CHAPTER 1
HCM USER'S GUIDE

CONTENTS

LIST OF EXHIBITS

1. INTRODUCTION

OVERVIEW

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. 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 Sixth 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.

This Sixth Edition of the HCM incorporates research to update older HCM content and research on a number of topics new to the HCM, including travel

New topics addressed by this Sixth Edition include travel time reliability and the operation of managed lanes, work zones, and alternative intersections.

time reliability and managed (e.g., high-occupancy vehicle) lane, work zone, and alternative intersection (e.g., displaced left turn) operations.

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 Sixth Edition adds 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:

Mobility consists of four dimensions:
- *Quantity of travel,*
- *Quality of travel,*
- *Accessibility, and*
- *Capacity.*

- *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.

The subtitle "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 "Sixth Edition," with a version number provided for each chapter, starting with Version 6.0 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, Sixth 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 HCM 2010.

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 Sixth 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

Quality of service describes how well a transportation facility or service operates from the traveler's perspective.

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.

Level of service is the A–F stratification of quality of service.

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 version of the HCM; Volume 4 is only available online. The sections below describe the contents of each volume.

VOLUME 1: CONCEPTS

VOLUME 1: CONCEPTS
1. HCM User's Guide
2. Applications
3. Modal Characteristics
4. Traffic Operations and Capacity Concepts
5. Quality and Level-of-Service Concepts
6. HCM and Alternative Analysis Tools
7. Interpreting HCM and Alternative Tool Results
8. HCM Primer
9. Glossary and Symbols

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 the 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.

Chapter 8, HCM Primer, serves as an executive summary of the HCM for decision makers.

VOLUME 2: UNINTERRUPTED FLOW
10. Freeway Facilities Core Methodology
11. Freeway Reliability Analysis
12. Basic Freeway and Multilane Highway Segments
13. Freeway Weaving Segments
14. Freeway Merge and Diverge Segments
15. Two-Lane Highways

Uninterrupted-flow system elements, such as freeways, have no fixed causes of delay or interruption external to the traffic stream.

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 11 was added as part of the Sixth Edition and presents methods for evaluating travel time reliability and the effects of ATDM strategies on freeways.

Because basic freeway segments and multilane highways operate similarly in many ways, they have been combined into a single chapter as part of the Sixth Edition.

Chapter 15, Two-Lane Highways, provides a method for evaluating bicycle LOS on multilane and two-lane highways.

- 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 various classes of two-lane highways.

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) (*6*) 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 3: INTERRUPTED FLOW
16. Urban Street Facilities
17. Urban Street Reliability and ATDM
18. Urban Street Segments
19. Signalized Intersections
20. TWSC Intersections
21. AWSC Intersections
22. Roundabouts
23. Ramp Terminals and Alternative Intersections
24. Off-Street Pedestrian and Bicycle Facilities

Interrupted-flow system elements, such as urban streets, have traffic control devices such as traffic signals and STOP signs that periodically interrupt the traffic stream.

Analysis methods for the pedestrian, bicycle, and transit modes are provided in Chapters 16 and 18 and selected other Volume 3 chapters.

Chapter 17 was added to the Sixth Edition and presents methods for evaluating travel time reliability and the effects of ATDM strategies on urban streets.

The alternative intersection and interchange material in Chapter 23 is new in the Sixth Edition.

VOLUME 4: APPLICATIONS GUIDE
Supplemental Chapters
- 25. Freeway Facilities
- 26. Freeway and Highway Segments
- 27. Freeway Weaving
- 28. Freeway Merges and Diverges
- 29. Urban Street Facilities
- 30. Urban Street Segments
- 31. Signalized Intersections
- 32. STOP-Controlled Intersections
- 33. Roundabouts
- 34. Interchange Ramp Terminals
- 35. Pedestrians and Bicycles
- 36. Concepts
- 37. ATDM

Interpretations and Errata
Technical Reference Library
Applications Guides
- HCM Applications Guide
- Planning and Preliminary Engineering Applications Guide to the HCM

Discussion Forum

VOLUME 4: APPLICATIONS GUIDE

Volume 4 is an online-only volume accessible at hcm.trb.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;
- *Interpretations* of HCM methods provided by the Transportation Research Board (TRB) Committee on Highway Capacity and Quality of Service;
- *Errata*;
- 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 (*7*, *8*) and planning and preliminary engineering projects (*9*) 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 may be added to Volume 4 in the future, as research develops new HCM material that the TRB Committee on Highway Capacity and Quality of Service chooses to adopt immediately, before the next HCM edition. This approach reduces the time between the completion of research and the adoption of research results and their consideration as official HCM methods. For example, three emerging topics chapters on travel time reliability and managed lanes were adopted after the original publication of the HCM 2010; that material has now been incorporated into Volume 2 and 3 chapters as part of the Sixth Edition.

Access Volume 4 at hcm.trb.org.

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

HCM chapters describe, at a minimum, the process used by a given methodology. For simpler methodologies, the chapters fully describe the computational steps involved.

Supplemental chapters in Volume 4 provide calculation details for the more computationally complex methods.

Computational engines document all the calculation steps for the most complex methods, such as those involving iterative calculations.

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 section 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 (*10*).

5. WHAT'S NEW IN THE HCM SIXTH EDITION

OVERVIEW

Research Basis for the HCM Sixth Edition

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

Reorganization from the HCM 2010

The Sixth Edition retains the HCM 2010's basic structure, with three printed volumes and one online-only volume. However, some noticeable changes have occurred as a result of the need to incorporate research on topics new to the HCM (e.g., travel time reliability, managed lanes) while keeping the size of the printed HCM similar to both the HCM2000 and the HCM 2010. The following are the most significant changes:

- Example problems have been moved from the Volume 2 and 3 chapters into the corresponding Volume 4 supplemental chapter.
- Two chapters related to travel time reliability (Chapter 11, Freeway Reliability Analysis, and Chapter 17, Urban Street Reliability and ATDM) have been added. Furthermore, the Volume 2 chapters on basic freeway segments and multilane highways have been combined into a single chapter. As a result, the chapter numbers for most Volume 2 and 3 chapters have been incremented by one relative to the HCM 2010.
- The Volume 2 and 3 chapters provide a more consistent set of sections. They generally contain an introduction and sections on concepts, motorized vehicle methodology, extensions to the methodology, modal methodologies (if applicable), and applications. Many Applications sections include a new Example Results subsection that illustrates the sensitivity of results to various methodological inputs and depicts typical ranges of results.
- Additional information on input data needs, data sources, default values, and interpretation of results has been added to Volume 2 and 3 chapters to assist practitioners in applying HCM methods, particularly when software is used.
- Material from the three emerging topics chapters on travel time reliability and managed lanes (36–38) that were adopted after the publication of the HCM 2010 has been incorporated into the applicable freeway and urban streets chapters; therefore, these chapters no longer exist.
- Volume 4 chapter numbers remain the same, except that Concepts: Supplemental is now Chapter 36; ATDM: Supplemental is now Chapter 37; and a new Chapter 35 has been added to supplement Chapter 24, Off-Street Pedestrian and Bicycle Facilities.

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

Project	Project Title	Project Objective(s)
NCFRP 41	Incorporating Truck Analysis into the *Highway Capacity Manual*	Develop improved capacity and LOS techniques for better evaluation of the effects of trucks on other modes of transportation and vice versa, for interrupted- and uninterrupted-flow facilities.
NCHRP 03-96	Analysis of Managed Lanes on Freeway Facilities	Develop methods for the performance assessment and capacity analysis of managed lanes on freeways.
NCHRP 03-107	Work Zone Capacity Methods for the *Highway Capacity Manual*	Develop improved material on the capacity of work zones on freeways, urban streets, and two-lane highways suitable for incorporation into the HCM.
NCHRP 03-100	Evaluating the Performance of Corridors with Roundabouts	Collect travel time field data for roundabouts in series and develop models for travel time prediction in an urban street context.
NCHRP 03-115	Production of a Major Update to the 2010 *Highway Capacity Manual*	Update the HCM 2010 to support the performance measure requirements of the Moving Ahead for Progress in the 21st Century Act, travel time reliability analysis, and ATDM strategy evaluation, while maintaining its support of the more traditional system planning, design, and operations activities.
NCHRP 07-22	Planning and Preliminary Engineering Applications Guide to the *Highway Capacity Manual*	Develop guidance, illustrated with case studies, on appropriate use of the HCM for a broad spectrum of planning and preliminary engineering applications, including scenario planning, coordinated use with other models, and use in evaluating oversaturated conditions in a planning context.
SHRP 2 L08	Incorporation of Travel Time Reliability into the *Highway Capacity Manual*	Determine how data and information on the impacts of differing causes of nonrecurrent congestion (incidents, weather, work zones, special events, etc.) in the context of freeway and urban street capacity can be incorporated into the performance measure estimation methods contained in the HCM.
Federal Highway Administration (FHWA-HOP-13-042)	Guide for Highway Capacity Analysis and Operations Analysis of Active Transportation and Demand Management Strategies	Develop HCM-related methodologies and measures of effectiveness for evaluating the impacts of ATDM strategies on highway and street system demand, capacity, and performance.
Federal Highway Administration (TOPR 34)	Accelerating Roundabout Implementation in the United States	Collect new roundabout field data, compare fit of new data to HCM 2010 model, and determine best course of action to improve fit.
Federal Highway Administration (Saxton Lab TOPR 2)	HCM Chapters; Guidance for Alternative Intersections; Interchanges	Collect field data and develop methodologies for HCM operational analysis for diverging diamond interchanges, restricted crossing U-turn intersections, median U-turn intersections, and displaced left-turn intersections.

A new *Planning and Preliminary Engineering Applications Guide to the HCM* (9) has been added to Volume 4. It provides guidance on effectively applying the HCM to a broad range of planning and preliminary engineering applications, on considering different project stages and scales, and on the role of the HCM in system performance monitoring. The guide includes a series of case study examples.

METHODOLOGICAL CHANGES BY SYSTEM ELEMENT

Freeway Facilities

The core methodology for estimating freeway performance measures for a single analysis period is contained in Chapter 10. The following changes and additions have been made to the methodology:

- The methodology has been revised to present individual steps more clearly and to distinguish steps performed by the user from those typically automated in software.
- A method has been added for evaluating freeway work zones.
- Material on evaluating managed lanes on freeway facilities, previously appearing in former Chapter 38, has been integrated into the chapter.
- New research has been incorporated on truck effects on freeway operations.
- A discussion has been added on estimating the effects of ATDM strategies on freeway operations on a single typical day (as opposed to a year-long analysis in a reliability context, which is covered in Chapter 11, Freeway Reliability Analysis).
- The guidance on freeway facility segmentation has been improved, and HCM segments and freeway analysis sections used in modern freeway data sources have been distinguished.

Chapter 25, Freeway Facilities: Supplemental, describes a new procedure for calibrating the methodology to existing conditions through the use of capacity and speed adjustment factors (CAFs and SAFs). It provides a new mixed-flow methodology for estimating truck performance on composite grades and a simplified planning method for freeway facilities. It also contains example problems illustrating the new Chapter 10 and 11 methodologies.

Freeway Reliability Analysis

Chapter 11 incorporates and updates the freeway travel time reliability material from former Chapters 36 and 37. It integrates the previous separate reliability and ATDM methods and provides a new process for calibrating the method to existing conditions. The description of the computational steps has been revised to present individual steps more clearly and to distinguish steps performed by the user from those typically automated in software, to be consistent with changes in Chapter 10.

The scenario generation process for freeway reliability analysis has been revised to reduce the number of scenarios needed for a reliability analysis and to improve the way in which weather and incident effects are accounted for in the scenarios. (The new scenario generation approach is discussed in detail in Chapter 25, Freeway Facilities: Supplemental.) Finally, a planning-level reliability methodology is presented.

Basic Freeway and Multilane Highway Segments

The chapters on basic freeway segments and multilane highways have been merged into a single Chapter 12, since the methods for these system elements are similar. The methodology has changed as follows:

- The speed–flow equation has been modified to provide one unified equation across all basic and multilane highway segments.
- New research has been incorporated on truck effects on freeway operations, which has resulted in revised truck passenger car equivalent tables and service volume tables.
- The method for evaluating basic managed lane segments has been integrated into the chapter.
- The method increases the emphasis on calibration through CAFs and SAFs.
- The driver population factor has been removed; the effects of nonfamiliar drivers on flow are handled instead through CAFs and SAFs.
- The density at capacity of multilane highway segments has been revised to a constant 45 passenger cars per mile per lane, consistent with basic freeway segments.
- The LOS E–F range for multilane highway segments has been revised to reflect the revised density at capacity.
- New speed–flow curves and capacities are provided for multilane highways for 65- and 70-mi/h free-flow speeds.

Chapter 26, Freeway and Highway Segments: Supplemental, provides a new method for measuring capacity in the field, a new method for evaluating truck performance on extended grades, and example problems related to the new methods.

Freeway Weaving Segments

Chapter 13 incorporates the methods for evaluating managed lane weaving segments, managed lane access segments, and cross-weave effects. The chapter increases the emphasis on calibration through the application of CAFs and SAFs. Chapter 27, Freeway Weaving: Supplemental, provides example problems that illustrate the new methods.

Freeway Merge and Diverge Segments

The method for evaluating managed lane merge and diverge segments has been integrated into Chapter 14. The chapter provides new formalized guidance for aggregating merge and diverge segment densities for segments with three or more lanes and increases the emphasis on calibration through the application of CAFs and SAFs. Similar to the other freeway chapters, discussion of managed lane merge and diverge segments has been added. Chapter 28, Freeway Merges and Diverges: Supplemental, provides example problems that illustrate the new methods.

Two-Lane Highways

No significant changes have been made to the Chapter 15 methodology, but additional guidance has been provided on applying the method and interpreting its results. In addition, some steps in the methodology that previously were always skipped (i.e., they were not needed in calculating 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 in that methodological step.

Urban Street Facilities

The following changes have been made in Chapter 16:

- The service measure average travel speed of through vehicles as a percentage of base free-flow speed has been changed to the average travel speed of through vehicles. No change in LOS results is intended by this revision, but the new units and the use of rounded values will likely result in a few segments near a LOS threshold having a LOS one letter higher or lower.
- The threshold for LOS A has been changed from 85% of base free-flow speed to average through-vehicle travel speed values equivalent to 80% of the base free-flow speed.
- A procedure has been added for evaluating facilities that include segments experiencing sustained spillback.
- Pedestrian and bicycle LOS scores are now weighted by travel time instead of segment length.

Urban Street Reliability and ATDM

Chapter 17 is a new chapter in Volume 3. It incorporates content from Chapter 35 (Active Traffic Management) in the HCM 2010 and Chapters 36 (Travel Time Reliability) and Chapter 37 (Travel Time Reliability: Supplemental) that were adopted after the publication of the HCM 2010. New conceptual information about ATDM and techniques to evaluate ATDM strategies have been added to the prior content.

Urban Street Segments

The following changes have been made in Chapter 18:

- The service measure average travel speed of through vehicles as a percentage of base free-flow speed has been changed to the average travel speed of through vehicles. No change in LOS results is intended by this revision, but the new units and the use of rounded values will likely result in a few segments near a LOS threshold having a LOS one letter higher or lower.
- The threshold for LOS A has been changed from 85% of base free-flow speed to average through-vehicle travel speed values equivalent to 80% of the base free-flow speed.

- A procedure has been added for evaluating segments with midsegment lane blockage.
- The procedure for predicting segment queue spillback time has been revised to improve its accuracy.
- A new adjustment factor for parking activity has been added to the base free-flow speed calculation.
- The procedure can now evaluate segments that have roundabouts as boundary intersections.
- The procedure for computing volume balance for flows into and out of a segment was revised to ensure that right-turn-on-red vehicles are considered.
- Pedestrian and bicycle LOS scores are now based on a weighted link and intersection score. The weight for the link is link travel time and the weight for the intersection is delay at the intersection.
- 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.
- The default bus acceleration rate was changed to 3.3 ft/s^2 from 4.0 ft/s^2.

Chapter 30, Urban Street Segments: Supplemental, provides a new procedure for estimating travel time on an urban street segment bounded by one or more roundabouts. In addition, the chapter's urban street segment planning application has added a f_{pa} term to calculate the progression adjustment factor. This factor was included in the HCM2000 but deleted for the HCM 2010. It has been brought back to minimize the differences in the predicted LOS when the HCM2000 method and the Sixth Edition's planning application are compared.

Signalized Intersections

The following changes have been made in Chapters 19 and 31:

- Delay for unsignalized movements is now considered in the calculation of approach delay and intersection delay. The analyst will have to provide these delays as input values.
- A combined saturation flow adjustment factor for heavy vehicles and grade is incorporated in the method. It replaces the previous individual factors for heavy vehicles and grade.
- New saturation flow adjustment factors are provided for work zone presence at the intersection, midsegment lane blockage, and a downstream segment with sustained spillback.
- A new planning application is provided, which simplifies the input data requirements and calculations.

STOP-Controlled Intersections

The application of the peak hour factor has been clarified in Chapter 20, Two-Way STOP-Controlled Intersections, and in Chapter 21, All-Way STOP-Controlled Intersections.

Roundabouts

The roundabout capacity models in Chapter 22 have been updated on the basis of new Federal Highway Administration (FHWA) research, a calibration procedure has been provided, and the application of the peak hour factor has been clarified.

Ramp Terminals and Alternative Intersections

Chapter 23 has been expanded to address a wider variety of distributed intersections—groups of two or more intersections that, by virtue of close spacing and displaced or distributed traffic movements, are operationally interdependent and are thus best analyzed as a single unit. Distributed intersections include interchange ramp terminals as well as a variety of alternative intersection and interchange forms where one or more traffic movements are rerouted to nearby secondary junctions. Interchange and intersection forms that are now addressed by the chapter's methodologies include diverging diamond interchanges, restricted crossing U-turn intersections, median U-turn intersections, and displaced left-turn intersections.

Local terminology for these alternative intersection types may be different—see Chapter 23 for details.

To accommodate the new material, the chapter has been reorganized into three parts:

A. Distributed Intersection Concepts,

B. Interchange Ramp Terminal Evaluation, and

C. Alternative Interchange Evaluation.

To allow different intersection forms to be compared on an equal basis, a new performance measure, experienced travel time, has been defined. It incorporates the sum of control delays experienced by a given movement through a distributed intersection plus any extra distance travel time experienced by rerouted movements. LOS in this chapter is now defined on the basis of experienced travel time.

Chapter 34, Interchange Ramp Terminals: Supplemental, provides new example problems demonstrating the application of the methodology.

Off-Street Pedestrian and Bicycle Facilities

No significant changes have been made in the Chapter 24 methodology, but additional guidance has been added on applying the method and interpreting its results. Some variable names and equations have been modified to improve their understandability without affecting the computational results.

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) (*11*) 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") (*12*) 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) (*13*) 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 (*6*) 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

A useful reference on traffic operations modeling is FHWA's Traffic Analysis Toolbox.

At the time of writing, FHWA had produced 14 volumes of the *Traffic Analysis Toolbox* (*14*), 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:

The Traffic Analysis Toolbox *is available at http://ops.fhwa.dot.gov/trafficanalysistools/.*

- *Volume I: Traffic Analysis Tools Primer* (*15*) 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* (*16*) 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* (*17*) 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* (*18*) 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

Some of these references can be found in the Technical Reference Library in Volume 4.

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18. Dowling, R. *Traffic Analysis Toolbox Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness*. Report FHWA-HOP-08-054. Federal Highway Administration, Washington, D.C., 2007.