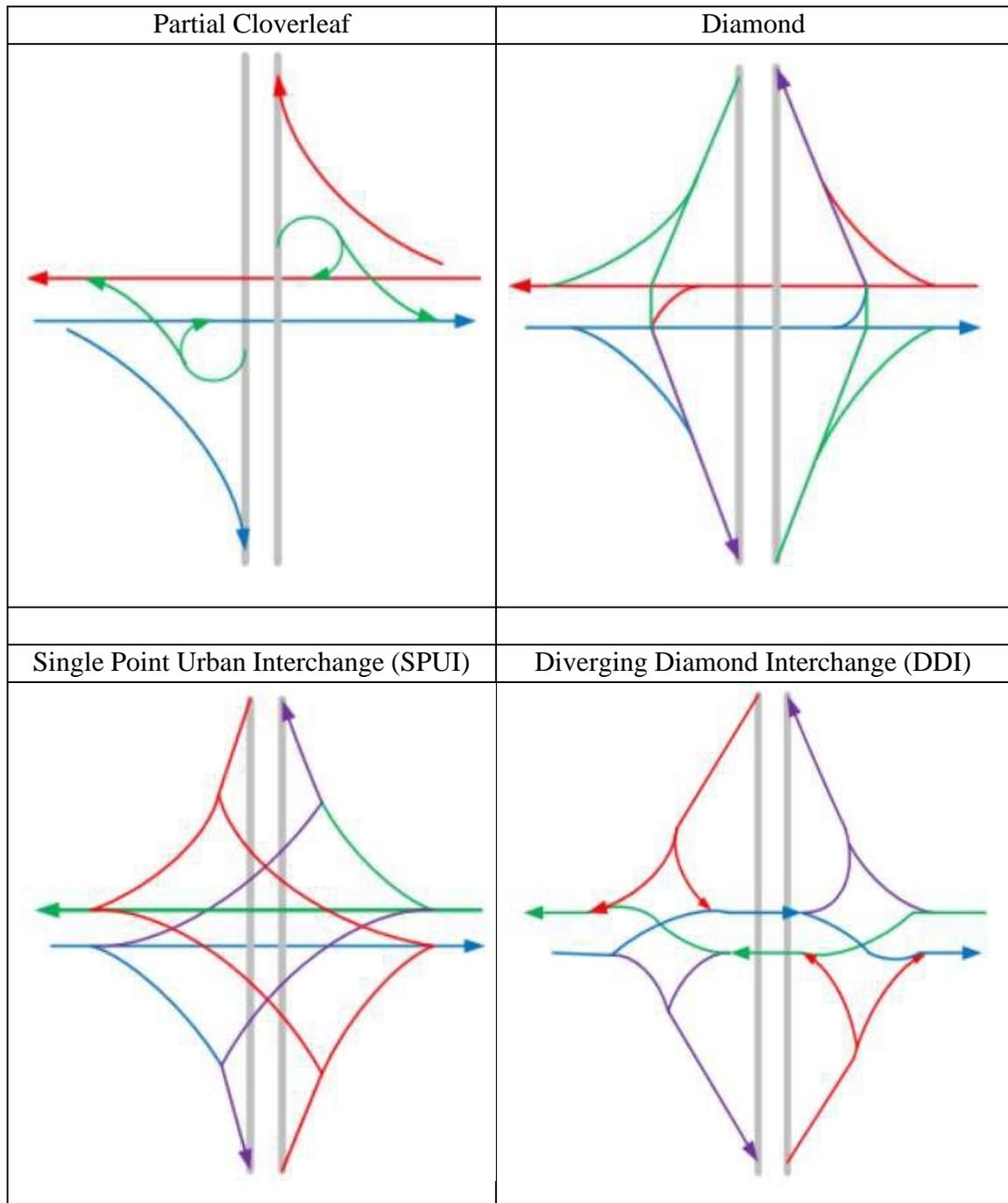
Figure 22. Ramp Terminal Forms

The distributed intersection forms addressed in Chapter 23 are displaced left-turn, restricted-crossing U-turn, and median U-turn intersections.

| Continuous Flow Intersection/ Displaced Left Turn	Restricted Crossing U-Turn (RCUT)
Median U-Turn (MUT)	
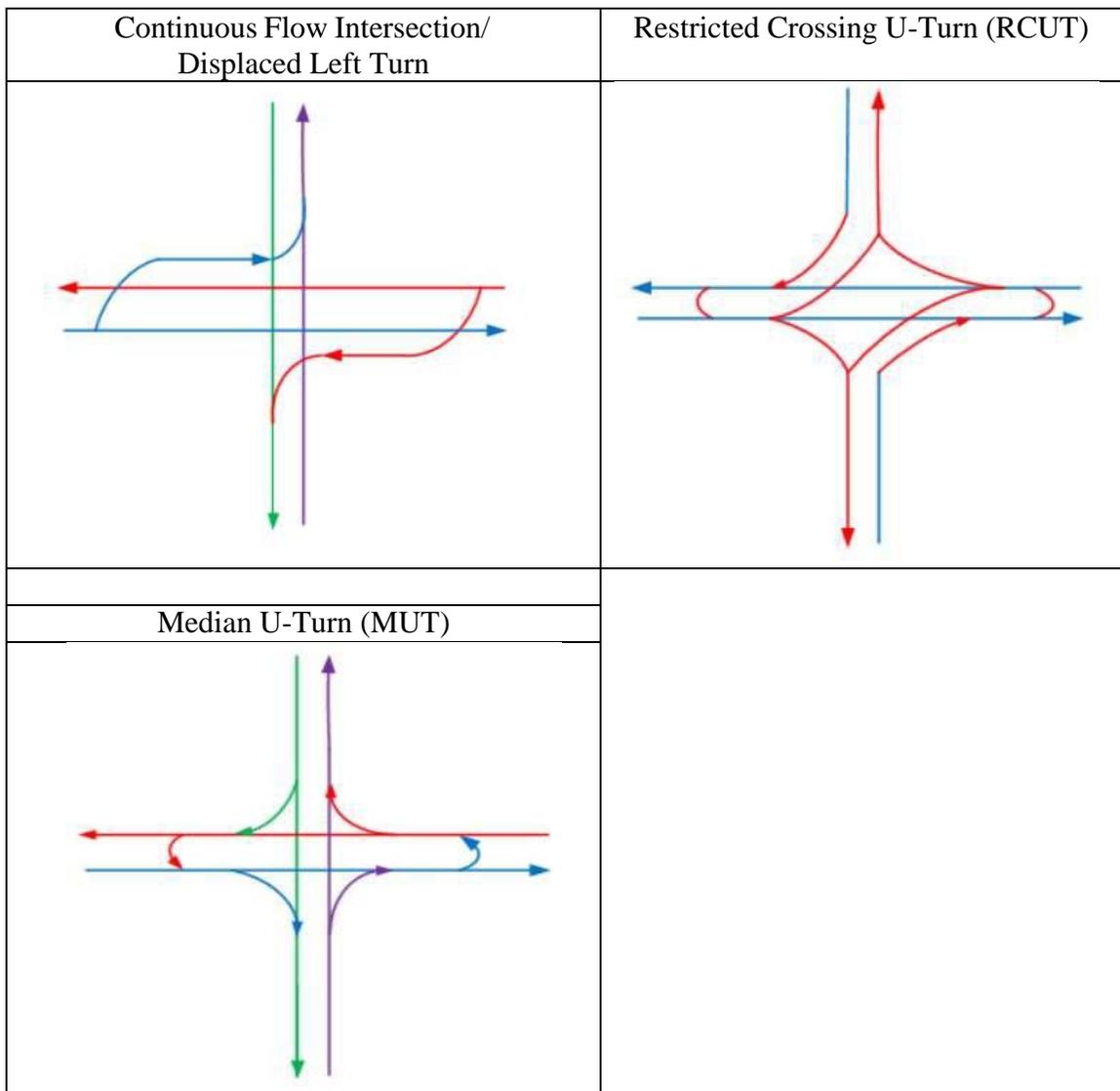
Figure 23. Intersection Forms

Both ramp terminals and alternative intersections now use a new service measure, experienced travel time (ETT), that is intended to allow these intersections' performance to be compared on an equivalent basis with other intersection forms. ETT includes the sum of average control delays experienced by a given movement, plus any extra distance travel time the movement may experience as a result of being rerouted.
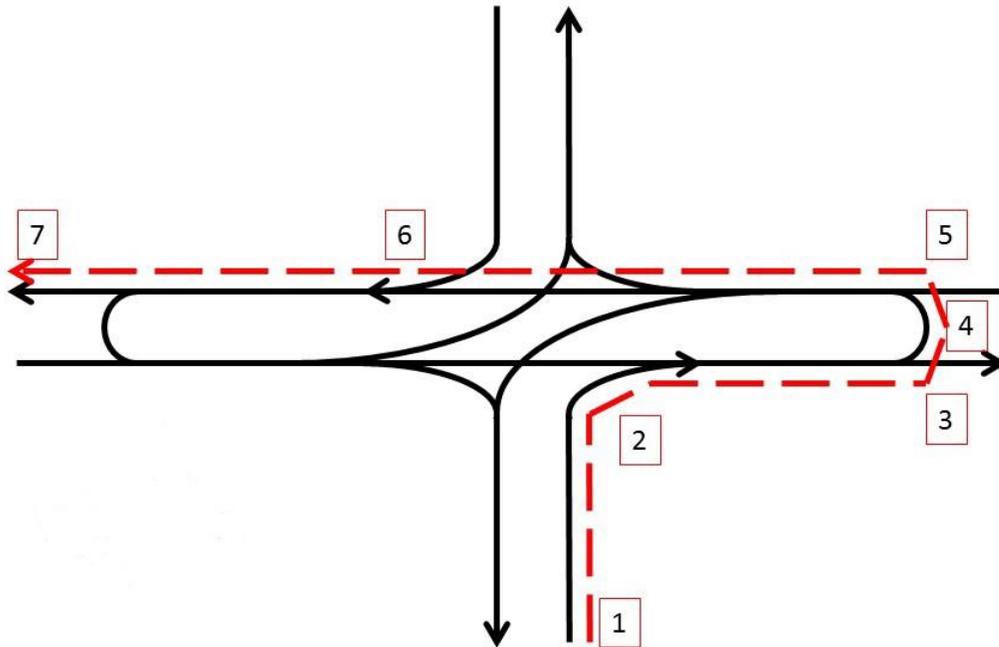

Figure 24. Example of experienced travel time at an RCUT intersection
Source: HCM

New and updated example problems are located in supplemental Chapter 34.

Off-Street Pedestrian and Bicycle Facilities (Chapter 24)

Some variable names and equations have been changed to improve their understandability without affecting results to the off-street pedestrian and bicycle facility calculations found in Chapter 24. Additional guidance has been provided on applying the methods and interpreting results such as graphs that demonstrates how the bicycle LOS score for a shared off-street path is influenced by path width and two-directional path volume. The new Chapter 35 provides example problems.

Advanced Traffic and Demand Management (ATDM) (Chapter 37)

Chapter 37 includes the emerging topics chapter in HCM 2010 that was later updated as a result of FHWA research. Most of the material has been integrated into Chapters 11 (freeways) and 17 (urban streets) but Chapter 37, ATDM: Supplemental provides descriptions of common ATDM strategies, guidance on analyzing shoulder lane, median lane, and ramp metering strategies and guidance on designing an ATDM program.

FUTURE UPDATES

Looking ahead, there are several areas the HCQS committee will be focused on for potential additions/revisions to the HCM, such as:

- Impacts on capacity and operations as a function of advances in connected and autonomous vehicles.
- Capacity measurement: Many default values for capacity, and methods for estimating capacity, have been included in the HCM over the years. However, little guidance was provided for methods/techniques for measuring capacity from the field. Some improvement in this area was made for the HCM 6th edition, but this will continue to be a major focus for the committee, so that transportation agencies can determine capacity values most appropriate for their region.
- ATDM adjustment values: Many of the adjustment factor values provided for the ATDM methodology are based on minimal research and/or expert opinion. The FHWA is putting considerable resources into quantifying the impacts of various ATDM strategies, and the HCQS committee will update the HCM with these results as they become available.
- Planning methods: Many of the operational analysis methods in the HCM have become quite complicated and difficult, if not impossible, to solve without software. Many transportation agencies, particularly those that include large rural areas, still desire simple-to-apply analysis methods that will give reasonably accurate results for planning purposes. The HCQS committee is focused on the continued development of planning methods, derived from the full operations methods.
- Simulation: While the HCM methods are not intended to compete, per se, with simulation methods, the increased complexity of the HCM methods over the last 15 years, combined with the near ubiquity of simulation, has blurred the line on which approach is most applicable for a given analysis situation. Some guidance to help practitioners determine when simulation might be a more appropriate approach than the HCM was provided in the HCM 2010 and 6th editions, but there is still much more room for improvement in this area. This will be a continued area of focus for the HCQS committee.
- Two-lane highway analysis: If the new two-lane highway analysis methodology, developed from the aforementioned NCHRP Project 17-65, is approved by the HCQS committee, it should appear in the HCM by the end of 2019.

While previous HCM edition titles included the publication year, the new HCM omits this element, with the intent that chapters will have their own version number, starting with 6.0. Version numbers will be incremented as errata are released and as new research is incorporated. This approach will allow the HCM to continue to present state-of-the-art methods, while allowing analysts to tie their analysis to a specific version of a methodology.

> *Examples of future updates include:*
> - *Connected and autonomous vehicles*
> - *Capacity measurement methods*
> - *Planning methods*
> - *Advances in ATDM*
> - *Simulation guidance*
> - *Two-lane highway analysis update*

RESOURCES

The *HCM 6th Edition, A Guide for Multimodal Mobility Analysis* can be purchased from the Transportation Research Board at https://www.mytrb.org/Store/Product.aspx?ID=8313.

Free Volume 4 Online http://www.hcmvolume4.org/

Transportation Research Board Highway Capacity and Quality of Service Committee ID: AHB40

https://www.mytrb.org/CommitteeDetails.aspx?CMTID=1526

https://sites.google.com/site/ahb40hcqs/

https://www.linkedin.com/groups/8493127/

Free HCM software is available at http://swashware.com/HCMCalc.

SOFTWARE

Improvements in computing power over time have resulted in increased use of technology to control the road system (e.g., more advanced signal systems), the ability to create more sophisticated models of roadway capacity and quality of service, and the development of software packages to perform HCM analyses. Today, most HCM users apply the HCM methods via software.

Even though the majority of HCM users apply HCM methods through software, there is still a need for analysts to understand how a method works, even though they may not be performing step-by-step calculations. They need to know what inputs are required, how variations in those inputs may impact the results, the research foundation for the method, the basic flow of calculations, the range of likely results, and resources to turn to in case of questions. In addition, a subset of users (including analysts who want to explore the reason behind a particular result) still require in-depth information about each method.

> *Originally, HCM methods could be applied with pencil and paper techniques.*
> *Today, the HCM is typically applied through software*
> - *Faster, reduces computational mistakes*
> - *Larger study areas*
> - *More complex phenomena being modeled*
> - *Iterative calculations increasingly required*

A software program, HCM-CALC, which implements the calculations for the uninterrupted flow analysis methodologies described in this document, is available free of charge. The software is not required for this course. To the knowledge of the authors, the software provided at the link below is the only free software available for the full range of uninterrupted flow analysis methodologies of the Highway Capacity Manual. The software runs both the 5th edition (2010) and 6th (2016) edition manual calculations. The Highway Capacity and Quality of Service Committee does not officially endorse any software implementation of the calculation procedures contained in the HCM.

For information on how to obtain the HCM-CALC software, please visit
http://swashware.com/HCMCalc/.

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