CHAPTER 1
HCM USER'S GUIDE

CONTENTS

LIST OF EXHIBITS

1. INTRODUCTION

OVERVIEW

The *Highway Capacity Manual, Seventh Edition: A Guide for Multimodal Mobility Analysis* (HCM) continues the manual's evolution from its original objective—providing methods for quantifying highway capacity. In its current form, it serves 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 Seventh Edition incorporates the latest research on highway capacity, quality of service, and travel time reliability and improves the HCM's chapter outlines. The objective is to help practitioners applying HCM methods understand their basic concepts, computational steps, and outputs. These changes are designed to keep the manual in step with its users' needs and present times.

The 1950 HCM (*1*) was the first document to quantify the concept of capacity for transportation facilities and focused almost entirely on that subject. This focus was in response to the rapid expansion of the U.S. roadway system after World War II and the need to determine lane requirements for the Interstate highway system and the roads that provided access to it. The manual was designed to be "a practical guide by which the engineer, having determined the essential facts, can design a new highway or revamp an old one with assurance that the resulting capacity will be as calculated."

The focus on design continued in the 1965 HCM (*2*), but the level-of-service (LOS) concept was also introduced with this edition, along with a chapter on bus transit. The HCM permitted the "determination of the capacity, service volume, or level of service which will be provided by either a new highway design, or an existing highway under specified conditions."

The 1985 HCM (*3*) was another significant step in the evolution of the HCM. It refined the concept of LOS and incorporated the results of several major research projects performed since the publication of the 1965 HCM. The target audience was broadened through the addition of chapters on pedestrians and bicycles and an expansion of the transit chapter.

A substantial increase in the volume and breadth of material occurred with the publication of the HCM2000 (*4*). The intent of the manual was "to provide a systematic and consistent basis for assessing the capacity and level of service for elements of the surface transportation system and also for systems that involve a series or a combination of individual facilities."

The HCM 2010 (*5*) added much new material from research projects completed after the publication of the HCM2000 and was reorganized to make its contents more accessible and understandable. That edition also promoted the consideration of all roadway users and the use of a broader range of performance measures in the assessment of transportation facility performance.

The Sixth Edition of the HCM (*6*) incorporated research to update older HCM content and research on a number of topics new to the HCM, including travel time reliability and managed (e.g., high-occupancy vehicle) lane, work zone, and alternative intersection (e.g., displaced left turn) operations.

This Seventh Edition of the HCM updates an older HCM methodology (two-lane highways), provides a new network analysis method for evaluating queue spillback effects between freeways and urban streets, and looks to the future with new planning-level methods for evaluating the effects of connected and automated vehicles on freeway, signalized intersection, and roundabout operations. This edition also updates the HCM's pedestrian analysis methods for signalized intersections and uncontrolled crossings.

As the preceding discussion indicates, the HCM has evolved over the years to keep pace with the needs of its users and society, as the focus of surface transportation planning and operations in the United States has moved from designing and constructing the Interstate highway system to managing a complex transportation system that serves a variety of users and travel modes. Transportation agencies daily face the challenges of constrained fiscal resources and rights-of-way. They increasingly focus on designing and

operating roadway facilities in the context of the surrounding land uses and the modal priorities assigned to a given facility.

Although the HCM's content has evolved, its name has stayed the same since 1950 and no longer conveys the HCM's full range of applications. Therefore, the HCM uses the subtitle "A Guide for Multimodal Mobility Analysis" to highlight to practitioners and decision makers the multimodal performance measurement tools and guidance provided by the HCM.

Providing *mobility* for people and goods is transportation's most essential function. It 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.

The HCM historically has been the leading reference document for analyzing the mobility dimensions of quality of travel and capacity. Quantity of travel is a key input to the HCM's methods for analyzing motorized vehicle quality of travel and capacity utilization. Thus, "A Guide for Multimodal Mobility Analysis" captures the HCM's ability to quantify roadway performance across multiple dimensions and travel modes.

Finally, many previous editions of the HCM have had a year attached to them. As both the HCM's breadth and the quantity of HCM-related research have increased over time, waiting for years for a critical mass of research to accumulate before production of a new HCM edition has become impractical. This edition is simply titled the "Seventh Edition," with a version number provided for each chapter, starting with Version 7.0 for the initial publication. This approach will allow individual chapters to be updated more quickly as new research is completed, while continuing to allow practitioners to link their analysis to a particular version of an HCM methodology.

The remainder of this chapter provides a starting point for using the *Highway Capacity Manual, Seventh Edition: A Guide for Multimodal Mobility Analysis* and for learning about the changes made in this edition.

CHAPTER ORGANIZATION

Readers new to the HCM can use this chapter as a road map to all of the resources available within the printed manual and online. Experienced HCM users are encouraged to read at least Section 5, which summarizes the significant changes in the HCM that have occurred relative to the Sixth Edition.

Section 2 presents the purpose, objectives, intended use, and target users of the HCM.

Section 3 describes the contents of the four printed and online volumes that make up the HCM, summarizes the additional user resources available through the online Volume 4, and discusses the relationship of commercial software that implements HCM methods to the HCM itself.

Section 4 provides guidance on applying the HCM for international users.

Section 5 lists the significant changes made in the Seventh Edition and identifies the research basis for these changes.

Section 6 describes companion documents to the HCM that address topics outside the HCM's scope and that may need to be applied during an analysis. These documents are updated on different schedules from the HCM and serve as fundamental resources for topics within their respective scopes.

RELATED HCM CONTENT

The remainder of Volume 1 presents basic capacity, quality-of-service, and analysis concepts that readers should be familiar with before they apply the HCM. Chapter 8, HCM Primer, provides an executive summary of the HCM, including its terminology, methods, and performance measures. It is written for a nontechnical audience (e.g., decision makers who may be presented with the results of HCM analyses for the purpose of establishing policy or public interest findings).

2. HCM PURPOSE AND SCOPE

PURPOSE AND OBJECTIVES

The purpose of the HCM is to provide methodologies and associated application procedures for evaluating the multimodal performance of highway and street facilities in terms of operational measures and one or more quality-of-service indicators.

The objectives of the HCM are to

1. Define performance measures and describe survey methods for key traffic characteristics,
2. Provide methodologies for estimating and predicting performance measures, and
3. Explain methodologies at a level of detail that allows readers to understand the factors affecting multimodal operation.

The HCM presents the best available techniques at the time of publishing for determining capacity and LOS. However, it does not establish a legal standard for highway design or construction.

INTENDED USE

The HCM is intended to be used primarily for the analysis areas listed below, to the extent that they are supported by the individual analysis methodologies.

- *Levels of analysis:* operations, design, preliminary engineering, and planning.
- *Travel modes:* motorized vehicles, pedestrian, and bicycle, plus transit when it is part of a multimodal urban street facility.
- *Spatial coverage:* points, segments, and facilities.
- *Temporal coverage:* undersaturated and oversaturated conditions.

TARGET USERS

The HCM is prepared for use by (*a*) engineers who work in the field of traffic operations or highway geometric design and (*b*) transportation planners who work in the field of transportation system management. To use the manual effectively and to apply its methodologies, some technical background is desirable—typically university-level training or technical work in a public agency or consulting firm.

The HCM is also useful to management personnel, educators, air quality specialists, noise specialists, elected officials, regional land use planners, and interest groups representing special users.

3. STRUCTURE

OVERVIEW

The HCM consists of four volumes:

1. Concepts,
2. Uninterrupted Flow,
3. Interrupted Flow, and
4. Applications Guide.

Volumes 1–3 are available in the print and electronic versions of the HCM; chapters in Volume 4 are available online and in the electronic versions. The sections below describe the contents of each volume.

VOLUME 1: CONCEPTS

Volume 1 covers the basic information that an analyst should be familiar with before performing capacity or quality-of-service analyses:

- Chapter 1, HCM User's Guide, describes the purpose, scope, structure, and research basis of the HCM.
- Chapter 2, Applications, describes the types of analysis and operating conditions to which the HCM can be applied, defines roadway system elements, and introduces the travel modes addressed by the HCM.
- Chapter 3, Modal Characteristics, discusses demand variations by mode, factors that contribute to a traveler's experience during a trip, the types of transportation facilities used by different modes, and the interactions that occur between modes.
- Chapter 4, Traffic Operations and Capacity Concepts, describes how basic traffic operations relationships, such as speed, flow, density,

capacity, and travel time reliability, apply to the travel modes covered by the HCM.

- Chapter 5, Quality and Level-of-Service Concepts, presents the concepts of quality of service and LOS and summarizes service measures used in the HCM to describe the quality of service experienced by modal travelers.
- Chapter 6, HCM and Alternative Analysis Tools, describes the types of analysis tools used by the HCM and presents the range of alternative tools that might be used to supplement HCM procedures.
- Chapter 7, Interpreting HCM and Alternative Tool Results, provides guidance on the level of precision to use during an analysis and during presentation of analysis results, as well as guidance on comparing HCM analysis results with results from alternative tools.
- Chapter 8, HCM Primer, serves as an executive summary of the HCM for decision makers.
- Chapter 9, Glossary and Symbols, defines the technical terms used in the HCM and presents the symbols used to represent different variables in HCM methods.

VOLUME 2: UNINTERRUPTED FLOW

Volume 2 contains the methodological chapters relating to uninterrupted-flow system elements. These elements include freeways, managed lanes, multilane highways, two-lane highways, and their components. Their key shared characteristic is that they have no fixed causes of delay or interruption external to the traffic stream.

All of the material necessary for performing an analysis of one of these system elements appears in these chapters: a description of the methodology thorough enough to allow an analyst to understand the steps involved (although not necessarily replicate them by hand), the scope and limitations of the methodology, suggested default values, LOS thresholds, and guidance on special cases and the use of alternative tools.

The following chapters are included in Volume 2:

- Chapter 10, Freeway Facilities Core Methodology, presents basic concepts related to freeways and their component elements, including managed lanes, and the methodology for evaluating the operation of an extended section of freeway. Both undersaturated (i.e., below capacity) and oversaturated (i.e., above capacity) conditions can be evaluated.
- Chapter 11, Freeway Reliability Analysis, describes how the Chapter 10 core methodology can be applied to evaluate the impacts of demand variation, severe weather, incidents, work zones, special events, and active traffic and demand management (ATDM) strategies on freeway operations and travel time reliability.
- Chapter 12, Basic Freeway and Multilane Highway Segments, presents methodologies for analyzing the operations of freeway and multilane highway segments outside the influence of merging, diverging, and weaving maneuvers and (in the case of multilane highways) of signalized intersections.
- Chapter 13, Freeway Weaving Segments, presents a methodology for evaluating freeway, managed lane, collector–distributor road, and multilane highway segments where traffic entering from an on-ramp interacts with traffic desiring to exit at a nearby downstream off-ramp.
- Chapter 14, Freeway Merge and Diverge Segments, presents methodologies for evaluating roadway segments downstream of on-ramps and upstream of off-ramps, where weaving does not occur.
- Chapter 15, Two-Lane Highways, describes methods for analyzing the operations of two-lane highway facilities.

VOLUME 3: INTERRUPTED FLOW

Volume 3 contains the methodological chapters relating to interrupted-flow system elements. These consist of urban streets and the intersections along them, as well as off-street pedestrian and bicycle facilities. These system elements provide traffic control devices, such as traffic signals and STOP signs, that periodically interrupt the traffic stream.

Similar to Volume 2, all of the material necessary for performing an analysis of an interrupted-flow system element appears in these chapters: a description of the methodology thorough enough to allow an analyst to understand the steps involved (although not necessarily replicate them by hand), the scope and limitations of the methodology, suggested default values, LOS thresholds, and guidance on special cases and the use of alternative tools. In addition, where supported by research, analysis methods for the pedestrian and bicycle modes are incorporated into these chapters. Public transit material specific to multimodal analyses also appears in selected Volume 3 chapters; readers are referred to the *Transit Capacity and Quality of Service Manual* (TCQSM) (7) for transit-specific analysis procedures.

The following chapters are included in Volume 3:

- Chapter 16, Urban Street Facilities, presents methods for evaluating the operation of motorized vehicles, bicyclists, pedestrians, and transit vehicles (and their passengers) along an extended section of an urban street.
- Chapter 17, Urban Street Reliability and ATDM, describes how Chapter 16's facility methodology can be applied to evaluate the impacts of demand variation, severe weather, incidents, work zones, special events, and ATDM strategies on urban street operations and travel time reliability.
- Chapter 18, Urban Street Segments, presents methods for evaluating the operations of the various travel modes along an urban street segment bounded by signalized intersections or other forms of traffic control that may require the street's traffic to stop.
- Chapters 19 through 22 provide methods for evaluating motorized vehicle operations at signalized intersections, two-way STOP-controlled (TWSC) intersections, all-way STOP-controlled (AWSC) intersections, and roundabouts, respectively. Some of these intersection-specific chapters also provide analysis guidance for the pedestrian or bicycle modes.
- Chapter 23, Ramp Terminals and Alternative Intersections, describes methods for analyzing closely spaced intersections, including

interchange ramp terminals and alternative intersection forms (e.g., displaced left-turn intersections) comprising multiple junctions.

- Chapter 24, Off-Street Pedestrian and Bicycle Facilities, provides methods for evaluating the operation of off-street walkways, stairways, shared-use paths, and exclusive bicycle paths from the perspectives of the pedestrian or bicycle modes, as appropriate.

VOLUME 4: APPLICATIONS GUIDE

Volume 4 is an online volume accessible at www.hcmvolume4.org. It serves as a resource to the HCM community by providing the following:

- *Supplemental chapters* containing example problems demonstrating the use of HCM methods, along with details of the more computationally complex HCM methodologies; these chapters are also provided in the electronic versions of the HCM;
- *Interpretations* of HCM methods provided by the Transportation Research Board (TRB) Committee on Highway Capacity and Quality of Service;
- *Corrections and clarifications*;
- A *technical reference library* providing access to much of the original research forming the basis of HCM methods;
- *Applications guides* demonstrating the process of applying HCM methods to the variety of operations (*8, 9*) and planning and preliminary engineering projects (*10*) that HCM users may work on; and
- A *discussion forum* that allows HCM users to pose questions and receive answers from other HCM users.

Emerging topics chapters are added to Volume 4, as research develops new HCM material that the TRB Committee on Highway Capacity and Quality of Service chooses to adopt immediately. This approach reduces the time between the completion of research and the adoption of research results and their consideration as official HCM methods. The Seventh Edition adds a new Chapter 38, Network Analysis, providing methodologies for evaluating the interactions between freeways and urban streets and the effects

of spillback from one facility to another. Chapter 38 can be applied to a network of interconnected freeways and to networks involving freeway–arterial connections.

Volume 4 is open to all but requires a free, one-time registration for access to its content. As part of the registration process, users can choose to be notified by e-mail (typically once or twice a year) when new material is added to Volume 4.

COMPUTATIONAL ENGINES

Historically, all HCM methodologies have been fully documented within the manual through text, figures, and worksheets (the Freeway Facilities chapter in the HCM2000 represented the first departure from this pattern). However, in response to practitioner needs and identified HCM limitations, methodologies have continued to grow in complexity, and some have reached the point where they can no longer be feasibly documented in such a manner (for example, methodologies that require multiple iterations to reach a solution). In these cases, computational engines become an important means by which details of some of the more complex calculations can be described fully. For the most complex methodologies, the respective Volume 2 or 3 chapter, the related Volume 4 supplemental chapter, and the computational engine together provide the most efficient and effective way of fully documenting the methodology.

The TRB Committee on Highway Capacity and Quality of Service maintains computational engines for most HCM methodologies for evaluating methodologies as they are developed, developing new example problems, identifying needed improvements, and judging the impact of proposed changes. These engines are "research-grade" software tools for developing and documenting HCM methodologies and do not have or need the sophisticated interfaces and input data manipulation techniques that would make them suitable for use in an engineering or planning office.

Unless specifically noted otherwise in a particular HCM chapter, computational engines are not publicly distributed but are made available on request to researchers, practitioners, software developers, students, and others who are interested in understanding the inner workings of a particular HCM methodology. Engines that are publicly distributed are provided in the

Technical Reference Library and Planning and Preliminary Engineering Applications Guide sections of online Volume 4. All computational engines are provided as is; neither TRB nor its Committee on Highway Capacity and Quality of Service provides support for them.

COMMERCIAL SOFTWARE

To assist users in implementing the methodologies in the manual, commercial software is available (and has been since the publication of the 1985 HCM) to perform the numerical calculations for the more computationally intensive methods. A variety of commercial software products are available that implement HCM techniques and provide sophisticated user interfaces and data manipulation tools. TRB does not review or endorse commercial products.

4. INTERNATIONAL USE

APPLICATIONS

Capacity and quality-of-service analyses have generated interest on an international scale. The HCM has been translated into several languages, and research conducted in numerous countries outside of North America has contributed to the development of HCM methodologies. However, HCM users are cautioned that most of the research base, the default values, and the typical applications are from North America, particularly from the United States. Although there is considerable value in the general methods presented, their use outside of North America requires an emphasis on calibration of the equations and procedures to local conditions and on recognition of major differences in the composition of traffic; in driver, pedestrian, and bicycle characteristics; and in typical geometrics and control measures.

METRIC CONVERSION GUIDE

The HCM2000 (*4*) was produced as two editions, one using U.S. customary units and the other using metric units. At that time, U.S. states were moving toward compliance with federal requirements to use metric units in the design of roadways. As a result, the HCM2000 was published in "U.S. customary" and "metric" versions. Because the federal metrication requirements were later dropped and most states returned to U.S. customary units, subsequent HCM editions have only used U.S. customary units. To assist international users, Exhibit 1-1 provides approximate conversion factors from U.S. customary to metric units.

Exhibit 1-1: Metric Conversion Table

Symbol	When You Know	Multiply By	To Find	Symbol
		Length		
in.	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m

yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		Area		
$in.^2$	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		Volume		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		Mass		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or metric tons)	Mg (or t)
		Temperature (exact conversion)		
°F	Fahrenheit	(F – 32)/1.8	Celsius	°C
		Force and Pressure or Stress		
lbf	pound force	4.45	newtons	N
$lbf/in.^2$	pound force per square inch	6.89	kilopascals	kPa

Source: Adapted from Federal Highway Administration (*11*).

5. WHAT'S NEW IN THE HCM SEVENTH EDITION

RESEARCH BASIS FOR THE HCM SEVENTH EDITION

This section describes the new research incorporated into the HCM as part of the Seventh Edition. Exhibit 1-2 lists the major research projects that contributed to this version. The impacts of these and other projects on individual HCM chapters are described later in this section.

Exhibit 1-2: Major Research Projects Contributing to the HCM Seventh Edition

Project	Project Title	HCM-Related Project Objective(s)
NCHRP 15-57	*Highway Capacity Manual* Methodologies for Corridors Involving Freeways and Surface Streets	Develop material for the HCM that allows the analysis of networks that include freeways and surface streets.
NCHRP 17-65	Improved Analysis of Two-Lane Highway Capacity and Operational Performance	Develop performance measures for operational and capacity analyses of two-lane highways and develop models to produce these performance measures in a HCM context.
NCHRP 17-87	Enhancing Pedestrian Volume Estimation and Developing HCM Pedestrian Methodologies for Safe and Sustainable Communities	Determine how pedestrian safety improvements on the roadway and in signal timing designs should be reflected in HCM pedestrian LOS and recommend corresponding enhancements to the HCM methodology.
Federal Highway Administration (FHWA-HOP-16-088)	Active Transportation and Demand Management Analytical Methods for Urban Streets	Develop analytical, HCM-compatible evaluation methods for urban street active transportation and demand management (ATDM).
Federal Highway Administration pooled fund study [TPF-5(371)], Oregon DOT lead	Developing *Highway Capacity Manual* Capacity Adjustments for Connected and Autonomous Vehicle under Varying Levels of Volume and Market Penetration	Develop capacity adjustment factors for connected and automated vehicles (CAVs) to allow existing HCM methodologies to be adapted for use in analyzing CAV applications.

METHODOLOGICAL CHANGES BY SYSTEM ELEMENT

This subsection describes major methodological changes from the Sixth Edition resulting from the research listed in Exhibit 1-2. It also summarizes smaller changes made in individual chapters to clarify methods and correct errata. A detailed list of the corrections and clarifications incorporated in the Seventh Edition can be found in the "Errata and Updates" section of HCM Volume 4, www.hcmvolume4.org. The following chapters are unchanged from the Sixth Edition: 16, 21, 24, and 35.

Freeway–Arterial Networks

A new Chapter 38, Network Analysis, found in the "Supplemental Chapters" section of HCM Volume 4, provides methodologies for evaluating the interactions between freeways and urban streets and the effects of spillback from one facility to another. Chapter 38's methodology can be applied to a network of interconnected freeways and to freeway–arterial connections. It can be applied when the freeway–arterial interchange consists of signalized intersections, STOP-controlled intersections, roundabouts, or a combination of these. The chapter's analysis tools provide travel times and speeds for origin–destination pairs within these networks.

Freeway Facilities

The core methodology for estimating freeway performance measures for a single analysis period is contained in Chapter 10. No major changes have been made to this methodology. Values of the lane closure severity index (LCSI) and speed ratio, used in estimating the work zone free-flow speed (FFS), have been capped to restrict their use to the range of values studied in the original research. The description of the sensitivity of the work zone FFS to various inputs has been updated. The term "time period," which is generic and does not have a definition, has been changed to "analysis period" throughout Chapter 10, referring to the 15-min analysis period defined in Chapter 9, Glossary and Symbols.

The following methodological changes have been made in Chapter 25, Freeway Facilities: Supplemental:

- Corrections to the units, coefficients, or both for selected variables in the "Glossary of Variable Definitions" section to clarify that time steps are used for oversaturated conditions and analysis periods for undersaturated conditions;
- Changes to Equations 25-2 through 25-5 and selected variables shown in Example Problem 2 for consistency with changes made in the "Glossary of Variable Definitions" section;
- Changing the global density parameters *KC* and *KJ* to use units of pc/h/ln instead of veh/h/ln, and adding a heavy vehicle adjustment factor to Equation 25-13 to convert these densities back to veh/h/ln.
- Corrections to Equations 25-6 and 25-8 in the oversaturated segment flow estimation procedure;
- Changes to variables or variable subscripts in Equations 25-43, 25-44, 25-47 through 25-52, 25-88, 25-89, and 25-93 to clarify that values are calculated or given for analysis periods and not time steps;
- Change to the number of time steps in the text following Equation 25-30 to reflect 15-second time steps rather than 15-minute analysis periods, and adding definitions of the variables $SF(i,p)$ and $NV(i,p)$ to Equations 25-30 and 25-31, respectively.
- Correction to the units given for the weaving area short length in Equation 25-46;
- Changes to Equations 25-7, 25-11, 25-32, and 25-52 to use per-lane density.
- Change to the free-flow speed variable name in Equation 25-45 for consistency with Chapter 12;
- Change in wording from "time period" to "analysis period" in the planning-level methodology and throughout the example problems;
- Change in the "Freeway Scenario Generation" section to clarify that 15-minute analysis periods are the smallest temporal units used for reliability analyses;
- Corrections to calculations in Example Problems 1 and 4; and

- Changing the term “time step” to “time interval” in Example Problem 2.

Freeway Reliability Analysis

Chapter 11 describes the freeway travel time reliability method. Other than changing the term “time period” to “analysis period,” no changes have been made in this chapter.

Basic Freeway and Multilane Highway Segments

A new section has been added to Chapter 26, Freeway and Highway Segments: Supplemental, that presents capacity adjustment factors (CAFs) that can be applied to the Chapter 12 basic freeway segment methodology to account for the presence of connected and automated vehicles (CAVs) in the traffic stream. This section also presents planning-level daily and hourly service volume tables for basic freeway segments where CAVs are present.

The flowchart for the core motorized vehicle methodology in Chapter 12 (Exhibit 12-19) has been updated to clarify that when demand exceeds capacity, the analyst proceeds to the Chapter 10 freeway facilities methodology only when a basic segment is being studied. If a multilane highway segment is being studied, the analysis ends when demand exceeds capacity.

Other changes in Chapter 12 consist of corrections to values in the hourly service flow rate tables presented in Exhibit 12-37 and Exhibit 12-38 and in the daily service volume tables presented in Exhibit 12-39 through Exhibit 12-42. In Chapter 26, the term “time period” has been replaced with “analysis period.” In addition, the calculation of the demand flow rate in Step 4 of freeway Example Problem 1 has been corrected. The maximum service flow rate used in freeway Example Problem 2 has been updated based on the changes made to Exhibit 12-37.

Freeway Weaving Segments

Chapter 13 presents the freeway weaving methodology. The only change in Chapter 13 consists of a clarification on how to determine the minimum

number of lane changes required for a ramp-to-ramp maneuver in a two-sided weaving segment in the vicinity of a major merge or major diverge.

Chapter 26 provides new CAFs that can be applied to the Chapter 13 weaving methodology to determine the capacity of a weaving segment when CAVs are present in the traffic stream. In addition, in Chapter 27, Freeway Weaving: Supplemental, selected inputs and calculation results in Example Problems 1, 2, and 3 have been corrected.

Freeway Merge and Diverge Segments

Chapter 14 presents the methodologies for freeway merge and diverge segments. Other than adding a limit on the value of v_{R12} to use when applying Exhibit 14-13, no changes have been made to these methodologies. However, typos in Exhibit 14-6, Exhibit 14-15, and Equation 14-22 have been corrected.

Chapter 26 provides new CAFs that can be applied to the Chapter 14 methodologies to determine the capacity of a merge or diverge segment when CAVs are present in the traffic stream. In addition, Example Problems 3 and 4 in Chapter 28, Freeway Merges and Diverges: Supplemental, have been recalculated using three decimal places.

Two-Lane Highways

The motorized vehicle methodology in Chapter 15 and the associated example problems in Chapter 26 have been completely updated based on research conducted by NCHRP Project 17-65. In addition, Equation 15-27 in the bicycle methodology has been corrected.

The two-lane highway work zone method (Chapter 26, Appendix B) has been updated to add exhibits and equations from Version 6.0 of Chapter 15 that are required to apply the work zone method. This material is no longer used by the core two-lane highway method and thus does not appear in Version 7.0 of Chapter 15.

Urban Street Facilities

No changes have been made to Chapter 16, Urban Street Facilities. The term "time period" was changed to "analysis period" in Chapter 29, Urban Street Facilities: Supplemental.

Urban Street Reliability and ATDM

Chapter 17, Urban Street Reliability and ATDM, and Chapter 37, ATDM: Supplemental, have been updated to add guidance on modeling dynamic lane grouping, reversible center lanes, and adaptive signal control using HCM methods.

Urban Street Segments

The roadway crossing difficulty factor used by the pedestrian methodology in Chapter 18, Urban Street Segments, has been modified to be more sensitive to segment length and to achieve the original method's intent of lowering the street's LOS when the pedestrian environment is otherwise good, but the street is hard to cross, and improving segment LOS when the pedestrian environment on one side is poor, but the street is easy to cross. Example Problem 2 in Chapter 30, Urban Street Segments: Supplemental, has been updated to reflect the change to the roadway crossing difficulty factor.

Signalized Intersections

The pedestrian methodology in Chapter 19, Signalized Intersections, has been updated to provide estimates of delay for an expanded range of situations:

- Crossing one intersection leg in two stages,
- Crossing two legs of an intersection,
- Crosswalk closures,
- Exclusive pedestrian phases, and
- Coordinated actuated signal operation with a permissive period.

Additionally, the sequence of steps in the Chapter 19 pedestrian methodology has been changed to calculate delay and LOS first. Street corner circulation area and crosswalk circulation area, formerly the first two steps,

are now presented as optional steps at the end of the method because these steps are not required to determine pedestrian LOS. Exhibit and equation numbers in the pedestrian and bicycle methodology sections have also changed. Example Problem 2 in Chapter 31, Signalized Intersections: Supplemental, has been updated to reflect the changed step sequence. In addition, new Example Problems 4 and 5 have been added to demonstrate the new two-stage and two-leg crossing delay methodologies, respectively. Finally, the term "time period" has been changed to "analysis period."

Changes made in Chapter 31 consist of:

- Adding a new section with CAFs and service volume tables for situations where CAVs are present in the traffic stream at a signalized intersection.
- Correcting a typo in Equation 31-45 and another typo in Example Problem 2,
- Updating exhibit and equation numbers in Example Problems 2 and 3 to reflect changes made in Chapter 19,
- Adding and modifying variable definitions in Equations 31-26 and 31-28,
- Modifying Step R of the process to calculate average phase duration, and
- Changing the guidance for determining the f_s factor used in Equation 31-62.
- Changing the term "time period" to "analysis period."

STOP-Controlled Intersections

The motorized vehicle methodology in Chapter 20, Two-Way STOP-Controlled Intersections (TWSC), has been updated as follows:

- Step 3, Determining Conflicting Flow Rates, has been updated to introduce a set of conflicting flow factors and associated default values, rather than having these factors embedded as coefficients in a series of equations. The intent is to allow the user to modify the

values as needed to match field conditions. The default values that are provided match the methodology in the Sixth Edition.

- Step 9a, Rank 4 Capacity for One-Stage Movements, has been updated to correct an overestimation of the capacity for minor-street left-turn movements.
- Step 10b, Flared Minor-Street Lane Effects, has been updated to simplify and improve the accuracy of the calculations.
- New Step 10c, Shared Major-Street Lane Effects, has been added to address the capacity limitation of a shared or short major-street left-turn lane in combination with a through lane.

The pedestrian methodology in Chapter 20, Two-Way STOP-Controlled (TWSC) Intersections, has been updated as follows:

- Situations producing step-function effects in the estimated pedestrian delay have been corrected.
- The table of motorist yielding rates for various pedestrian crossing treatments has been updated based on new research.
- A new perception-based method has been added that estimates pedestrian satisfaction at an uncontrolled pedestrian crossing (midblock or across the major street at a TWSC intersection), based on the annual average daily traffic over the crossing, the likelihood of a pedestrian not being delayed making the crossing, and the type(s) of crossing treatment(s) provided at the crossing. Pedestrian satisfaction is then used to determine pedestrian LOS for the crossing.

In Chapter 32, STOP-Controlled Intersections: Supplemental, TWSC Example Problems 1, 3, 4, and 5 have been updated to reflect the changes to the motorized vehicle methodology. TWSC Example Problem 2 has been updated and expanded to reflect the changes to the pedestrian delay method and the new pedestrian LOS method.

Other changes made to Chapter 20 consist of:

- Clarifying margin notes have been added adjacent to Equations 20-49 and 20-56.

- Equation 20-35 has been modified to address a potential divide-by-zero error.
- References to Chapter 18 in Exhibit 20-6 and to Chapter 17 in Step 5b of the methodology have been changed to Chapter 30.
- The term "analysis time period" has been changed to "analysis period."

No changes have been made to Chapter 21, All-Way STOP-Controlled Intersections.

Roundabouts

The term "analysis time period" has been changed to "analysis period" in Chapter 22, Roundabouts. A new section has been added to Chapter 33, Roundabouts: Supplemental, providing CAFs for situations where CAVs are present in the traffic stream at roundabouts.

Ramp Terminals and Alternative Intersections

An additional computational step has been added in Chapter 23, Ramp Terminals and Alternative Intersections, to facilitate comparisons between different interchange configurations. This step calculates interchangewide Experienced Travel Time (ETT) and LOS, rather than reporting LOS strictly based on origin–destination pairs, as was the case in Version 6.0 of the method. All of the example problems in Chapter 34, Interchange Ramp Terminals: Supplemental, have been updated to demonstrate the new methodological step, including renumbering equation references when necessary. To make room for the new step in Chapter 23 without having to renumber all the following pages, Exhibit 23-33 has been reduced in size and pages 23-48 through 23-56 have been reformatted.

Other changes to Chapter 34 consist of:

- Correcting selected traffic volumes and traffic control devices shown in Exhibits 34-30, 34-58, and 34-66;
- Correcting selected traffic volumes in Exhibit 34-30 and recalculating subsequent calculation results in Example Problem 3; and

- Changing Example Problem 13 to add detail needed to apply the TWSC intersection procedure, to correct inconsistencies with the application of the TWSC procedure, and to link the subsections to the computational steps described in Chapter 23.

Finally, the term "time period" has been changed to "analysis period" in Chapter 23.

Off-Street Pedestrian and Bicycle Facilities

No changes have been made to Chapter 24, Off-Street Pedestrian and Bicycle Facilities, or to Chapter 35, Pedestrians and Bicycles: Supplemental.

CHANGES TO CONCEPTS CHAPTERS

The following changes have been made to chapters in Volume 1:

- Chapter 1, HCM User's Guide, has been updated to describe the new content in HCM Version 6.1 and to update the web address for HCM Volume 4.
- Exhibit 2-1 and related text in Chapter 2, Applications, have been updated to describe the network system element studied by new Chapter 38. Exhibit 2-2 and Exhibit 2-3 have been updated to reflect changes in service measures and perception-based measures in the Seventh Edition. Finally, the "System Performance Measurement" portion of Section 6 has been updated to reflect federal rule-making.
- Section 2 of Chapter 3, Modal Characteristics, has been updated to use current terminology related to connected and automated vehicles (CAVs) and to cross-reference HCM chapters where CAV-related material appears.
- Section 4 of Chapter 5, Quality and Level-of-Service Concepts, has been updated to describe the new service measures for two-lane highways and uncontrolled pedestrian crossings. In addition, the term "time period" was changed to "study period" in the discussion of reliability.

- Sections 3 and 4 of Chapter 6, HCM and Alternative Analysis Tools have been updated to note the ability of new Chapter 38 to analyze interactions between two facilities and to update information about simulation tools for two-lane highways. Exhibit 6-6 has been updated to include the new two-lane highway service measure.
- Section 3 of Chapter 7, Interpreting HCM and Alternative Tool Results, and Exhibit 7-4 have been updated to incorporate performance measures produced by new Chapter 38 and changes to performance measures in Chapter 15. The term "time period" has been changed to "analysis period."
- Sections 1–3 of Chapter 8, HCM Primer, including Exhibits 8-2 and 8-3, have been updated to incorporate new service measures introduced in HCM Version 6.1.
- Chapter 9, Glossary and Symbols, has been updated to add definitions of terms introduced in HCM Version 6.1 and to reflect new and changed variable names throughout the HCM.

Finally, old Section 6 of Chapter 36, Concepts: Supplemental, which described changes from the HCM 2010 to the Sixth Edition, has been removed.

6. COMPANION DOCUMENTS

Throughout its 60-year history, the HCM has been one of the fundamental reference works used by transportation engineers and planners. However, it is but one of a number of documents that play a role in the planning, design, and operation of transportation facilities and services. The HCM provides tools for evaluation of the performance of highway and street facilities in terms of operational and quality-of-service measures. This section describes companion documents to the HCM that cover important topics beyond the HCM's scope.

HIGHWAY SAFETY MANUAL

The *Highway Safety Manual* (HSM) (*12*) provides analytical tools and techniques for quantifying the safety effects of decisions related to planning, design, operations, and maintenance. The information in the HSM is provided to assist agencies as they integrate safety into their decision-making processes. It is a nationally used resource document intended to help transportation professionals conduct safety analyses in a technically sound and consistent manner, thereby improving decisions made on the basis of safety performance.

A POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS

The American Association of State Highway and Transportation Officials' *A Policy on Geometric Design of Highways and Streets* ("Green Book") (*13*) provides design guidelines for roadways ranging from local streets to freeways, in both urban and rural locations. The guidelines "are intended to provide operational efficiency, comfort, safety, and convenience for the motorist" and to emphasize the need to consider other modal users of roadway facilities.

MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES

FHWA's *Manual on Uniform Traffic Control Devices* (MUTCD) (*14*) is the national standard for traffic control devices for any street, highway, or bicycle trail open to public travel. Of particular interest to HCM users are the sections of the MUTCD pertaining to warrants for all-way STOP control and traffic signal control, signing and markings to designate lanes at intersections, and associated considerations of adequate roadway capacity and less restrictive intersection treatments.

TRANSIT CAPACITY AND QUALITY OF SERVICE MANUAL

The TCQSM (*7*) is the transit counterpart to the HCM. The manual contains background, statistics, and graphics on the various types of public transportation, and it provides a framework for measuring transit availability, comfort, and convenience from the passenger point of view. The manual contains quantitative techniques for calculating the capacity of bus, rail, and ferry transit services and transit stops, stations, and terminals.

TRAFFIC ANALYSIS TOOLBOX

At the time of writing, FHWA had produced 14 volumes of the *Traffic Analysis Toolbox* (*15*), in addition to documents providing guidance on the selection and deployment of a range of traffic analysis tools, including the HCM. Four volumes of the *Toolbox* provide general guidance on the use of traffic analysis tools:

- *Volume I: Traffic Analysis Tools Primer* (*16*) presents a high-level overview of the different types of traffic analysis tools and their role in transportation analyses.
- *Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools* (*17*) identifies key criteria and circumstances to consider in selecting the most appropriate type of traffic analysis tool for the analysis at hand.
- *Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software* (*18*) provides a recommended process for using traffic microsimulation software in traffic analyses.

- *Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness* (19) provides information and guidance on which measures of effectiveness should be produced for a given application, how they should be interpreted, and how they are defined and calculated in traffic analysis tools.

Other volumes of the *Toolbox* deal with the use of alternative tools for specific application scenarios. They are referenced when appropriate in specific HCM chapters.

7. REFERENCES

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