

# Springer Tracts on Transportation and Traffic

Volume 5

*Series editor*

Roger P. Roess, New York University Polytechnic School of Engineering,  
New York, USA  
e-mail: rpr246@nyu.edu

For further volumes:

<http://www.springer.com/series/11059>

### *About this Series*

The book series “Springer Tracts on Transportation and Traffic” (STTT) publishes current and historical insights and new developments in the fields of Transportation and Traffic research. The intent is to cover all the technical contents, applications, and multidisciplinary aspects of Transportation and Traffic, as well as the methodologies behind them. The objective of the book series is to publish monographs, handbooks, selected contributions from specialized conferences and workshops, and textbooks, rapidly and informally but with a high quality. The STTT book series is intended to cover both the state-of-the-art and recent developments, hence leading to deeper insight and understanding in Transportation and Traffic Engineering. The series provides valuable references for researchers, engineering practitioners, graduate students and communicates new findings to a large interdisciplinary audience.

Roger P. Roess · Elena S. Prassas

# The Highway Capacity Manual: A Conceptual and Research History

Volume 1: Uninterrupted Flow

 Springer

Roger P. Roess  
Emeritus Professor  
NYU Polytechnic School of Engineering  
New York, NY  
USA

Elena S. Prassas  
Associate Professor of Transportation  
Engineering  
NYU Polytechnic School of Engineering  
New York, NY  
USA

ISSN 2194-8119                      ISSN 2194-8127 (electronic)  
ISBN 978-3-319-05785-9            ISBN 978-3-319-05786-6 (eBook)  
DOI 10.1007/978-3-319-05786-6  
Springer Cham Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014934174

© Springer International Publishing Switzerland 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media ([www.springer.com](http://www.springer.com))

# Dedication

This book is dedicated to the members of the Highway Capacity and Quality of Service Committee of the Transportation Research Board and its subcommittees. From the first Committee, led by the legendary O.K. Normann, to the current group, led by Lily Elefteriadou, the past and present members comprise a family of professionals passionate about the study and development of concepts, criteria, and methodologies for the planning, design, analysis and operation of traffic facilities. Through their efforts and dedication, the profession has had the benefit of 5 editions of the *Highway Capacity Manual*, each representing the state-of-the-art at the time of their publication. It has been a privilege to work among this tireless group for many years. We look forward to many more years of working in their company, and sharing in their passionate pursuit of engineering excellence.

# Preface

For over sixty years, the *Highway Capacity Manual* has served as a key standard used in planning, design, analysis and operation of the nation's vast highway systems. It has been used internationally as well, and has spurred a number of nations to develop their own versions of the document and its methodologies. It covers every type of highway one can think of, from freeways and rural highways to signalized intersections, urban arterials, and streets. In the U.S. no highway can be designed without using it; no analysis of traffic impacts can be conducted without using it; no comprehensive highway plan can be developed without using it.

The manual is now in its 5<sup>th</sup> full edition, but a number of interim documents and revisions have taken place as well, and a new update to the latest edition is, at this writing, underway. The responsibility for producing the manual and evaluating its use has fallen to the Highway Capacity and Quality of Service Committee of the Transportation Research Board, an arm of the National Academies of Science and Engineering. The Committee was first formed in 1944, and consisted of eleven members. The Committee was chaired by O.K. Normann, who was already a driving force on the subject of highway capacity and related issues. The Committee has now grown to 32 members, with a full set of subcommittees in place which involve well over an additional 100 people.

The first two manuals, in 1950 and 1965, were written directly by Committee members. Subsequent manuals have been assembled and produced under contracts with the National Cooperative Highway Research Program, and have involved a variety of contracting agencies.

My first interactions with the Committee came in 1970, when I was a Ph.D. student at the then Polytechnic Institute of Brooklyn (now the NYU Polytechnic School of Engineering). With my advisor, William McShane, I was working on a research contract aimed at developing a new methodology for weaving areas on freeways. As a Ph.D. student, I was privileged to meet Powell Walker, one of the original 11 Committee members, and worked on another unrelated project with Nate Cherniak, another of the founding 11. I also got to work with Jack Leisch, who developed the weaving methodology of the 1965 HCM, and who was an early member of the Committee. My work has brought me into contact with some of the great leaders of early research in traffic engineering in general, and highway capacity analysis in particular, including such luminaries as Jim Kell, Carlton Robinson, Dolf May, and others. At one Transportation Research Board meeting,

as a Master's student, I actually met and got to talk to Bruce Greenshields, generally recognized as the father of traffic engineering.

In my first interactions with the Committee, I was the "new kid" on the block, but I was actually working with professionals who literally started and defined the profession. Those early interactions greatly affected me, and set high standards for me and countless others to reach the same level of professionalism and dedication.

These days, I have reached the other end of the spectrum. I am the "old guy" on a Committee dominated by younger, thoroughly dedicated, and energetic professionals. Time, however, provides many opportunities, but denies others. Most of the professionals now on the Committee did not have the opportunity to meet the founders of the Committee and the profession. This book is written for them, and for the future professionals that will follow, indeed, for anyone with an interest in the rich historical background of the *Highway Capacity Manual*.

I came away from this effort with a great sense of awe at the work done by some of the earliest professionals, saddled with a new medium (superhighways), little data collection technology, and no tested approaches to studying and establishing the methodologies needed to properly design, analyze, and operate the nation's growing highway system. They took what they had and created a viable set of procedures that led to a better highway system for the nation. Over time, data collection, reduction, and analysis capabilities and technologies have made the job simpler, while complexities in highway operations made the job harder. Through it all, the Highway Capacity and Quality of Service Committee, with the help of dedicated contractors, have continued to advance the profession and the utility of the manual itself. It's a job that will go on for a long time.

My co-author has been involved with the Committee since the early 1980's, and has been an integral part of developing and preparing materials for the last three editions of the manual.

Together, we hope that we have provided an interesting documentary of why and how the key concepts and models that comprise the *Highway Capacity Manual* were developed, and we hope that current and future researchers in the field will find this to be a valuable tool in their efforts.

Roger P. Roess

# Contents

<b>1</b>	<b>An Overview of the <i>Highway Capacity Manual</i> and Its History .....</b>	<b>1</b>
1.1	The Emerging Need for National Standards .....	1
1.1.1	Early Toll Roads [1-3].....	1
1.1.2	The National Road [4-6] .....	3
1.1.3	The Good Roads Movement [8, 9].....	3
1.1.4	The National Trails Movement .....	4
1.2	Developing a National Program for Highways .....	4
1.3	The Automobile Emerges and the Need for a National Highway System.....	5
1.4	The Formation of the Highway Capacity and Quality of Service Committee .....	6
1.5	The First Edition: The 1950 Highway Capacity Manual .....	9
1.6	The Second Edition: The 1965 Highway Capacity Manual .....	10
1.7	The Third Edition: The 1985 Highway Capacity Manual .....	13
1.8	Updates to the 1985 Highway Capacity Manual .....	17
1.9	The Fourth Edition: The 2000 Highway Capacity Manual .....	19
1.10	The Fifth Edition: The 2010 Highway Capacity Manual .....	20
1.10.1	Organization of the 2010 HCM.....	21
1.10.2	Into the Future .....	23
	References .....	25
<b>2</b>	<b>The Fundamental Concept of Capacity.....</b>	<b>27</b>
2.1	The Early Years.....	29
2.2	The 1950 Highway Capacity Manual.....	30
2.3	The 1965 Highway Capacity Manual.....	33
2.4	The 1985 Highway Capacity Manual.....	36
2.5	The Interim Updates: 1994 and 1997 .....	38
2.6	The 2000 Highway Capacity Manual.....	40
2.7	The 2010 Highway Capacity Manual.....	41
2.7.1	The “Capacity Drop” and Related Issues .....	41
2.7.2	A Task Force Is Formed.....	42
2.7.3	The 2010 Definition of Capacity.....	43



2.8	What’s in the Future? .....	43
2.8.1	The Capacity of What? .....	44
2.8.2	What Time Interval? .....	44
2.8.3	The “Capacity Drop” Issue .....	45
2.8.4	Oh, Those Random Variables .....	45
	References .....	46
<b>3</b>	<b>The Fundamental Concept of Level of Service .....</b>	<b>49</b>
3.1	In the Beginning: The 1950 <i>Highway Capacity Manual</i> .....	50
3.2	Level of Service Concept Introduced: The 1965 <i>Highway Capacity Manual</i> .....	50
3.3	Some Key Changes in the Level of Service Concept: The 1985 <i>Highway Capacity Manual</i> .....	58
3.4	A Brave New World Is Entered: The 2000 <i>Highway Capacity Manual</i> .....	61
3.5	The Introduction of User Perceptions: The 2010 <i>Highway Capacity Manual</i> .....	63
3.6	A New Challenge: Incorporating Reliability and Other Factors .....	68
3.7	Level of Service – Some Structural and Theoretical Issues .....	69
3.7.1	Who Are We Talking To? .....	69
3.7.2	The Issue of Aggregation .....	71
3.7.3	What Information Does LOS Represent? .....	71
3.7.4	The Step-Function Nature of Level of Service .....	72
3.7.5	Level of Service F and Failure .....	72
3.7.6	The Problem of Relativity .....	73
3.8	Uncertainty in Level of Service Predictions .....	73
3.9	What Is the Future of Level of Service? .....	74
	References .....	75
<b>4</b>	<b>Passenger Car Equivalent and Other Adjustment Factors .....</b>	<b>77</b>
4.1	What Are We Adjusting? .....	77
4.2	Defining Equivalence .....	78
4.3	Non-standard Elements Considered in Capacity Methodologies .....	81
4.4	Representing the General Geometric Environment of a Facility .....	82
4.5	Adjusting for Lane Width and Lateral Clearance .....	83
4.5.1	The 1950 HCM .....	83
4.5.2	The 1965 HCM .....	84
4.5.3	The 1985 HCM .....	86
4.5.4	The 1994 Update .....	87
4.5.5	The 1997 Update .....	89
4.5.6	The 2000 HCM .....	90
4.5.7	The 2010 HCM .....	91

- 4.5.8 Summary and Comments ..... 91
- 4.6 Passenger Car Equivalents: The Impacts of Heavy Vehicles  
on Traffic Operations ..... 92
  - 4.6.1 The 1950 HCM ..... 93
  - 4.6.2 The 1965 HCM ..... 94
    - 4.6.2.1 Two-Lane Highways: The Walker Method..... 94
    - 4.6.2.2 Multilane Highways (and Freeways) ..... 99
  - 4.6.3 The 1985 HCM ..... 102
    - 4.6.3.1 Two-Lane Rural Highways ..... 102
    - 4.6.3.2 Multilane Highways and Freeways ..... 105
  - 4.6.4 The 2000 Highway Capacity Manual..... 109
    - 4.6.4.1 Two-Lane, Two-Way Highways ..... 109
    - 4.6.4.2 Multilane Highways and Freeways ..... 110
  - 4.6.5 The 2010 Highway Capacity Manual..... 112
- 4.7 Adjustment Factors for Signalized Intersections..... 112
- 4.8 Adjustments: Theory vs. Practice..... 113
- References ..... 116

**5 Overview of Uninterrupted Flow Methodologies of the *Highway Capacity Manual* ..... 119**

- 5.1 Freeway Facilities and Components..... 120
- 5.2 Basic Freeway Segments..... 121
- 5.3 Freeway Weaving Segments ..... 122
- 5.4 Freeway Merge and Diverge Segments..... 122
- 5.5 Freeways as Facilities ..... 123
  - 5.5.1 The Time-Space Domain for Freeway Facility Analysis .... 124
  - 5.5.2 Levels of Service for Freeway Facilities ..... 126
  - 5.5.3 Capacity Adjustments ..... 127
    - 5.5.3.1 Adjustment for Short-Term Work Zones ..... 127
    - 5.5.3.2 Adjustments Due to Long-Term Construction  
Zones ..... 127
    - 5.5.3.3 Adjustments Due to Inclement Weather ..... 127
    - 5.5.3.4 Adjustments Due to Incidents ..... 128
  - 5.5.4 Analysis of Oversaturated Conditions..... 129
- 5.6 Multilane Highways ..... 129
- 5.7 Two-Lane Highways ..... 130
- References ..... 131

**6 Speed-Flow-Density Relationships: The Fundamental Basis of Uninterrupted Flow Analysis ..... 133**

- 6.1 Ideal or Base Conditions ..... 133
- 6.2 The Appetite for Data and the Need for Professional Judgment .... 134
- 6.3 The Early Days: Bruce D. Greenshields and Others ..... 134

- 6.4 Greenshield’s Breakthrough Study of 1934 ..... 141
- 6.5 The 1950 Highway Capacity Manual..... 145
- 6.6 Exciting Times: The Late 1950’s and Early 1960’s ..... 147
  - 6.6.1 Harold Greenberg’s Logarithmic Speed-Density Curves ..... 147
  - 6.6.2 Robin Underwood’s Exponential Speed-Density Curves ..... 149
  - 6.6.3 Leslie Edie’s Discontinuous Curves..... 152
  - 6.6.4 The Lost Study of Raymond Ellis ..... 153
  - 6.6.5 Drake, Shofer, and May, Jr.: Comparing the Alternatives ..... 154
- 6.7 The 1965 Highway Capacity Manual..... 158
- 6.8 The 1985 Highway Capacity Manual..... 162
- 6.9 The Updates ..... 166
  - 6.9.1 1994: A New Multilane Highway Procedure ..... 166
  - 6.9.2 1994: Updating Freeway Procedures..... 168
  - 6.9.3 1997: A New Methodology for Freeway Analysis..... 172
- 6.10 The 2000 *Highway Capacity Manual* ..... 173
- 6.11 Developing Speed-Flow Curves for the 2010 HCM ..... 173
  - 6.11.1 The Original Effort and Recommendations..... 174
    - 6.11.1.1 The Issue of Capacity ..... 177
    - 6.11.1.2 Shaping the Speed-Flow Curves ..... 177
  - 6.11.2 Controversies Concerning the Recommended Curves ..... 179
    - 6.11.2.1 Freeways vs. Multilane Highways ..... 179
    - 6.11.2.2 The Form and Substance of the Speed-Flow Curves ..... 182
  - 6.11.3 Back to the Drawing Board ..... 184
    - 6.11.3.1 Three-Segment Linear Curves ..... 185
    - 6.11.3.2 Werner Brilon’s Continuous Equation ..... 185
    - 6.11.3.3 Equations in the General Form of the 2000 HCM ..... 186
    - 6.11.3.4 The Classic Parabola ..... 186
    - 6.11.3.5 The Anchoring Process ..... 187
    - 6.11.3.6 Determining the Value of BP1 ..... 189
    - 6.11.3.7 The Regression Analysis and Final Curves..... 192
    - 6.11.3.8 Revised Recommended Curves..... 197
- 6.12 Comparisons, Conclusions, and Recommendations for Future Researchers ..... 198
- References ..... 201
  
- 7 Basic Freeway and Multilane Highway Segments..... 205**
  - 7.1 A General Model Format ..... 205
  - 7.2 The 1950 Highway Capacity Manual..... 206

- 7.3 The 1965 Highway Capacity Manual..... 209
- 7.4 The 1985 Highway Capacity Manual..... 213
  - 7.4.1 Setting Level of Service Criteria ..... 213
  - 7.4.2 What Is the Appropriate Defining Measure for LOS?..... 214
  - 7.4.3 Base Speed-Flow Curves ..... 215
  - 7.4.4 Basic Freeway Segment Methodology ..... 217
  - 7.4.5 Multilane Highway Methodology ..... 220
- 7.5 The 2000 Highway Capacity Manual..... 221
  - 7.5.1 Level of Service Definitions..... 222
  - 7.5.2 Capacity Under Ideal or Base Conditions ..... 223
  - 7.5.3 Estimating Free-Flow Speed ..... 224
  - 7.5.4 General Methodology..... 226
- 7.6 The 2010 Highway Capacity Manual..... 228
  - 7.6.1 Predicting Free-Flow Speed for Basic Freeway Segments ..... 229
  - 7.6.2 Revised Values of MSF for Basic Freeway Segments ..... 229
- 7.7 Sample Problems..... 230
- References ..... 230

- Appendix: Sample Problems in Basic Freeway Segment and Multilane Highway Analysis..... 231**
- Problem 7A.1 – Design of a Rural Freeway Segment..... 231
- Problem 7A.2 - Analysis of an Existing Urban Freeway ..... 237
- Problem 7A.3 – A Suburban Multilane Highway ..... 243

- 8 Analysis of Weaving Segments..... 249**
- 8.1 Weaving Segments: Definition and Terminology..... 249
- 8.2 Historic Problems in Dealing with Weaving Segments ..... 252
  - 8.2.1 Weaving on Non-freeway Facilities ..... 252
  - 8.2.2 Weaving between Ramps ..... 252
  - 8.2.3 Out of the Realm of Weaving..... 253
- 8.3 Weaving Analysis in the 1950 HCM ..... 254
- 8.4 Weaving Analysis in the 1965 HCM ..... 258
  - 8.4.1 The Leisch/Normann Method: Chapter 7 of the 1965 HCM..... 259
  - 8.4.2 The Hess and Moskowitz/Newman Methods: Chapter 8 of the 1965 HCM..... 262
  - 8.4.3 Inconsistencies in the 1965 HCM ..... 263
- 8.5 New Approaches Involving Configuration and Other New Concepts..... 263
  - 8.5.1 NCHRP 3-15: First Steps towards the 1985 HCM..... 264
    - 8.5.1.1 The NCHRP 3-15 Data Base..... 264
  - 8.5.2 NCHRP 3-15: Approach and General Results ..... 265

8.5.3	The NCHRP 3-15 Methodology.....	267
8.5.4	Revising the NCHRP 3-15 Method.....	271
8.5.5	The Leisch Method.....	276
8.5.6	The Reilly Method .....	280
8.6	Weaving Analysis in the 1985 HCM .....	282
8.7	Weaving Analysis in the 2000 HCM .....	288
8.8	Evolution of $N_{w,MAX}$ .....	292
8.9	Weaving Analysis in the 2010 HCM .....	293
8.9.1	A Data Base for the 2010 HCM Methodology.....	294
8.9.2	Length of a Weaving Segment Redefined.....	295
8.9.3	Lane-Changing Behaviour in a Weaving Segment .....	296
8.9.4	Predicting Speed.....	299
8.9.5	Levels of Service.....	301
8.9.6	Capacity of a Weaving Segment .....	301
8.9.7	Maximum Length of a Weaving Segment.....	302
8.9.8	Some Final Thoughts on the 2010 HCM Method .....	303
8.10	Multiple Weaving Segments .....	303
8.11	Base Conditions for Weaving Analysis.....	304
8.12	Sample Problems.....	304
	References .....	304
	<b>Appendix: Sample Problems in Weaving Segment Analysis.....</b>	<b>306</b>
	Problem 8A.1 – A Ramp-Weave Segment.....	306
	Problem 8A.2 – A Major Weaving Segment.....	323
<b>9</b>	<b>Analysis of Merge and Diverge Segments .....</b>	<b>339</b>
9.1	The 1950 Highway Capacity Manual.....	339
9.2	The 1965 Highway Capacity Manual.....	342
9.2.1	Levels of Service.....	343
9.2.2	Determining the Key Variable: Lane 1 Volume Immediately Upstream of the Ramp Junction .....	345
9.2.2.1	The Level of Service A – C Methodology for Determining Lane 1 Volume.....	345
9.2.2.2	The Weaving Checkpoint Volume – LOS A-C Methodology .....	347
9.2.2.3	The Level of Service D-E Methodology for Determining Lane 1 Volume.....	349
9.2.2.4	Weaving Checkpoint for the LOS D-E Methodology .....	350
9.2.3	Applying Adjustment Factors .....	351
9.3	The 1985 Highway Capacity Manual.....	353
9.3.1	Determining Lane 1 Volume.....	353
9.3.2	Converting to Flow Rates and Base Conditions.....	354

- 9.3.3 Computing Checkpoint Flow Rates and Checkpoint Criteria ..... 354
- 9.4 A New Procedure for the 1994 and 1997 Updates ..... 355
  - 9.4.1 Capacity and Level of Service Criteria for Ramp Junctions..... 357
  - 9.4.2 Determining the Flow in Lanes 1 and 2 Immediately Upstream of a Ramp Junction ..... 359
  - 9.4.3 Predicting Density and Speed in the Ramp Influence Area ..... 362
  - 9.4.4 Special Cases..... 363
- 9.5 The 2000 Highway Capacity Manual..... 363
  - 9.5.1 Changes in Capacity and Interpretation ..... 364
  - 9.5.2 Selecting an Equation for  $v_{12}$  on 6-Lane Freeways ..... 364
  - 9.5.3 Predicting Speed across All Freeway Lanes..... 366
- 9.6 The 2010 Highway Capacity Manual..... 367
  - 9.6.1 The Reasonableness Check ..... 367
    - 9.6.1.1 Reasonableness Check and Adjustment for 6-Lane Freeways ..... 368
    - 9.6.1.2 Reasonableness Check and Adjustment for 8-Lane Freeways ..... 368
    - 9.6.1.3 After Adjustments Are Made ..... 368
  - 9.6.2 Changing Equation 5, Table 9.9 ..... 368
- 9.7 An Observation ..... 369
- 9.8 Sample Problems..... 369
- References ..... 369

**Appendix: Sample Problems in Merging and Diverging Segment Analysis ..... 370**

- Problem 9A.1: – On-Ramp, Off-Ramp Sequence on a 6-Lane Freeway ..... 370
- Problem 9A.2: – An On-Ramp on an 8-Lane Freeway ..... 382
- Problem 9A.3 – A Segment with Auxiliary Lane ..... 388

**10 Analysis of Two-Lane, Two-Way Highways ..... 393**

- 10.1 The 1950 Highway Capacity Manual..... 393
- 10.2 The 1965 Highway Capacity Manual..... 395
- 10.3 The 1985 Highway Capacity Manual..... 398
  - 10.3.1 Methodology for General Terrain Segments..... 399
  - 10.3.2 Methodology for Significant Grades..... 401
  - 10.3.3 Design Treatments ..... 404
- 10.4 The 2000 Highway Capacity Manual..... 405
  - 10.4.1 Adjusting Demand Flow Rates ..... 407
  - 10.4.2 Grade Adjustment Factor ( $f_G$ )..... 408

- 10.4.3 Adjustment Factor for Heavy Vehicles ..... 409
- 10.4.4 Predicting the Average Travel Speed..... 412
- 10.4.5 Predicting the Percent Time Spent Following..... 415
- 10.4.6 Impacts of Passing Lanes and Truck Climbing  
Lanes ..... 415
- 10.4.7 A Problem with the Methodology ..... 418
- 10.5 The 2010 Highway Capacity Manual..... 419
  - 10.5.1 NCHRP 20-7, Task 160 ..... 419
  - 10.5.2 Correcting the Iteration Problem..... 422
  - 10.5.3 Another Problem: The Daily Service Volumes..... 428
  - 10.5.4 A New Category of Two-Lane Highway ..... 429
  - 10.5.5 Estimating Capacity ..... 430
  - 10.5.6 Summary ..... 431
- 10.6 Sample Problems..... 431
- References ..... 431
  
- Appendix: Sample Problems in Two-Lane Highway Analysis..... 432**
  - Problem 10A.1: – A Rural Two-Lane Highway in General Terrain ..... 432
  - Sample Problem 10A.2: – A Specific Grade Analysis ..... 441
  
- 11 The Future of the Highway Capacity Manual ..... 451**
  - 11.1 The Issues Keep Coming..... 451
  - 11.2 The Overall Form and Organization of the HCM ..... 452
    - 11.2.1 How Big? and How to Manage the Process ..... 454
    - 11.2.2 Who’s the Audience? ..... 456
  - 11.3 Where Do We Go with Level of Service?..... 458
  - 11.4 Uninterrupted Flow vs. Interrupted Flow? Or Points and  
Segments vs. Facilities and Systems? ..... 461
  - 11.5 The Software Is the Manual! ..... 462
  - 11.6 The Sixth Edition of the HCM ..... 463
  - 11.7 Some Specific Recommendations..... 465
  - 11.8 Some Closing Thoughts ..... 466
  
- Subject Index..... 467**

# List of Tables

Table 1.1:	Facility Types Covered in the 1950 Highway Capacity Manual.....	10
Table 1.2:	Facility Types Covered in the 1965 Highway Capacity Manual.....	12
Table 1.3:	Sponsored Research Projects Contributing to the Third Edition of the HCM .....	14
Table 1.4:	Facility Types Covered in the 1985 HCM.....	16
Table 1.5:	Facility Types Covered in the 2000 HCM.....	20
Table 1.6:	Contents of the 2010 Highway Capacity Manual.....	22
Table 2.1:	Capacity Values for Uninterrupted Flow in the 1950 HCM.....	32
Table 2.2:	Capacity Under Ideal Conditions for Uninterrupted Flow in the 1965 Highway Capacity Manual .....	34
Table 2.3:	Capacities for a 40-ft Signalized Intersection Approach for Typical Conditions in the 1965 HCM.....	35
Table 2.4:	Values of Ideal or Base Capacity in the 1985 HCM.....	38
Table 2.5:	Base Capacities in the 1994 and 1997 Updates to the HCM.....	40
Table 2.6:	Ideal or Base Capacity Values in the 2010 HCM.....	43
Table 3.1:	Level of Service Criteria for Freeways in the 1965 HCM...	54
Table 3.2:	Service Measures Used to Evaluate Level of Service in the 1965 HCM.....	57
Table 3.3:	Service Measures Used to Evaluate Level of Service in the 1985 HCM (1997 Update).....	59
Table 3.4:	Recommended Performance Measures from NCHRP Project 3-55(4).....	62
Table 3.5:	Service Measures Used to Evaluate Level of Service in the 2000 HCM.....	63
Table 3.6:	Factors Influencing Perceived Service Quality .....	64
Table 3.7:	LOS Definitions Based Upon a Common Numerical Scale .....	66
Table 3.8:	Independent Variable Parameters Used in LOS Predictions .....	67
Table 4.1:	Basic Capacity Values in the 2010 HCM.....	77



Table 4.2:	Combined Effect of Lane Width and Edge Clearances on Highway Capacity – 1950 HCM .....	84
Table 4.3:	Combined Effect of Lane Width and Lateral Clearance on Capacity and Service Volume – 1965 HCM .....	85
Table 4.4:	Combined Effect of Narrow Lanes and Restricted Shoulder Width ( $f_w$ ) – 1985 HCM, Two-Lane Highways.....	86
Table 4.5:	Adjustment Factor for Median Type for Multilane Highways – 1994 Update .....	87
Table 4.6:	Adjustment Factor for Lane Width for Multilane Highways – 1994 Update .....	88
Table 4.7:	Adjustment Factors for Lateral Clearance on Multilane Highways – 1994 Update .....	88
Table 4.8:	Adjustment Factors for Restricted Lane Width and Lateral Clearance for Basic Freeway Segments – 1994 Update .....	89
Table 4.9:	Adjustment for Lane Width on Basic Freeway Segments – 1997 Update .....	89
Table 4.10:	Adjustment for Lateral Clearance on Basic Freeway Segments – 1997 Update .....	90
Table 4.11:	Adjustment for Lane Width and Lateral Clearance for Two-Lane Highways – 2000 HCM .....	90
Table 4.12:	Effect of Commercial Vehicles on Practical Capacities of Multilane Facilities-1950 HCM .....	94
Table 4.13:	Some Passenger Car Equivalents for Two-Lane Highways in the 1965 HCM.....	99
Table 4.14:	Passenger Car Equivalents for Trucks on a 16,000-ft Multilane Grade – From Figure 4.4.....	101
Table 4.15:	Sample Passenger Car Equivalents for Multilane Highways in the 1965 HCM.....	101
Table 4.16:	PCE's for General Terrain Segments on Two-Lane Highways – 1985 HCM.....	103
Table 4.17:	Selected Values of Passenger Car Equivalents on Specific Two-Lane Highway Grades – 1985 HCM.....	105
Table 4.18:	300 lb/hp Trucks vs. Reference Trucks for MRI Simulations .....	106
Table 4.19:	Sample PCE Values from the 1985 Highway Capacity Manual (For 5% Trucks, RV's, or Buses).....	109
Table 4.20:	Sample Passenger Car Equivalents for Two-Lane Highways – 2000 HCM.....	110
Table 4.21:	Selected Passenger Car Equivalents for Trucks/Buses on Grades for Multilane Highways and Freeways – 2000 HCM.....	111
Table 5.1:	Level of Service Criteria for Freeway Facilities – 2010 HCM .....	126

Table 5.2:	Default Adjustments Due to Long-Term Construction Zones – 2010 HCM .....	127
Table 5.3:	Capacity Adjustments Due to Weather – 2010 HCM.....	128
Table 5.4:	Capacity Adjustments Due to Traffic Incidents – 2010 HCM .....	128
Table 6.1:	Key Values from Early Volume-Speed Relationships.....	140
Table 6.2:	Data Sites for the 2010 HCM speed-Flow Curves .....	174
Table 6.3:	Equations for the Curves of Figure 6.28.....	178
Table 6.4:	Differences in Multilane and Freeway Service Flow Rates .....	179
Table 6.5:	Historic Relationship Between Freeway and Multilane Highway Service Flow Rates (Volumes) .....	182
Table 6.6:	Regression Results for 3-Segment Linear Curves .....	192
Table 6.7:	Regression Results for the 2000 HCM Approach .....	194
Table 6.8:	Equations for the Brilon Approach.....	196
Table 6.9:	Revised Equations for the 2000 HCM Approach .....	198
Table 6.10:	Comparing Prediction STDs .....	200
Table 7.1:	Capacities for Multilane Flow – 1950 HCM .....	206
Table 7.2:	Adjustment Factor for Lane Width and Lateral Clearance for Multilane Highways – 1950 HCM.....	207
Table 7.3:	Commercial Vehicle Adjustment Factors ( $f_{HV}$ ) for Multilane Highways – 1950 HCM .....	209
Table 7.4:	Level of Service Criteria for Basic Freeway Segments – 1965 HCM.....	210
Table 7.5:	Level of Service Criteria for Multilane Highways – 1965 HCM.....	211
Table 7.6:	Passenger Car Equivalents for Trucks and Buses on General Terrain Segments of Freeways and Multilane Highways – 1965 HCM.....	212
Table 7.7:	Passenger Car Equivalents for Buses on Specific Grades on Freeways and Multilane Highways – 1965 HCM.....	212
Table 7.8:	Levels of Service for Basic Freeway Segments – 1985 HCM.....	218
Table 7.9:	Passenger Car Equivalents for General Terrain Segments – 1985 HCM.....	219
Table 7.10:	Adjustment Factor for Driver Population .....	220
Table 7.11:	Levels of Service for Multilane Highways – 1985 HCM....	220
Table 7.12:	Adjustment Factor for Type of Multilane Highway and Development Environment ( $f_E$ ) – 1985 HCM.....	221
Table 7.13:	Levels of Service for Basic Freeway Segments and Multilane Highways: 1985 through 2000 .....	222
Table 7.14:	Capacity Under Ideal or Base Conditions on Multilane Uninterrupted Flow Segments: 1950 through 2000.....	223

Table 7.15:	Free-Flow Speed Adjustment for Number of Lanes on Basic Freeway Segments – 2000 HCM .....	225
Table 7.16:	Adjustments to Free-Flow Speed for Freeway Interchange Density – 2000 HCM.....	226
Table 7.17:	Free-Flow Speed Adjustment for Access Points on Multilane Highways – 2000 HCM .....	226
Table 7.18:	Maximum Service Flow Rates (pc/h/ln) for Basic Freeway Segments and Multilane Highways – 2000 HCM .....	227
Table 7.19:	Passenger Car Equivalents for General Terrain Segments – 2000 HCM.....	227
Table 7.20:	Sample Passenger Car Equivalents for RV's ( $E_R$ ) on Grades – 2000 HCM.....	228
Table 7.21:	Passenger Car Equivalents for Trucks/Buses ( $E_T$ ) on Downgrades – 2000 HCM.....	228
Table 7.22:	Maximum Service Flow Rates (MSF) for Basic Freeway Segments – 2010 HCM .....	230
Table 8.1:	Common Symbols Used in Weaving Analysis.....	250
Table 8.2:	Service Volumes for Use in the 1965 HCM Weaving Methodology .....	261
Table 8.3:	Quality of Flow vs. Level of Service for Weaving Segments in the 1965 HCM.....	261
Table 8.4:	Maximum Number of Lanes that Can Be Used by Weaving Vehicles in a Weaving Segment.....	267
Table 8.5:	Relationships for the NCHRP 3-15 Methodology .....	268
Table 8.6:	Levels of Service in Weaving Segments: NCHRP 3-15 Method.....	269
Table 8.7:	Relationships for the PINY Method .....	274
Table 8.8:	Levels of Service in Weaving Segments - PINY Method ...	275
Table 8.9:	Levels of Service and Composite Service Volumes – Leisch Method.....	277
Table 8.10:	Levels of Service for the Reilly Method.....	283
Table 8.11:	Speed Prediction Equations for the 1985 HCM Method .....	286
Table 8.12:	Equations for $N_w$ and Values for $N_{w,MAX}$ – 1985 HCM.....	287
Table 8.13:	Limitations on Weaving Segment Parameters - 1985 HCM.....	287
Table 8.14:	Levels of Service for Weaving Segments – 1985 HCM.....	288
Table 8.15:	Constants of Calibration for the Weaving Intensity Factor – 2000 HCM.....	290
Table 8.16:	Limitations on Weaving Segment Operations – 2000 HCM.....	290
Table 8.17:	Levels of Service in Weaving Segments – 2000 HCM .....	291

Table 8.18:	Sample Table for Weaving Segment Capacity (pc/h) – 2000 HCM (For Type A Weaving Segments on a Freeway with a FFS of 70-75 mi/h) .....	292
Table 8.19:	Value of $N_{w,MAX}$ in HCM Weaving Methodologies .....	293
Table 8.20:	Equations for $LC_{NW}$ – 2010 HCM .....	300
Table 8A.1:	Summary Results of Sample Problems.....	339
Table 9.1:	Level of Service Criteria for Ramp Junctions – 1965 HCM.....	384
Table 9.2:	Directory of Regression Equations for Lane 1 Volume Determination – LOS A-C Methodology, 1965 HCM.....	387
Table 9.3:	Equations for Lane 1 Volume Estimations – LOS A-C Methodology, 1965 HCM.....	388
Table 9.4:	Percentage of through Vehicles in Lane 1 in the Vicinity of a Ramp Terminal – LOS D-E Methodology, 1965 HCM.....	391
Table 9.5	Level of Service Criteria for Ramp Junctions – 1985 HCM .....	397
Table 9.6:	Level of Service Criteria for Ramp Junctions .....	399
Table 9.7:	Freeway, Merge, and Diverge Capacity .....	401
Table 9.8:	Capacity of Ramp Roadways .....	401
Table 9.9:	Regression Equations for $P_{FM}$ – 1994 HCM.....	403
Table 9.10:	Regression Equations for $P_{FD}$ – 1994 HCM .....	404
Table 9.11:	Models for Prediction of Density in Ramp Influence Areas.....	405
Table 9.12:	Models for Prediction of Average Speed in Ramp Influence Areas.....	405
Table 9.13:	Capacity Values for Total Freeway Flow Rate Upstream of a Diverge or Downstream of a Merge – 2000 HCM .....	407
Table 9.14:	Equations for Equivalent Distance ( $L_{EQ}$ ) Between Adjacent Ramps on Six-Lane Freeways.....	408
Table 9.15:	Estimating Average Speeds in Merge Areas .....	409
Table 9.16:	Estimating Average Speed in Diverge Areas .....	410
Table 10.1:	Basic and Practical Capacities for Two-Lane, Two-Way Highways – 1950 HCM.....	440
Table 10.2:	Capacity and Maximum Service Volume Criteria for Two-Lane Highways – 1965 HCM .....	442
Table 10.3:	Passenger Car Equivalents for Trucks and Buses in General Terrain Segments – 1965 HCM .....	443
Table 10.4:	Passenger Car Equivalents for Intercity Buses ( $E_B$ ) on Specific Grades – 1965 HCM.....	443
Table 10.5:	Level of Service and Maximum v/c Ratios for Two-Lane Highways – 1985 HCM .....	447

Table 10.6:	Adjustment Factor for Directional Distribution on Two-Lane Highways – 1985 HCM .....	447
Table 10.7:	Level of Service Criteria for Two-Lane Significant Grades 1985 HCM.....	448
Table 10.8:	Maximum v/c Ratios for Two-Lane Highway Significant Grades – 1985 HCM.....	449
Table 10.9:	Adjustment Factor for Directional Distribution on Significant Grades – 1985 HCM .....	450
Table 10.10:	Level of Service Criteria for Two-Lane Highways – 2000 HCM.....	453
Table 10.11:	Free-Flow Speed Adjustment for Lane and Shoulder Width ( $f_{LS}$ ) – 2000 HCM.....	454
Table 10.12:	Free-Flow Speed Adjustment for Access Point Density ( $f_A$ ) - 2000-HCM .....	454
Table 10.13:	Grade Adjustment Factors for General Terrain Segments And Specific Downgrades ( $f_G$ ) on Two-Lane Highways – 2000 HCM.....	456
Table 10.14:	Sample Grade Adjustment Factors for Specific Upgrades ( $f_G$ ) on Two-Lane Highways – 2000 HCM .....	456
Table 10.15:	Passenger Car Equivalents ( $E_T, E_R$ ) for General Terrain Segments on Two-Lane Highways – 2000 HCM.....	458
Table 10.16:	Passenger Car Equivalents ( $E_T, E_R$ ) for Specific Upgrades on Two-Lane Highways: ATS Determination – 2000 HCM.....	458
Table 10.17:	Passenger Car Equivalents ( $E_T, E_R$ ) for Specific Upgrades on Two-Lane Highways: PTSF Determination – 2000 HCM.....	459
Table 10.18:	Passenger Car Equivalents of Trucks Operating at Crawl Speed on Two-Lane Highway Downgrades ( $E_{TC}$ ) – 2000 HCM.....	459
Table 10.19:	Adjustment for the Effect of No Passing Zones ( $f_{np}$ ) on ATS for Two-Directional Segments – 2000 HCM.....	461
Table 10.20:	Adjustment for the Effect of No Passing Zones on Two-Lane Highway ATS for Single-Lane Analysis ( $f_{np}$ ) – 2000 HCM .....	462
Table 10.21:	Adjustment to PTSF for Directional Distribution and No Passing Zones ( $f_{d/np}$ ) – 2000 HCM.....	464
Table 10.22:	Adjustment for PTSF for No Passing Zones ( $f_{np}$ ) – 2000 HCM .....	465
Table 10.23:	Coefficient “a” and “b” for Use in Equation 10-16 - 2000 HCM .....	466
Table 10.24:	A Sample Problem: Two-Lane Highway in Rolling Terrain .....	466

Table 10.25: Coefficients “a” and “b” for Use in Equation 10-17 - 2010 HCM .....	468
Table 10.26: Corrected PTSF Adjustment Factor ( $f_{np}$ ) for Directional Analysis of Two-Lane Highways – 2010 HCM .....	469
Table 10.27: Grade Adjustment Factors ( $f_G$ ) for General Terrain Two-Lane Highway Segments – 2010 HCM .....	472
Table 10.28: Grade Adjustment Factor for ATS Determination on Two-Lane Highway Specific Upgrades – 2010 HCM.....	473
Table 10.29: Grade Adjustment Factor for PTSF Determination on Two-Lane Highway Specific Upgrades – 2010 HCM.....	474
Table 10.30: Passenger Car Equivalents ( $E_T$ , $E_R$ ) for General Terrain Segments on Two-Lane Highways – 2010 HCM .....	474
Table 10.31: ATS Passenger Car Equivalents for Trucks ( $E_T$ ) on Two-Lane Highway Specific Grades – 2010 HCM.....	475
Table 10.32: ATS Passenger Car Equivalents for RVs ( $E_R$ ) on Two- Lane Highway Specific Upgrades – 2010 HCM.....	476
Table 10.33: ATS Passenger Car Equivalents for Trucks on Two-Lane Highway Downgrades Traveling at Crawl Speeds ( $E_{TC}$ ) – 2010 HCM ... ..	476
Table 10.34: PTSF Passenger Car Equivalents ( $E_T$ , $E_R$ ) on Two-Lane Highway Specific Grades – 2010 HCM .....	477
Table 10.35: Level of Service Criteria for Two-Lane Highways – 2010 HCM .....	479
Table 11.1: Types of Measures and Performance.....	460
Table 11.2: Potential Organization of the Sixth Edition HCM.....	464

# List of Figures

Fig. 2.1:	Greenshields' Original Speed-Density Curve (1934).....	30
Fig. 3.1:	Typical Speed-Flow-Density Relationship.....	52
Fig. 3.2:	Level of Service Criteria Illustrated .....	53
Fig. 3.3:	Service Volumes and Level of Service Illustrated.....	57
Fig. 4.1:	Auto Speed Distributions Used to Calibrate PCEs for Two-Lane Highways in the 1965 HCM .....	97
Fig. 4.2:	Truck Performance Curves Used to Calibrate PCEs for Two-Lane Highways in the 1965 HCM.....	97
Fig. 4.3:	PCEs for Two-Lane Highways in the 1965 HCM.....	98
Fig. 4.4:	Equivalent Service Volumes for Trucks on Two-Lane, One-Way Roadways at Level of Service B .....	100
Fig. 4.5:	Determining Equivalent Mixed Flow for the MRI Simulation .....	107
Fig. 4.6:	Truck Deceleration Curves for a 300 lb/hp Truck .....	108
Fig. 4.7:	Passenger Car Equivalents Calibrated at Constant Spacing .....	115
Fig. 5.1:	Influence Areas for Weaving, Merging, and Diverging Segments on Freeways .....	120
Fig. 5.2:	The Time-Space Domain for Freeway Facility Analysis – 2010 HCM.....	125
Fig. 6.1:	Greenshields, 1934: Speed vs. Spacing of Vehicles.....	138
Fig. 6.2:	Volume – Speed Relationship Resulting from Early Studies .....	139
Fig. 6.3:	Results of Greenshields' 1934 Speed Study.....	141
Fig. 6.4:	Greenshields' 1934 Speed-Density Curve.....	142
Fig. 6.5:	Greenshields' Speed-Flow Curve of 1934.....	143
Fig. 6.6:	Greenshields Time-Lost Curve, 1934.....	144
Fig. 6.7:	Minimum Spacings vs. Speed, 1950 HCM.....	146
Fig. 6.8:	Speed vs. Flow for Uninterrupted Flow, 1950 HCM.....	146
Fig. 6.9:	Greenberg's Logarithmic Speed-Flow Curves .....	148
Fig. 6.10:	Comparison of Underwood's Merritt Parkway Data to Previous Theories of Speed – Density.....	150
Fig. 6.11:	Underwood's Exponential Speed-Density Curve for the Merritt Parkway (mid-1950's data) .....	151

Fig. 6.12:	The Linear “Fix” for Underwood’s Exponential Model.....	151
Fig. 6.13:	Edie’s Discontinuous Model for the Lincoln Tunnel .....	153
Fig. 6.14:	Illustration of Study Locations: Drake et al.....	154
Fig. 6.15:	Range of Data Used by Drake et al. ....	155
Fig. 6.16:	Edie’s Model Applied to the Eisenhower Expressway – 1966 Data .....	157
Fig. 6.17:	Speed-Flow Studies for the 1965 HCM.....	158
Fig. 6.18:	Speed-Flow Curves for Freeways in the 1965 HCM.....	160
Fig. 6.19:	Speed-Flow Curves for Multilane Highways in the 1965 HCM .....	161
Fig. 6.20:	Speed-Flow Results for 6- and 4-lane Freeways with 70-mi/h Design Speed .....	164
Fig. 6.21:	Speed-Flow Relationship for a 6-Lane Freeway in Toronto.....	165
Fig. 6.22:	Speed-Flow Curves for Freeways in the 1985 HCM.....	165
Fig. 6.23:	Speed-Flow Data for the 1994 Update .....	167
Fig. 6.24:	Speed-Flow Curves for Multilane Highways, 1994 Update .....	168
Fig. 6.25:	Speed-Flow Curves for Freeways, 1994 Update .....	171
Fig. 6.26:	Speed-Flow Curves for Freeways, 1997 Update and 2000 HCM.....	172
Fig. 6.27:	Data Plots for 2010 Speed-Flow Curves .....	175
Fig. 6.28:	Original Freeway Speed-Curves Recommended for the 2010 HCM.....	178
Fig. 6.29:	The Anomaly Between Freeway and Multilane Highway Service Flows –60 mi/h FFS .....	180
Fig. 6.30:	Determining the Break-Point for the Constant-Speed Portion of the Speed-Flow Curve .....	190
Fig. 6.31:	“Best Fit” 3- Segment Linear Model.....	193
Fig. 6.32:	Revised 3-Segment Linear Curves .....	194
Fig. 6.33:	Revised 2000 HCM Approach Curves .....	195
Fig. 6.34:	Revised Brilon Equations .....	197
Fig. 6.35:	Recommended Curves for 2010 HCM .....	199
Fig. 7.1:	Level of Service Boundaries vs. Speed-Flow Characteristics – Multilane Highways – 1950 HCM.....	214
Fig. 7.2:	Base Speed-Flow Curves for Basic Freeway Segments – 1985 HCM.....	216
Fig. 7.3:	Base Speed-Flow Curves for Multilane Highways – 1985 HCM .....	216
Fig. 8.1:	Formation of a Weaving Segment .....	249
Fig. 8.2:	Types of Weaving Segments Illustrates .....	251
Fig. 8.3:	Weaving Configurations in the 1950 HCM.....	254
Fig. 8.4:	Operating Characteristics of Weaving Segments – 1950 HCM .....	256
Fig. 8.5:	Compound Weaving Segment – 1950 HCM.....	257



Fig. 8.6:	Weaving Intensity Chart from the 1965 Highway Capacity Manual.....	260
Fig. 8.7:	Measuring the Length of a Weaving Segment in the 1965 HCM.....	262
Fig. 8.8:	Configurations Identified in NCHRP 3-15 .....	266
Fig. 8.9:	Relationships Among $S_{NW}$ , VR, $N_{NW}$ and $N_W$ (W) for Major and Ramp-Weaves – NCHRP 3-15 Method .....	270
Fig. 8.10:	Configurations for the PINY Method .....	273
Fig. 8.11:	Nomograph 1 for Leisch Method .....	278
Fig. 8.12:	Nomograph 2 for Leisch Method .....	279
Fig. 8.13:	Nomograph 3 for the Leisch Method.....	279
Fig. 8.14:	Nomograph 4 for Leisch Method .....	280
Fig. 8.15:	Weaving Configurations for the 1985 HCM .....	285
Fig. 8.16:	Lengths for the 2010 HCM Methodology .....	297
Fig. 8.17:	Weaving Segment Parameters Illustrated – 2010 HCM.....	298
Fig. 8.18:	Weaving Movements – 2010 HCM.....	298
Fig. 9.1:	Distribution of Traffic on a Four-Lane Highway – 1950 HCM.....	340
Fig. 9.2:	Lane Distribution of Vehicles on a Four-Lane Expressway Near an On-Ramp with Heavy Flow – 1950 HCM.....	341
Fig. 9.3:	Checkpoint Volumes for Ramp Methodology Illustrated – 1965 HCM.....	343
Fig. 9.4:	On- and Off-Ramp Vehicles in Auxiliary Lane – 1965 HCM.....	348
Fig. 9.5:	Ramp Volume in the Auxiliary Lane and/or Lane 1 – LOS D-E Methodology, 1965 HCM.....	351
Fig. 9.6:	Trucks in Lane 1 Immediately Upstream of a Ramp Junction – 1965 HCM .....	352
Fig. 9.7:	Ramp Influence Areas Illustrated .....	356
Fig. 9.8:	Critical Variables in the Ramp Junction Analysis Methodology .....	357
Fig. 10.1:	Average Travel Speed, Percent Time Delay, and Volume for Two-Lane, Two-Way Highways – 1985 HCM.....	398
Fig. 10.2:	Solution for Capacity and Speed at Capacity on a Two-Lane Highway Significant Grade – 1985 HCM.....	404
Fig. 10.3:	Corrections to the PTSF vs. Directional Flow Relationship for Two-Lane Highways – 2010 HCM.....	420