

USER AND NON-USER BENEFIT ANALYSIS FOR HIGHWAYS

September 2010



American Association of State Highway and Transportation Officials

USER AND NON-USER BENEFIT ANALYSIS FOR HIGHWAYS

September 2010



American Association of State Highway and Transportation Officials

© 2010 by the American Association of State Highway and Transportation Officials.
All rights reserved. Duplication is a violation of applicable law.

© Copyright 2010, by the American Association of State Highway and Transportation Officials. All rights reserved.
This book, or parts thereof, may not be reproduced in any form without written permission of the publisher. Printed in
the United States of America.

ISBN: 978-1-56051-467-1

Publ. Code: UBA-3

Foreword

This manual and accompanying CD-ROM provide a valuable resource for people who analyze the benefits and costs of highway projects. These analysts have the difficult and often cumbersome responsibility of performing complex benefit–cost calculations and presenting the results to decision makers, the media, and the public. It has been the practice of the American Association of State Highway and Transportation Officials (AASHTO) to publish materials to support transportation planners in state, regional, and local governments who evaluate highway investments. This manual is the merger of two, related research efforts that should simplify the efforts of these planners.

The first of these efforts, NCHRP Project 02-23, “User Benefit Analysis for Highways,” was conducted by the research team of ECONorthwest, in association with Kittelson & Associates, Inc., and Parsons Brinckerhoff, Inc. This effort yielded a major update of the original, 1977 AASHTO user benefit manual. The update incorporated new theory, new measurement methodologies, and new procedural guidance for the measurement of user benefits associated with highway improvements. It also introduced a CD-ROM containing the manual itself, worksheets and a software “Wizard” for guiding the analyst through the user benefit measurement process. The user benefit manual was adopted and published by AASHTO in 2003, and is commonly referred to as the “Red Book”.

In response to requests by users of the Red Book, a second research effort was undertaken as an extension of NCHRP Project 02-23. It is entitled “Non-User Benefit Analysis for Highways: A Supplement to AASHTO’s User Benefit Analysis for Highways” and was completed in 2007. Its purpose was to add non-user benefit measurement capability to the user-benefit capabilities of the AASHTO Red Book. This project was supported by an agreement between NCHRP and the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the National Academy of Sciences. The research team was lead by ECONorthwest, with assistance from Kittelson & Associates, Inc.

By combining these two, related resources, practitioners now have a single, integrated resource to assist in evaluating highway improvements that incorporates both user and non-user benefits. The theory and methods for estimating the benefits and costs of highway projects are presented in an integrated fashion, first for user benefits and then for non-user benefits. The CD-ROM contains an electronic copy of this manual in Portable Document Format (PDF). It also contains practical materials and resources for conducting and presenting benefit–cost analyses of highway improvements. These resources include the following:

- *Analytical Tools.* An interactive Microsoft Excel “wizard” is provided. This wizard takes the user through a series of dialogs where information about a project is collected and then calculates and presents the results of a benefit–cost analysis in a printable format. A series of Microsoft Excel spreadsheets also are included to help analysts organize data and make calculations to carry out

benefit–cost analyses. These spreadsheets are electronic versions of the calculation worksheets in the manual. The analyst can choose to examine just user benefits, non-user benefits or both. In addition, experience with the use of the Wizard by the research team and planners in the field has been exploited to improve the Wizard interface and add more flexibility to characterize highway projects.

- *Presentation Materials.* Microsoft PowerPoint slideshows that can be easily customized are provided to help practitioners prepare presentations about the results of benefit–cost analyses of highway projects. The slideshows complement the guidebook and can be used for presentations to decision-makers, the public, and the media. A library of relevant, royalty-free images for use in presentations and documents is also provided.
- *A Resource Library.* The CD-ROM contains resources to support practitioners as they evaluate the costs and benefits of highway projects. These resources include a glossary of terms used in the manual, a list of transportation organizations and website links where additional data may be found for benefit–cost analyses, and a list of websites that contain useful electronic maps and geographic information systems data.



Preface

This document updates and expands the American Association of State Highway and Transportation Officials (AASHTO) *User Benefit Analysis for Highways*, also known as the Red Book. This AASHTO publication helps state and local transportation planning authorities evaluate the economic benefits of highway improvements. This update incorporates improvements in user-benefit calculation methods and, for the first time, provides guidance for evaluating important non-user impacts of highways. Previous editions of the Red Book provided guidance regarding user benefit measurement only. This update provides a framework for project evaluations that accurately account for both user and non-user benefits.

The preparation of this update was done on behalf of the National Academy of Sciences, National Cooperative Highway Research Program (NCHRP) under project Number 02-23. This project is supported by an agreement between NCHRP and the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the National Academy of Sciences. The prime contractor for the research is ECONorthwest.

Executive Committee

2009–2010

Voting Members

OFFICERS:

President: Larry “Butch” Brown, Mississippi

Vice President: Susan Martinovich, Nevada

Secretary-Treasurer: Carlos Braceras, Utah

REGIONAL REPRESENTATIVES:

REGION I: Joseph Marie, Connecticut
Gabe Klein, District of Columbia

REGION II: Dan Flowers, Arkansas
Mike Hancock, Kentucky

REGION III: Nancy J. Richardson, Iowa
Thomas K. Sorel, Minnesota

REGION IV: Paula Hammond, Washington
Amadeo Saenz, Jr., Texas

Nonvoting Members

Immediate Past President: Allen Biehler, Pennsylvania

Executive Director: John Horsley, Washington, DC

Acknowledgments

The following people contributed to the preparation or review of these products.

NCHRP

Dianne Schwager, Senior Program Officer
Joe Snell, Senior Program Assistant

ECONorthwest

Dr. Randall Pozdena
Dr. Stephen Grover
Dr. Eric Fruits
Dr. Andrew Dyke
Carl Batten
Geo Lee
Dr. David Lindahl
Terry Moore
James Pozdena
Brett Sheckler
John Tapogna
Chris Mefford

FHWA Liaison

Eric Gabler
Martine Micozzi, TRB Liaison

Kittelson & Associates

Mark Vandehay
Judith Gray
Bruce Robinson

Parsons Brinckerhoff

Sam Seskin
John Boroski

NCHRP Review Panel

Patrick DeCorla-Souza, Federal Highway Administration
Norman Foster, Minnesota Department of Finance
Kevin Freeman, TRB
James Gillespie, Virginia Transportation Research Council
Richard Iovanna, U.S. Environmental Protection Agency
Thomas Keane, Federal Highway Administration
Jay Klagge, University of Phoenix
Arthur C. Jacoby, Federal Highway Administration
Jay Klagge, University of Phoenix
Ysela Llort, Florida Department of Transportation
David Lutz, Oregon Department of Transportation
Tom Stephens, Nevada Department of Transportation
Sandra Straehl, Montana Department of Transportation
Jon Williams, TRB
Ron Williams, Arizona Department of Transportation

Standing Committee on Planning

2009–2010

Chair: Debra L. Miller, Kansas

Vice Chair: Susan P. Mortel, Michigan

Secretary: Michelle Maggiore, AASHTO

Alabama

Don T. Arkle P.E.

Robert J. Jilla P.E.

Alaska

Ronald G. King

Jeffery Ottesen

Arizona

John E. McGee

Jennifer Toth P.E.

Arkansas

Scott E. Bennett

Alan Meadors

California

Joan Sollenberger

Colorado

Jennifer Finch

Sandi Kohrs

Connecticut

Robbin L. Cabelus

Delaware

Ralph Reeb

Michael Strange

District of Columbia

Karina Ricks

Florida

W. David Lee

Kathleen Neill

Georgia

Angela T. Alexander

Harvey D. Keepler

Todd I. Long

Hawaii

Ken Tatsuguchi

Idaho

Matthew E. Moore P.E.

Illinois

Dick Smith

Indiana

Vacant

Iowa

Stuart P. Anderson P.E.

Kansas

Chris J. Herrick P.E.

Kyle Schneweis

Kentucky

Keith Damron P.E.

Mike Hancock

Louisiana

Eric I. Kalivoda

Michael G. Schiro

Maine

Peter M. Coughlan P.E.

Dale F. Doughty

Kat Fuller, Chief

Maryland

Douglas H. Simmons

Massachusetts

David Mohler

Michigan

Polly Kent

Minnesota

Timothy A. Henkel

Jonette R. Kreideweis

Mississippi

Steven K. Edwards P.E., P.L.S.

Juan Flores

Jeffrey A. Pierce

Missouri

Machelle Watkins

Montana

Vacant

Lynn Zanto

Nebraska

Randall D. Peters P.E.

Nevada

Tracy Larkin-Thomason P.E., PTOE,

CPM

New Hampshire

William E. Watson Jr.

New Jersey

Brent Barnes

Robert Miller

New Mexico

Patricia Oliver-Wright

New York

Lynn Weiskopf

Robert Zerrillo

North Carolina

Deborah M. Barbour P.E.

Mike Bruff P.E.

Calvin W. Leggett P.E.

North Dakota

Scott Zainhofsky

Ohio

Jennifer Townley

Oklahoma

Ginger McGovern P.E.

David C. Streb P.E.

Oregon

Jerri Bohard

Rian Windsheimer

Pennsylvania

James D. Ritzman

Larry S. Shifflet

Thomas E. TenEyck

Puerto Rico

Gabriel A. Rodriguez-Fernandez

Rhode Island

Robert A. Shawver P.E.

South Carolina

Ron Patton

Mark Pleasant

South Dakota

Tim Bjorneberg

Ben Orsbon

Jerry Ortbahn

Tennessee

Ed Cole

Chief of Environment and Planning

Jeanne Stevens AICP

Texas

James L. Randall P.E.

Utah

Ahmad Jaber P.E.

John H. Thomas P.E.

Vermont

Vacant

Virginia

Marsha C. Fiol

Mary Lynn Tischer Ph.D.

Washington

Brian J. Smith AICP

West Virginia

Robert L. Pennington P.E.

Wisconsin

Sandra K. Beaupre' AICP

Mark J. Wolfgram

Wyoming

Martin Kidner P.E.

U.S. DOT Member**FHWA**

James A. Cheatham P.E.

FRA

Robert E. Martin Jr.

FTA

Charles R. Goodman

Associate Member—Federal**USDA Forest Service**

Joel Krause

Associate Member—International**Alberta**

Brian Marcotte

Manitoba

Amar Chadha P.E.

Northwest Territories

Russell Neudorf

Saskatchewan

George Stamatinos

Table of Contents

Chapter 1. Overview	1-1
Preface: Why Use This Manual?	1-1
General Purpose	1-1
Complicating Issues	1-2
Introduction to Benefit Measurement	1-5
The Workflow Structure of This Manual	1-7
Highway, Project, and Improvement Types	1-7
Project Management Options	1-11
Economic Analysis	1-13
A Guide to the Chapters of the Manual	1-13
Glossary of Terms	1-14
Chapter 2. Concepts and Basic Methodologies	2-1
Basic Concepts	2-1
The Economic Basis of Highway User Benefit Analysis	2-2
A <i>QuickGuide</i> to User Benefit Analysis	2-3
The Basic Steps of the Process	2-3
The Base Case vs. the Project Alternative	2-7
Defining the Base Case and the Project Alternative	2-8
Benefits and Costs	2-9
Project Performance Over Time: The Concept of Present Value and the Discount Rate	2-11
Basic Methodologies	2-13
User Benefit Measurement	2-13
The User Benefit Formulae	2-23
Project Cost Measurement	2-28
Performing Benefit–Cost Analysis and Project Selection	2-30
Chapter 3. Evaluating Operational Improvements	3-1
Additional Lanes	3-1
The Basic Elements of Additional Lane Analysis	3-2
Calculating User Benefits of Additional Lanes	3-12
Where to Go from Here	3-14

TABLE OF CONTENTS

New Highway 3-15
 The Basic Elements of New Highway Analysis..... 3-15
 The Special Case of Wilderness Roads..... 3-16
Traffic Control 3-17
 Basic Elements of Traffic Control 3-17
 Incorporating Traffic Control Delay in User Benefit Analysis 3-25
Signal Systems 3-28
 Basic Elements of Signal Systems 3-28
Intelligent Transportation Systems Improvements 3-31
 General Categories of ITS Improvements 3-31
 Calculating the Value of Time Savings 3-40
 Where to Next? 3-41
 Pricing and Regulatory Policies 3-41
 The Basic Elements of Evaluating Pricing Policies 3-41
 The Basic Elements of Evaluating Regulatory Policies 3-45
 Where to Next? 3-51
Chapter 4. Evaluating Safety Improvements 4-1
 Sources of Information Relating to the Effects of Safety Improvements 4-2
 Geometric Improvements 4-2
 Lane Improvements 4-3
 Access Management 4-6
 Roadside Improvements 4-13
 Incorporating the Effects of Safety Improvements in User Benefit Analysis..... 4-15
Chapter 5. User Benefit Analysis Modules..... 5-1
 Introduction 5-1
 Value of Time Module..... 5-2
 Application: Value of Time Calculation..... 5-6
 Operating and Ownership Costs Module..... 5-9
 Application: Operating Cost Calculation..... 5-20
 Accident Costs Module..... 5-23
 Accident Frequency 5-23
 Modeling Changes in Accidents 5-25
 Accident Unit Costs 5-42
 Combining Accident Frequency and Accident Cost Information..... 5-45
 Application: Accident Cost Calculation 5-46
 Project Management Module 5-50
 The Basic Elements of Project Management 5-51
 Effect of Project Management on Construction Costs..... 5-54
 Effect of Project Management on User Costs 5-55
 Calculating Costs and Benefits of Project Management Options..... 5-58

Application: Project Management Cost Calculations 5-60

Where to Next? 5-62

Chapter 6. Benefit–Cost Calculations 6-1

Drawing Together The Calculation Elements 6-2

 Improvement Formats. 6-2

 Traffic Formats. 6-3

Extrapolating and Aggregating User Benefit Calculations 6-3

 General Guidance for Extrapolation and Interpolation 6-4

 Formulaic Extrapolation and Interpolation Approaches 6-5

Setting Up the Benefit–Cost Framework 6-32

 The Project Horizon 6-33

 Basic Present Value Arithmetic and the Selection of the Discount Rate. 6-36

 Assembling Project Cost Data. 6-43

Present Value Calculations and Sensitivity Analysis. 6-59

 Assembling Module Information 6-59

Identifying Feasible Projects 6-63

 The Role of Budget Constraints 6-63

 Performing Sensitivity Analysis. 6-65

Application: Expansion and Extrapolation of Time-Savings Benefits 6-68

Chapter 7. Survey of Available Software Tools 7-1

Overview 7-1

Tools for Project-Level Evaluation. 7-2

 MicroBENCOST 7-2

 HEEM III. 7-3

 WSDOT Benefit–Cost Software 7-3

 ROADSIDE 7-3

Tools for Corridor- or Network-Level Evaluation. 7-4

 SPASM 7-4

 STEAM 7-5

 HDM4 7-6

 StratBENCOST 7-6

 Net BC 7-7

 IDAS. 7-7

 CAL-BC 7-8

Summary 7-9

DOT Survey of Software Tools. 7-10

TABLE OF CONTENTS

Chapter 8. Introduction 8-1
 The Principal of Implicit Valuation 8-2
 Using Part Two 8-3
 Goals 8-3
 Project-Specific Studies 8-5
 Definition of Terms 8-6
 Overview of Topical Coverage 8-7
 Economic Development 8-7
 Environmental Impacts 8-8
 Secondary Impacts 8-8
 Enhancements to the Wizard 8-9

Chapter 9. Primary Impacts 9-1
 Identifying User Benefits 9-1
 Measuring User Benefits 9-3
 Economic Development Impacts 9-4
 The Benefits from Investment in Transportation Infrastructure 9-6
 Measuring Economic Development Benefits 9-11
 Enhancements to the Wizard 9-21
 Environmental Impacts 9-26
 Vehicle Emissions 9-32
 Surface Water 9-41
 Noise 9-50
 Barrier Effects 9-57

Chapter 10. Secondary Impacts 10-1
 Construction Spending Impacts 10-3
 Slack in the Supply of Resources 10-4
 Small Geographic Area 10-4
 Measuring Construction Impacts 10-5
 Translating Economic Impacts into Economic Benefits 10-10
 Enhancements to the Wizard 10-10
 Land Use Impacts 10-13
 Identifying Changes in Land Use 10-15
 Modeling Land Use 10-16
 Cross-Sectional Data Analysis 10-16
 Identifying the Benefits Associated with Changes in Land Use 10-17
 Implications for the Wizard 10-18
 Property Value Impacts 10-18
 Capitalization of Primary Impacts 10-19
 Estimating Changes in Property Value 10-21
 Implications for the Wizard 10-23

Equity Measures 10-23
 Distributing User Benefits and Costs 10-24
 Implications for the Wizard 10-25

Appendix. Wizard User Manual A-1

Starting the Wizard A-1
 Define Your Project A-4
 Data Needs A-7
 Analysis Period. A-9
 User Classes A-10
 Economic and Other Parameters. A-14
 Construction Management Alternatives. A-16
 Base Case (Unimproved) Segment User Benefit Data A-19
 Improved Segment User Benefit Data A-23
 Traffic Conversion Factors A-28
 Non-User Benefit Modules A-30
 Economic Development A-31
 Construction Spending. A-35
 Vehicle Emissions A-37
 Water Runoff A-40
 Noise A-43
 Other A-47
 Results A-51

References R-1

FIGURES

Figure 1-1. Relationship of User Benefit Analysis with Other Analysis Areas1-6

Figure 1-2. The Workflow Path from Project to Evaluation Parameters 1-10

Figure 1-3. The Workflow Path from Evaluation Parameters to Economic Feasibility
Measurement 1-12

Figure 2-1. Stylized Calculation of Consumer Surplus 2-16

Figure 2-2. Stylized Calculation of Benefits with Shift in Demand..... 2-19

Figure 2-5. Stylized Representation of the User Cost Linkages 2-28

Figure 3-1. The Effects of Lane Additions on Speed on Urban Freeways and
Expressways for Various Increases in Capacity (Speeds in Miles per Hour)3-6

Figure 3-2. The Effects of Lane Additions on Speed on Urban Collectors and
Arterials for Various Increases in Capacity (Speeds in Miles per Hour)3-7

Figure 3-3. The Effects of Lane Additions on Speed on Rural Freeways and
Expressways for Various Increases in Capacity (Speeds in Miles per Hour)3-8

Figure 3-4. The Effects of Lane Additions on Speed on Rural Collectors and
Arterials for Various Increases in Capacity (Speeds in Miles per Hour)3-9

Figure 3-5. Stylized Transportation Analysis Zone Overlay..... 3-16

Figure 3-6. Intersection Control Delay for Minor Movements, by Entering Flow
and Intersection Capacity (below saturation; $T = 0.25$) 3-20

Figure 3-7. Intersection Control Delay for Minor Movements by Entering Flow
and Intersection Capacity (Above Saturation; $T = 0.40$) 3-21

Figure 3-8. The Effect of Metering on Ramp Users' Travel Time by Ramp Volume
and Location of the Metering Facility 3-25

Figure 3-9. The Effect of Tolls on Traffic Volume, User Benefits, and Toll Revenue 3-43

Figure 5-1. Fuel Cost (Cents per Mile) by Speed—Automobiles 5-13

Figure 5-2. Fuel Costs (Cents per Mile) by Speed—Heavy Trucks 5-13

Figure 5-3. Annual Amortized Cost, by Interest Rate and Life
(per \$1,000 of Capital Value) 5-16

Figure 5-4. Inventory Costs per-Vehicle Mile, by Speed and Cargo Value
(at 10 Percent Interest Rate) 5-18

Figure 5-5. Accidents and Volume-Capacity Relationship for Urban Freeways 5-27

Figure 6-1. Diurnal Pattern of V/C Ratios and Relative Travel Time Savings
(Low Exponent BPR Function)6-8

Figure 6-2. Diurnal Pattern of V/C Ratios and Relative Travel Time Savings
(High Exponent BPR Function).....6-8

Figure 6-3. Peak Hour Share of Total Daily Volume (250 Highway Sample) 6-15

Figure 6-4. Peak Traffic Shares, Primary vs. Secondary Direction
(for 250 Highway Sample)..... 6-15

Figure 6-5. The Relationship Between Peak Hour and Daily Benefits
(Using $b = 10$) 6-16

Figure 6-6. The Benefit Expansion Factor for Capacity Enhancements,
for Various BPR Exponents (b) and Various Daily Peak Traffic Factors 6-17

Figure 6-7. Peaking Factors Tend to Decline with ADT 6-18

Figure 6-8. Examples of Seasonal Patterns for Different Road Locations 6-23

Figure 6-9. Average Daily Traffic in Peak Month as Share of Annual Daily Traffic
(from 122 Oregon Facility Count Data) 6-24

Figure 6-10. Relationship Between Seasonal Peaking Factor and
Seasonal Expansion Factor ($b = 10$ in BPR Function) 6-24

Figure 6-11. Expansion Factor from Peak Month to Annual Benefits
(For Various BPR Exponents (b) and Seasonal Peaking Factors) 6-26

Figure 6-12. User Travel Time Savings, by Project Year and Initial V/C Ratio 6-29

Figure 6-13. Timeline of Highway Project Planning and Implementation,
Forward Evaluation Date 6-34

Figure 6-14. Timeline of Highway Project Planning and Implementation,
Contemporaneous Evaluation Date 6-34

Figure 6-15. Annual Rates of Change of the ENR Construction Index 6-45

Figure 6-16. Operating Costs for Urban Highways
(in 1997 Cents per Vehicle-Mile) 6-54

Figure 6-17. Operating Costs for Urban Highways
(in 1997 Cents per Vehicle-Mile), cont. 6-55

Figure 6-18. Operating Costs for Rural Highways
(in 1997 Cents per Vehicle-Mile) 6-56

Figure 6-19. Operating Costs for Rural Highways
(in 1997 Cents per Vehicle-Mile), cont. 6-57

Figure 6-20. Stylized Representation of User Benefit Aggregation and Extrapolation . . . 6-61

Figure 6-21. Stylized Representation of Present Value Calculations 6-62

TABLES

Table 2-1. *QuickGuide* Table to the Basic Steps of User Benefit Analysis 2-4

Table 2-2. Stylized Calculation of User Benefits Resulting from a
Reduction in Trip Cost. 2-17

Table 2-3. Hypothetical Project Costs for Selected Years and Activities 2-30

Table 2-4. Passenger Car Equivalents at Typical Operating Weights
by Vehicle Configuration and Facility Class (Battelle, 1998) 2-32

Table 3-1. Worksheets in *HCM 2000* for Calculating Speed on
Roadway Segments of Various Types. 3-3

Table 3-2. Typical BPR Function Parameters in Volume-Delay Analysis 3-5

Table 3-3. Sources for Detailed Traffic Control Delay Measurements. 3-22

Table 3-4. Capacity and Freeflow Speeds of Typical Freeway Ramps 3-24

Table 4-1. Worksheets in the *HCM 2000* for Calculating Speed or Delay
on Roadway Segments or Intersections of Various Types. 4-3

Table 4-2. Relevant Highway Types, Lane Improvement Categories,
and Appropriate Sections of the *HCM 2000* 4-4

Table 4-3. *HCM 2000* Worksheets by Improvement and Highway Type 4-5

Table 4-4. Worksheets in *HCM 2000* for Calculating Speed on Roadway
Segments of Various Types 4-8

TABLE OF CONTENTS

Table 4-5. Access Management Techniques Covered in NCHRP Report 420. 4-9

Table 4-6. Annual Delay (Hours) to Major Street Left-Turn and Through Vehicles 4-10

Table 4-7. Threshold Traffic Volumes for Installing Non-Traversable Medians,
by Road Type and Land Use 4-10

Table 4-8. Simplified Capacity Calculations for Left-Turn Lanes. 4-12

Table 4-9. Impedance Factor for Simplified Left-Turn Lane Capacity Calculations 4-12

Table 4-10. Chapter References for Roadside Design Improvement Types. 4-14

Table 4-11. Worksheets in *HCM 2000* for Calculating Speed on
Roadway Segments of Various Types. 4-15

Table 5-1. Guidelines for Assigning Values of Time in Highway Project Analysis 5-3

Table 5-2. Average Wages and Total Compensation, by Industry (2000 \$). 5-4

Table 5-3. Hours of Delay per Heavy Vehicle Crash by Roadway Class,
Location, and Severity 5-5

Table 5-4. Automobile Operating and Ownership Costs (Cents), 2010. 5-10

Table 5-5. Fuel Consumption for Autos and Trucks, by Average Operating Speed. 5-12

Table 5-6. Fuel Consumption (Gallons) per Minute of Delay by Vehicle Type 5-14

Table 5-7. Motor Vehicle Accident Involvement and Costs in 2000. 5-24

Table 5-8. Sources for Information on Accident Prediction Tools 5-26

Table 5-9. Values for Overdispersion Parameter in the Empirical Bayes Procedure. 5-34

Table 5-10. Recommended Negative Binomial Coefficient Values for
Urban Three-Leg Stop-Controlled Intersections (For Use in Equation 5-22). 5-36

Table 5-11. Recommended Lognormal Coefficient Values for Urban Four-Leg
Intersections—Stop-Controlled and Signalized (For Use in Equation 5-22) 5-37

Table 5-12. Accident per Million VMT by Median Type—Urban and
Suburban Areas 5-41

Table 5-13. Accidents per Million VMT by Median Type—Rural Areas. 5-41

Table 5-14. Accident Rates Based on an Average of Seven Computer Models. 5-42

Table 5-15. Summary of Accident Reductions Due to Left-Turn Treatments 5-42

Table 5-16. Accident Cost by Abbreviated Injury Scale (2000 \$). 5-43

Table 5-17. Insurance Reimbursement Calculation (Year 2000 Dollars and Rates) 5-45

Table 5-19. Sample Comparison of Two Contracting Methods 5-61

Table 6-1. Recommended Uses of Extrapolation Procedures 6-5

Table 6-2. Summary of Expansion Factors for Measuring Annual Benefits 6-27

Table 6-3. HERS Estimates of Construction Costs, per Lane Mile
(Updated to 2000 Dollars) 6-46

Table 6-4. HERS Estimates of Unit Construction Costs, per Element
(Urban Facilities, Updated to 2000 Dollars) 6-47

Table 6-5. HERS Estimates of Unit Construction Costs, per Element
(Rural Facilities, Updated to 2000 Dollars) 6-48

Table 6-6. HERS State Adjustment Factors 6-49

Table 7-1. Summary of User Benefit Calculations for MicroBENCOST. 7-2

Table 7-2. Summary of User Benefit Calculations for WSDOT Benefit–Cost Software. . . 7-3

Table 7-3. Summary of User Benefit Calculations for ROADSIDE7-4

Table 7-4. Summary of User Benefit Calculations for SPASM.7-5

Table 7-5. Summary of User Benefit Calculations for STEAM7-6

Table 7-6. Summary of User Benefit Calculations for HDM47-6

Table 7-7. Summary of User Benefit Calculations for StratBENCOST.....7-7

Table 7-8. Summary of User Benefit Calculations for IDAS7-7

Table 7-9. Summary of User Benefit Calculations for CAL-BC.....7-8

Table 7-10 Comparison of Available Benefit–Cost Software7-9

Table 7-11. Summary of State DOT Software Survey Results. 7-10

Table 8-1. Construction Costs for Three Hypothetical Projects.....8-2

Table 9-1. Output Elasticities for Investment in Transportation Infrastructure. 9-17

Table 9-2. Environmental External Costs of Motor Vehicle Use 1990–1991
(1991 Dollars) 9-27

Table 9-3. Transportation Contributions to U.S. Pollutant Emissions in 2002 9-34

Table 9-4. Air Pollution Costs (2005 U.S. Dollars per VMT) 9-35

Table 9-5. Suggested Distribution of VMT by Vehicle Type..... 9-39

Table 9-6. Water Pollution and Hydrologic Impacts of Stormwater Runoff..... 9-41

Table 9-7. Pollution Levels in Road Runoff (Milligrams per Liter) 9-42

Table 9-8. Typical Mitigation Costs as a Share of Project Costs..... 9-47

Table 9-9. Marginal Pavement, Congestion, Crash, and Noise Costs for
Illustrative Vehicles Under Specific Conditions (2000)..... 9-52

Table 9-10. Estimated Highway Noise Costs (1997 U.S. Cents per VMT)..... 9-52

Table 9-11. Base-Case Marginal Noise Costs in Urban Areas
(1991 U.S. Dollars per 1,000 VMT)..... 9-53

Table 9-12. Barrier Effects (2005 U.S. Dollars per VMT) 9-61

Table 10-1. Representative Output, Personal Income, and Employment Multipliers 10-9

Table 10-2. Hypothetical Distribution of User Benefits by Multiple Characteristics ... 10-24

WORKSHEETS

Worksheet 3-1. Travel Time Savings from Intelligent Transaction Processing—
Sample Calculation 3-36

Worksheet 3-1. Travel Time Savings from Intelligent Transaction Processing..... 3-38

Worksheet 5-1. Value of Time—Sample Calculation5-7

Worksheet 5-1. Value of Time5-8

Worksheet 5-2. Operating and Ownership Cost—Sample Calculation 5-21

Worksheet 5-2. Operating and Ownership Cost..... 5-22

Worksheet 5-3. Accident Cost—Sample Calculation..... 5-48

Worksheet 5-3. Accident Cost 5-49

Worksheet 5-4. User Cost for Project Management Options—Sample Calculation..... 5-63

Worksheet 5-4. User Cost for Project Management Options 5-64

Worksheet 6-1. Calculation of Time-Savings Benefits When Hourly
Volumes Are Known 6-69

TABLE OF CONTENTS

Worksheet 6-2A. Formulaic Calculation of Time-Savings Benefits..... 6-72
Worksheet 6-2B. Formulaic Calculation of Time-Savings Benefits 6-73
Worksheet 6-3. Extrapolation and Present Valuation of Benefits from a
Capacity-Improvement Project 6-74
Worksheet S-1A. Economic Development Impacts (Elasticity Method) 9-24
Worksheet S-1B. System Capacity Calculator..... 9-25
Worksheet S-2. Vehicle Emission 9-41
Worksheet S-3. Stormwater Runoff 9-49
Worksheet S-4. Noise 9-57
Worksheet S-5. Other Impacts 9-63
Worksheet S-6. Construction Spending Impacts 10-12

CHAPTER 1

Overview

Preface: Why Use This Manual?

Transportation planners and policy makers are charged with the responsibility of identifying and selecting the projects that deserve implementation. Often, there are competing project designs to serve the same purpose. The project-selection process is complicated further, in most cases, by limited budgets and a host of candidate projects that might benefit the community. In these situations, analytic tools are needed to evaluate the relative merits of each candidate project and ultimately provide a means for allocating resources to that set of projects that will maximize the total benefits. The purpose of this manual is to assist in this process by providing the tools necessary to evaluate the costs and benefits related to transportation improvement projects.

General Purpose

There are many different types of benefits related to transportation improvements. Part One of this manual focuses on *user benefits*, or benefits that are enjoyed by travelers that are directly affected by a transportation improvement. User benefits are determined by travel costs in three distinct areas: travel time costs, operating costs, and accident costs. Taken together, the total of these costs is essentially the price that travelers must pay to travel. When a comparison is made between the costs of traveling and the number of trips taken at each price level, a relationship is determined between the cost of travel and the demand for trips. When all users are aggregated together, the difference between the travel “price” that travelers are required to pay and what they would have been willing to pay is the user benefit affiliated with the trip. Any reduction in travel costs (i.e., trip price), then, will result in a benefit to the traveler. For example, with a cost reduction, users who were already making the trip receive the benefit of making the same trip at a lower cost.

Focusing first on user benefits is appropriate because most of the economic benefits of transportation projects come from the reduction in user costs. When trips in a particular corridor are perceived as costly, perhaps due to long travel times or high accident rates, travelers sacrifice taking some trips in that corridor, and the economic activity associated with those trips is lost. Reducing user costs makes the

perceived cost of travel cheaper, and facilitates trip making and the accompanying economic activities. By balancing these accompanying user benefits against project costs, we can determine which projects will provide the optimal level of net benefits to society.

Obviously, however, a project will also impact people other than direct users of the facility. These effects are referred to as *indirect benefits* or *non-user benefits*. Examples of indirect benefits include environmental impacts, effects on urban growth, economic influences, and the distribution of costs and benefits attached with the project. The methods for measuring non-user benefits are different in some ways from the methods used to measure user benefits. To facilitate exposition of those differences, non-user benefit measurement is discussed in Part 2 of this manual, beginning at Chapter 8.

Regardless of whether one examines a project's benefits from the user or non-user perspective, the general framework for measuring project benefits is similar. Project benefit estimation requires that each project being evaluated be compared against some alternative outcome. The alternative outcome could be a "Base Case" or "No-Build Scenario" that maintains current facility conditions into the future. The alternative scenario could also be a different improvement project. In either case, to conduct the project benefit analysis, benefit levels are estimated for two different scenarios. When measuring user benefits, for example, the difference in user costs (that is, the combined effect on user benefits due to changes in travel costs, operating costs, and accident costs) is the impact to the users linked to the project. Since an improvement should result in a *reduction* in these costs, the difference in these cost levels is used to determine the total user benefit of the project. Measurement of non-user benefits also requires a comparison of the project outcome with some alternative outcome. The non-user project benefits are also measured as the difference of the two outcomes.

Complicating Issues

The preceding discussion provides the simplest overview of determining the user benefits connected to the transportation projects. To summarize, this manual provides the tools needed to estimate benefits from changes in travel time costs, operating costs, and accident costs—the factors that directly affect travelers' transportation choices.

Naturally, applying these principles to specific project applications is a much more complicated endeavor in the real world. Complicating issues that need to be addressed include:

- How do you measure the benefits of something that does not yet exist, especially when it interacts in a complicated way with other products or services?
- What do you do if some benefits or costs are not susceptible, at all, to measurements? What if the saving or loss of human life potentially is involved?
- What if the benefits and/or costs play out over a period of time? How should these delays be incorporated in the analysis?