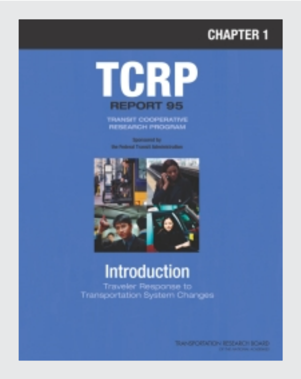

Traveler Response to Transportation System Changes Handbook, Third Edition: Chapter 1, Introduction

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 95

Traveler Response to Transportation System Changes

Chapter 1—Introduction

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), Transportation 2000, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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FOREWORD

By Stephan A. Parker
Staff Officer
Transportation Research Board

TCRP Report 95, *Traveler Response to Transportation System Changes Handbook, Third Edition; Chapter 1—Introduction: Traveler Response to Transportation System Changes*

This third edition *Traveler Response to Transportation System Changes Handbook* provides comprehensive information on travel demand effects of alternative urban transportation policies, operating approaches and systems, and built environment options, by building upon, expanding, and selectively replacing the earlier editions to provide a contemporary assessment of the experience and insights gained from the application and analysis of various system changes and alternatives. The focus is on aiding transportation, transit, and land use planners in their conduct of travel demand and related analyses, and to inform elected officials, administrators, operators, designers, and the general public as well.

This *Traveler Response to Transportation System Changes Handbook* consists of these Chapter 1 introductory materials and 15 stand-alone published topic area chapters. Each topic area chapter provides traveler response findings including supportive information and interpretation, and also includes case studies and a bibliography consisting of the references utilized as sources.

The *Handbook* findings derive primarily from reported results and analyses of real-world transportation system and policy applications and trials. Experimental or quasi-experimental empirical data have been the information source of choice. Other empirical data derivations and simple accounts of outcomes have been employed as necessary. Forecasts and other estimates derived from travel demand model applications and similar techniques have been used, but on a very selective basis; mostly for augmenting the empirical data where gaps exist, and for providing additional insights and context.

TCRP Report 95: Traveler Response to Transportation System Changes Handbook will be of interest to transit, transportation, and land use planning practitioners; transportation engineers; land developers, employers, and school administrators; researchers and educators; and professionals across a broad spectrum of transportation and planning; MPO; and local, state, and federal government agencies.

The overarching objective of the *Traveler Response to Transportation System Changes Handbook* is to equip members of the transportation profession with a comprehensive, readily accessible, interpretive documentation of results and experience obtained across the United States and elsewhere from (1) different types of transportation system changes and policy actions and (2) alternative land use and site development design approaches. While the focus is on contemporary observations and assessments of traveler responses as expressed in travel demand changes, the presentation is seasoned with earlier experiences and findings to identify trends or stability, and to fill information gaps that would otherwise exist. Comprehensive referencing of additional reference materials is provided to facilitate and encourage in-depth exploration of topics of interest. Travel demand and related impacts are expressed using such measures as usage of transportation facilities and services, before-and-after market shares and percentage changes, and elasticity.

The findings in the *Handbook* are intended to aid—as a general guide—in preliminary screening activities and quick turn-around assessments. The *Handbook* is not intended for use as a substitute for regional or project-specific travel demand evaluations and model applications, or other independent surveys and analyses.

The Second Edition of the handbook *Traveler Response to Transportation System Changes* was published by USDOT in July 1981, and it has been a valuable tool for transportation professionals, providing documentation of results from different types of transportation actions. This Third Edition of the *Handbook* covers 15 topic areas relative to the nine in the 1981 edition, seven that are new, and the remainder representing topic area updates, modified slightly in scope or expanded. Each topic is published as a chapter of TCRP Report 95. To access the chapters, see the project write-up on the TCRP website: http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=1034.

A team led by Richard H. Pratt, Consultant, Inc. is responsible for the *Traveler Response to Transportation System Changes Handbook, Third Edition,* through work conducted under TCRP Projects B-12, B-12A, and B-12B.

Handbook Outline Showing Publication and Source-Data-Cutoff Dates

General Sections and Topic Area Chapters (TCRP Report 95 Nomenclature)	U.S. DOT Publication First Edition	U.S. DOT Publication Second Edition	TCRP Report 95 Source Data Cutoff Date	TCRP Report 95 Publication Date
Ch. 1 – Introduction (with Appendices A, B)	1977	1981	2003 [a]	2000/03/12[a]
Multimodal/Intermodal Facilities				
Ch. 2 – HOV Facilities	1977	1981	1999-05[b]	2006
Ch. 3 – Park-and-Ride/Pool	—	1981	2003[c]	2004
Transit Facilities and Services				
Ch. 4 – Busways, BRT and Express Bus	1977[d]	1981	Future	Future
Ch. 5 – Vanpools and Buspools	1977	1981	1999-04[b]	2005
Ch. 6 – Demand Responsive/ADA	—	—	1999	2004
Ch. 7 – Light Rail Transit	—	—	Future	Future
Ch. 8 – Commuter Rail	—	—	Future	Future
Public Transit Operations				
Ch. 9 – Transit Scheduling and Frequency	1977	1981	1999	2004
Ch. 10 – Bus Routing and Coverage	1977	1981	1999	2004
Ch. 11 – Transit Information and Promotion	1977	1981	2002	2003
Transportation Pricing				
Ch. 12 – Transit Pricing and Fares	1977	1981	1999	2004
Ch. 13 – Parking Pricing and Fees	1977[d]	—	1999	2005
Ch. 14 – Road Value Pricing	1977[d]	—	2002-03[b]	2003
Land Use and Non-Motorized Travel				
Ch. 15 – Land Use and Site Design	—	—	2001-02[b]	2003
Ch. 16 – Pedestrian and Bicycle Facilities	—	—	2007-11[b]	2012
Ch. 17 – Transit Oriented Development	—	—	2004-06[b]	2007
Transportation Demand Management				
Ch. 18 – Parking Management and Supply	—	—	2000-02[b]	2003
Ch. 19 – Employer and Institutional TDM Strategies	1977[d]	1981[d]	2007-09[b]	2010

NOTES: [a] Published in TCRP Web Document 12, *Interim Handbook* (March 2000), without Appendix B. The "Interim Introduction," published as *Research Results Digest 61* (September 2003), is a replacement, available at http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rrd_61.pdf. Publication of an updated version of Chapter 1, "Introduction," as part of the TCRP Report 95 series, is anticipated for 2012.
[b] Primary cutoff was first year listed, but with selected information up into second year listed.
[c] The source data cutoff date for certain components of this chapter was 1999.
[d] The edition in question addressed only certain aspects of later edition topical coverage.

CHAPTER 1 AUTHOR AND CONTRIBUTOR ACKNOWLEDGMENTS

TCRP Report 95, the third edition of the "Traveler Response to Transportation System Changes" Handbook, has been prepared under TCRP Project B-12, as amended, by Richard H. Pratt, Consultant, Inc. in association with Jay Evans Consulting LLC; the Texas Transportation Institute; Parsons Brinckerhoff, Inc.; J. Richard Kuzmyak, L.L.C.; Cambridge Systematics, Inc.; Vanasse Hangen Brustlin, Inc./VHB; Gallop Corporation; McCollom Management Consulting, Inc.; Herbert S. Levinson, Transportation Consultant; and K.T. Analytics, Inc.

Richard H. Pratt has been the Principal Investigator. Dr. Katherine F. Turnbull of the Texas Transportation Institute and John E. (Jay) Evans, IV, then of Jay Evans Consulting LLC, each assisted as co-Principal Investigator during individual project B 12 phases. Lead Handbook chapter authors and co authors, in addition to Mr. Pratt, are Mr. Evans (initially with Parsons Brinckerhoff and now with Cambridge Systematics); Dr. Turnbull; J. Richard Kuzmyak, initially of Cambridge Systematics, latterly of J. Richard Kuzmyak, L.L.C., and now of Renaissance Planning Group; Frank Spielberg of VHB; Brian E. McCollom of McCollom Management Consulting, Inc.; Herbert S. Levinson, Transportation Consultant; Erin Vaca of Cambridge Systematics, Inc.; and Dr. G. Bruce Douglas of Parsons Brinckerhoff. Contributing authors include Dr. Kiran U. Bhatt, K.T. Analytics, Inc.; Shawn M. Turner, Texas Transportation Institute; Dr. Rachel Weinberger, Cambridge Systematics (now with the University of Pennsylvania); Andrew Stryker, Parsons Brinckerhoff; Dr. C. Y. Jeng, Gallop Corporation; and Daniel Nabors, VHB. Richard H. Pratt is the author for this *TCRP Report 95* volume: Chapter 1, "Introduction."

Other research agency team members contributing to the preparatory research, synthesis of information, and development of this Handbook have been Stephen Farnsworth, Laura Higgins, and Rachel Donovan of the Texas Transportation Institute; Nick Vlahos, Vicki Ruiter, and Karen Higgins of Cambridge Systematics, Inc.; Greg Benz, Bill Davidson, G.B. Arrington, and Lydia Wong of PB, along with the late travel demand modeler/planner extraordinaire Gordon W. Schultz; Kris Jagarapu of VHB; Sarah Dowling of Jay Evans Consulting LLC; and Laura C. (Peggy) Pratt of Richard H. Pratt, Consultant, Inc. Dr. C. Y. Jeng of Gallop Corporation provided pre-publication numerical quality control review, including eight initial chapters reviewed as a volunteer. By special arrangement, Dr. Daniel B. Rathbone of The Urban Transportation Monitor searched past issues. Assistance in word processing, graphics and other essential support has been provided by Bonnie Duke and Pam Rowe of the Texas Transportation Institute; Karen Applegate, Laura Reseigh, Stephen Bozik, and Jeff Waclawski of PB; others too numerous to name but fully appreciated; and lastly the warmly remembered late Susan Spielberg of SG Associates (now part of VHB).

Special thanks go to all involved for supporting the cooperative process adopted for topic area chapter development. Members of the TCRP Project B 12/B 12A/B 12B Project Panel, named elsewhere, provided review and comments for what will total some 18 individual publication documents/chapters. They have gone the extra mile in providing support on call, including leads, reports, documentation, advice, and direction over the decade-and-a-half duration of the project. Four consecutive appointed or acting TCRP Senior Program Officers have given their support: Stephanie N. Robinson, who took the project through scope development and contract negotiation; Stephen J. Andrle, who led the work during the Project B-12 Phase and on into the TCRP B-12A Project Continuation; Harvey Berlin, who saw the Interim Handbook through to website publication; and Stephan A. Parker, who has guided the entire project to its ultimate fruition, including the publication of each of 16 final chapters/volumes. Editor Natassja Linzau has provided her careful examination and fine touch, while Director of Publications Eileen Delaney and her team have handled the numerous publication details. TRB Librarian Jessica Fomalont provided invaluable literature procurement aid and TRB Intern Calvin D. Cheeks error-checked Chapter 16 tables. The efforts of all are greatly appreciated.

The Chapter 16 development effort was joined by the National Center for Environmental Health of the Centers for Disease Control and Prevention (CDC). Continued recognition is due to the participants in preparation of the first and second editions, key elements of which are retained in various chapters. Co-authors to Mr. Pratt were Neil J. Pedersen and Joseph J. Mather for the first edition, and John N. Copple for the second edition. Crucial support and guidance for both editions was provided by the Federal Highway Administration's Technical Representative (COTR), Louise E. Skinner.

Participation by the profession at large has been absolutely essential to the development of the Handbook. Sincere thanks are due to the Transportation Research Board (TRB) Pedestrian Committee ANF10, Bicycle Transportation Committee ANF20, Transportation and Land Development Committee ADD30, and Transportation Demand Management Committee ABE50 for aiding this participation and serving as forums for Chapter 16, 17, and 19 resource material information exchange and chapter review solicitation. Greatly appreciated similar roles were played in development of the other chapters by "Review Groups" comprised of volunteer expert professionals. Over 70 individual chapter or section reviews addressing the 16 currently published chapters were provided by reviewer volunteers, mainly from the supporting TRB committees and review groups. Though impractical to list here, they are individually identified in the "Author and Contributor Acknowledgments" of the relevant chapters. The comments, contributions, and advice received have substantially benefited the final product.

Finally, sincere thanks are due to the many other practitioners and researchers who were contacted for information and unstintingly supplied both that and all manner of statistics, data compilations, and reports. Though much too numerous to individually credit, many appear in the "References" section entries of the applicable chapters. Specific recognition is provided in various chapters of individuals and organizations that granted personal interviews, undertook original analyses, or provided other equally special contributions in support of chapter development. The contribution of each and all is truly valued.

CONTENTS

*NOTE: **CHAPTER 4** is not included in this Table of Contents.
This chapter has been deferred for a future TCRP project effort.

*NOTE: **CHAPTERS 7 and 8** are not included in this Table of Contents.
These chapters have been deferred for a future TCRP project effort.

**A corrected and updated version of this case study is provided as the “Arlington County, Virginia, Transit Oriented Development Densities” case study of Chapter 17.

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

1 – Introduction

TCRP Report 95: Traveler Response to Transportation System Changes, is the product of combined TCRP Projects B-12, B-12A, and B-12B, "Updating the 'Traveler Response to Transportation System Changes' Handbook (DOT-FH-11-9579)." The overall TCRP project objective has been to provide an up-to-date and expanded sourcebook on how travel demand is affected by changes in the transportation system, program and promotional actions, and built environment options. This Chapter 1, "Introduction," contains a four-level "Table of Contents" for the 16 published *TCRP Report 95* chapter/volumes, describes the *Traveler Response* Handbook and its development, offers guidance to the prospective Handbook user, and includes two Handbook appendices plus known errata. It is the only source of four-level table of contents information for the published chapters, and contains important context and technical information supportive of each of the topic-specific chapters in the series.

Changes/differences in urban transportation system provisions, operations and policy, and the built environment: How do they affect travel demand? The answers are vital in planning and evaluating transportation proposals, and for making effective design, operational, and policy changes to urban transportation systems. Projections of the trips by persons, mode use, and other manifestations of individual travel choices are a fundamental input to most transportation planning estimates including those of traffic and passenger volumes, congestion, revenues, costs, feasibility, travel benefits and disbenefits, economic impacts, energy use, and environmental effects. The *Traveler Response to Transportation System Changes* Handbook has served to assist—since 1977—as a travel demand reference for transportation professionals, providing accessible, interpretative documentation of actual results obtained from various types of urban transportation actions and options. This *TCRP Report 95* is the third edition.

HANDBOOK CONTEXT AND PREPARATION

In this first of the two major "Introduction" sections, the *Traveler Response* Handbook is placed in context with its origins, the current update, and companion reference documents. Its scope and key research steps are outlined. The second major section, "Use of the Handbook," provides information in support of informed and effective application of the work.

Genesis and Coverage of the Handbook

Earlier Editions

The U.S. Department of Transportation published the first and second editions of the *Traveler Response to Transportation System Changes* Handbook (Pratt, Pedersen, and Mather, 1977, Pratt and Copple, 1981). At the time of the first edition, energy and environmental concerns and a shift in emphasis away from capital intensive projects had caused serious consideration of transportation alternatives to constantly increasing low occupancy auto use. Regulations had been issued requiring Transportation System Management (TSM) as part of the urban planning process. Accordingly, low capital urban transportation improvements, both TSM and transit, were the primary system focus of the first edition.

By the time of the second edition, shrinking transportation revenues, rising construction costs, and energy scarcity had made more effective use of existing transportation systems essential. There was expanded emphasis on traffic operations improvements, ridesharing, priority for high occupancy vehicles, transit service enhancements, variable work hours, and other TSM actions. More experience had been gained in application of these types of actions. However, while the second edition reflected that advancement in practical knowledge, and substantially expanded on each topic retained from the first edition, only nine categories of system change were covered—and that was two decades prior to the new millennium.

Current Update

Further substantial innovations and advancements have occurred in transportation services provision and management since publication of the second edition *Traveler Response* Handbook, given impetus by the various Transportation Efficiency/Equity Acts of Congress. Electronic media have expanded fare, fee, and toll payment options; high occupancy toll (HOT) lanes have introduced value pricing to High Occupancy Vehicle (HOV) facilities; federal interest in non-motorized transportation (NMT) provisions has vastly increased; and new emphasis has been placed on land use and transportation interrelationships. More has been learned from approaches new or unseasoned a quarter century ago. The concept of Travel Demand Management (TDM) has taken form and been widely applied.

Connecting people with their daily activities, meeting needs for mobility, and addressing congestion in a context of continuing resource constraints, quality of life issues, and environmental concerns, calls for timely and practical information on how travel demand is shaped and altered by changes in our urban transportation systems and urban fabric. In response, the TCRP has undertaken this major update and expansion of the *Traveler Response* Handbook.

The topic area coverage of the updated *Traveler Response to Transportation System Changes* Handbook has been shaped by project research on practitioner needs, including Handbook user surveys, ongoing outreach to the transportation planning profession, and project panel work sessions. The focus is on transportation system changes and alternatives, or land use and site design differences, that directly affect the traveler. With individual-volume publication of each chapter extending from 2003 through 2012, plus the three future volumes marked with asterisks, this third edition contains the following topic area chapters/volumes:

- HOV Facilities
- Park-and-Ride/Pool
- Busways, BRT and Express Bus*
- Vanpools and Buspools
- Demand Responsive Transit/ADA
- Light Rail Transit*
- Commuter Rail*
- Transit Scheduling and Frequency
- Bus Routing and Coverage
- Transit Information and Promotion
- Transit Pricing and Fares
- Parking Pricing and Fees
- Road Value Pricing
- Land Use and Site Design
- Pedestrian and Bicycle Facilities
- Transit Oriented Design
- Parking Management and Supply
- Employer and Institutional TDM Strategies

Companion Handbooks

The *Traveler Response to Transportation System Changes* Handbook has, from its inception, been part of an overall transportation systems and travel demand research effort by the U.S. Department of Transportation, and now the Transit Cooperative Research Program. Related handbooks in this effort are *Characteristics of Urban Transportation Systems (CUTS),* currently in its seventh revision by the Federal Transit Administration (Cambridge Systematics, 1992), and *Characteristics of Urban Travel Demand (CUTD),* available in its third version as *TCRP Report 73* (Reno, Kuzmyak, and Douglas, 2002). All three handbooks have received wide distribution and have become standard references in the transportation field.

The three handbooks were joined in 1999 by the *Transit Capacity and Quality of Service Manual,* now in its second edition as *TCRP Report 100* (Kittelson and Associates et al., 2003). This manual was designed to provide the public transit equivalent of the *Highway Capacity Manual* while also addressing transit quality of service concepts and measurement. The fifth edition of the *Highway Capacity Manual 2010* (HCM 2010) now provides multimodal incorporation of transit, pedestrian, and bicycle facility capacity and level of service (LOS) evaluation including assessment of off-road pedestrian and bicycle facilities and on-road bicycle provisions (Highway Capacity Manual, 2010).

Publication Timeline of this Handbook

The magnitude of this third edition *Traveler Response to Transportation System Changes* Handbook project led to advance and staged publication in an effort to provide access to available findings pending completion of the full 19-chapter, 18-topic Handbook. The process has been as follows:

- Seven topic area chapters and an initial "Introduction" were electronically published in March 2000 as an *Interim Handbook—TCRP Web Document 12* (Pratt et al., 2000b). That *Interim Handbook* is now completely superseded by *TCRP Report 95.*

- Print publication of the third edition *Traveler Response to Transportation System Changes* Handbook began in mid-2003, chapter by chapter, as *TCRP Report 95.* Each chapter is a separate volume. As each chapter has been printed, the electronic equivalent has been linked to from http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1034. Access is also available through http://www.trb.org/main/blurbs/162432.aspx.

- An *Interim Introduction* (with Appendices A and B) was published as *TCRP Research Results Digest 61* in 2003 to replace Chapter 1, "Introduction" and "Appendix A" of the *Interim Handbook* and accompany the *TCRP Report 95* series (Pratt, 2003). That *Interim Introduction* is now superseded by this *TCRP Report 95,* Chapter 1, "Introduction."

- All *TCRP Report 95* chapter/volumes are, with this 2012 publication of Chapter 1, "Introduction," printed and electronically posted except for future Chapters 4, 7, and 8. This makes a total of 16 chapter/volumes currently available to the profession, including 15 topic area chapters.

Table 1-1 lists the 18 *TCRP Report 95* topic area chapters and "Introduction" in outline order, and summarizes publication and source data cutoff information.

The later source data cutoff dates for the most recently published chapter/volumes have allowed some "cross-chapter" updating where there are areas of common interest. Users of Chapter 11, "Transit Information and Promotion," will find vastly expanded information on "individualized marketing" programs and results (including U.S. and Australian transit ridership effects) in Chapter 16, "Pedestrian and Bicycle Facilities." Users of Chapter 14, "Road Value Pricing," should turn to Chapter 2, "HOV Facilities," for additional experience with HOT lanes. And finally, users of Chapter 15, "Land Use and Site Design," should see the "Pedestrian/Bicycle Friendly Neighborhoods" subsection in Chapter 16 for an update on elasticities of travel with respect to urban form parameters.

Table 1-1 Handbook Outline Showing Publication and Source Data Cutoff Dates

General Sections and Topic Area Chapters (*TCRP Report 95* Nomenclature)	U.S. DOT Publication First Edition	U.S. DOT Publication Second Edition	*TCRP Report 95* Source Data Cutoff Date	*TCRP Report 95* Publication Date
Ch. 1 – Introduction (with Appendices A, B)	1977	1981	1999-2012 [a]	2000/03/12 [b]
Multimodal/Intermodal Facilities				
Ch. 2 – HOV Facilities	1977	1981	1999-2005 [a]	2000/2006 [c]
Ch. 3 – Park-and-Ride/Pool	—	1981	2003 [d]	2004
Transit Facilities and Services				
Ch. 4 – Busways, BRT and Express Bus	1977 [e]	1981 [e]	future	future
Ch. 5 – Vanpools and Buspools	1977	1981	1999-2004 [a]	2000/2005 [c]
Ch. 6 – Demand Responsive/ADA	—	—	1999-2003 [a]	2000/2004 [c]
Ch. 7 – Light Rail Transit	—	—	future	future
Ch. 8 – Commuter Rail	—	—	future	future
Public Transit Operations				
Ch. 9 – Transit Scheduling and Frequency	1977	1981	1999-2004 [a]	2000/2004 [c]
Ch. 10 – Bus Routing and Coverage	1977	1981	1999-2004 [a]	2000/2005 [c]
Ch. 11 – Transit Information and Promotion	1977	1981	2002	2003
Transportation Pricing				
Ch. 12 – Transit Pricing and Fares	1977	1981	1999-2004 [a]	2000/2004 [c]
Ch. 13 - Parking Pricing and Fees	1977 [e]	—	1999-2003 [a]	2000/2005 [c]
Ch. 14 – Road Value Pricing	1977 [e]	—	2002-2003 [a]	2003
Land Use and Non-Motorized Travel				
Ch. 15 – Land Use and Site Design	—	—	2001-2002 [a]	2003
Ch. 16 - Pedestrian and Bicycle Facilities	—	—	2007-2011 [f]	2012
Ch. 17 – Transit Oriented Development	—	—	2004-2006 [a]	2007
Transportation Demand Management				
Ch. 18 – Parking Management and Supply	—	—	2000-2002 [a]	2003
Ch. 19 – Employer and Institutional TDM Strategies	1977 [e]	1981 [e]	2007-2009 [a]	2010

Notes:
[a] Global cutoff was first year listed, but with selected information up into second year listed.
[b] Published in *TCRP Web Document 12*, *Interim Handbook*, in 2000, without Appendix B. Updated in 2003 as an *Interim Introduction* and published as *TCRP RRD 61*. Published in this current version, as part of the *TCRP Report 95* series, in 2012.
[c] Published in *TCRP Web Document 12*, *Interim Handbook*, in 2000. Published as part of the *TCRP Report 95* series on the second date shown.
[d] The source data cutoff date for certain components of this chapter was 1999.
[e] The edition in question addressed only certain aspects of later edition (or planned) topical coverage.
[f] Global cutoff was first year listed, but with extensive information up into second year listed.

Scope and Development of the Handbook

This updated *Traveler Response to Transportation System Changes* Handbook responds to the need for up-to-date and comprehensive information on travel demand effects of alternative urban transportation policies, operating approaches and systems, and built environment options, by building upon, expanding, and selectively replacing the earlier editions to provide a contemporary assessment of the experience and insights gained from the application and analysis of various system changes and alternatives. The focus is on aiding transportation, transit, and land use planners—and public health practitioners in the case of Chapter 16, “Pedestrian and Bicycle Facilities”—in their conduct of travel demand and related analyses, and to inform elected officials, administrators, operators, designers, and the general public as well.

Handbook Goal and Scope

The goal of the *Traveler Response* Handbook series is to equip members of the transportation profession and others with a comprehensive, readily accessible, interpretive documentation of results and experience obtained across the United States and elsewhere from different types of transportation system changes and policy actions, and also alternative land use and site development design approaches. While the focus is on contemporary observations and assessments of traveler responses as expressed in travel demand changes, the presentation is seasoned with earlier experiences and findings to identify trends or stability, and to fill research gaps that would otherwise exist. Comprehensive referencing of additional study materials is provided to facilitate and encourage in-depth exploration of topics of interest.

The Handbook is not intended for use as a substitute for regional or project-specific travel demand evaluations and model applications, or other independent surveys and analyses. They perform a vital function in that they address location-specific characteristics of travel that make blind transfer of results from other areas a risky proposition.

The findings in the *Traveler Response* Handbook are intended to aid—as a general guide—in preliminary screening activities and quick turn-around assessments. The presentation is also designed to serve as a complement to location-specific analyses, providing a basis for comparison and helping to fill gaps in model-derived demand estimates. The Handbook is further intended to enlighten transportation systems and operations specialists concerning potential or likely travel demand implications of their individual and collective policy and design decisions. It is with improved information from a variety of sources and techniques that transportation and other professionals can most effectively formulate responses to transportation needs and opportunities, and reliably predict the efficacy of their plans.

Research Approach

The *Traveler Response* Handbook findings derive primarily from reported results and analyses of real-world transportation system and policy applications and trials. Experimental or quasi-experimental empirical data have been the information source of choice, with rigorous revealed-preference (actual response) analyses accorded somewhat more weight than stated (perceived) preference experiments. Other empirical data derivations and simple accounts of outcomes have been employed as necessary. Forecasts and other estimates derived from travel demand model applications and similar techniques have been used, but on a very selective basis; mostly for augmenting the empirical data where gaps exist, and for providing additional insights and context.

The TCRP Project B-12/B-12A handbook updating and expansion was not intended to require original research. The process has been one of synthesizing, distilling, and interpreting reports, papers, and research by others. Nevertheless, to fill major gaps, the research team has performed original assessments of key undertakings and situations, most often relying on cooperative operating and planning agency staff to assemble significant data and analyses. In addition, the TCRP Project B-12B work effort involves more formalized and extensive original assessments, along the same lines, addressing Transit Oriented Development (TOD).

Preparatory Tasks. The assembly and review task which began the development of this third edition Handbook started with both a formal WinSPIRS based literature search and the foundational stage of extensive networking to locate papers, articles, reports, manuals, and syntheses with information on any aspect of traveler response to urban transportation system or policy changes.

The bibliographic information thus obtained, mostly from the 1981 through late 1997 period, was categorized, screened, and entered into a database. This initial phase of the literature search served to ensure that important materials only available in print, as contrasted to electronic postings, were not overlooked. The second edition had covered up through 1980.

The second and longer-running phase of source material gathering continued throughout the topic development process, as the research team remained alert to new sources, contacted a number of organizations and individuals known to be active in research areas of concern, and also performed various supplementary literature searches. Particular use was made of news sources such as the TRB Transportation Research E-Newsletter, rapidly developing electronic search capabilities, and the assistance of several pertinent TRB committees. A number of key documents became available during this extended period, especially in the case of highly active areas of research and application. In addition, as noted above, the research team did undertake certain of its own original assessments to supplement available literature and reportings. Table 1-1 indicates how far into the 1998–2012 period these information gathering activities continued for each individual chapter.

References were selected using criteria such as the timeliness or enduring relevancy of the studies reported on, the clarity with which traveler response was measured, the apparent completeness of the work, and the extent of other literature on the same topic or event. In order to expand the base of evidence and fill research gaps, the sources employed were not limited solely to peer-reviewed papers and documents, but also included so-called "gray literature." Government reports and other publications deemed suitable were consulted, and a variety of other sources were used when necessary and where context supported a reasonable presumption of sufficient reliability.

Similar criteria were used to choose between retaining and deleting individual references and information available from the earlier Handbook editions. Old information found redundant or made suspect by the passage of time was rejected. The study team leaned toward retaining older high quality data, however, where it was still some of the best available on either presently relevant or recurring issues. This choice was in the interests of "[not losing] the message before gain[ing] the knowledge," to rephrase the title of a Transportation Research Board Annual Meeting paper on the loss of older documentation (Rogers, 1997).

Assembly and review activities were paralleled by tasks designed to solicit advice on content and presentation; to define, detail, and outline the structure of the updated Handbook; and to develop a coordinated and comprehensive approach for moving the finished product into practice. The user outreach employed a mail-out survey as the initial vehicle for obtaining the desired information. As the project progressed, volunteer review groups were formed for each topic area chapter to augment the work of the project panel in outline review, source data identification, and chapter draft review. A modified approach was used for Chapters 16, 17, and 19, wherein communication and consultation with the TRB Pedestrian Committee, Bicycle Transportation Committee, Transportation and Land Development Committee, Transportation Demand Management Committee, and interested committee members, substituted for review group establishment.

Preparation of first-cut literature summaries—following the literature search and related tasks—supported topic area synthesis and provided the starting point for case studies. This process was structured to define the nature of system change reported and the degree of influence of concurrent changes, actions, and events; establish the methodology and likely reliability of the reported data sources and collection techniques; examine the nature and logic of analysis techniques used to measure or model traveler response; and assess conclusions, degree of reliability, and transferability to other situations and locations. The process was adapted to the situation and source material, and ranged from highly structured to less formal, but always guided the approach to findings derivation.

Classification System Development. The organizational structure and classification system for this updated Handbook not only provides a Handbook framework, but also served initially as a starting point for the topic area selection process. This process went through two primary rounds, setting priorities for the *Interim Handbook* and for the full *TCRP Report 95* coverage. The most recent change was the addition of the Transit Oriented Development topic, introduced under TCRP Project B-12B, and entered into the Handbook outline as redesignated Chapter 17. (See Table 1-1 and also see Footnote 2 for the resulting chapter renumbering.)

The transportation system change classification structure as outlined in the first iteration encompassed 27 system change topics, each assigned to one of seven broad system change categories. In the course of the research, two of the broad categories were determined to be poorly suited for inclusion. They covered three Transportation Systems Management topics and two general purpose highway capacity topics. One of the broad categories has been split, giving the six system change categories listed in Table 1-1. Of the initial list of 27 system change topics, after subdivisions, recombinations, eliminations, and additions, 18 remain. These form the topic area chapter/volumes of the third edition Handbook, listed earlier in Table 1-1 along with availability information.

The earlier editions of the Handbook were organized to match the classification system used for the TSM actions published by the U.S. Department of Transportation. These actions were part of the regulations governing the urban transportation planning process at the time. With the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, the subsequent promulgation of regulations by federal agencies, and the reauthorizations since, the previous classification system is no longer relevant.

Accordingly, a new basis for a classification system was developed. A number of topical classifications used in planning efforts current at the outset of this update were reviewed as part of this process. The proposed Congestion Management System strategies in the December 1, 1993, Interim Final Rule published by the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) were considered an important source. That listing of strategies matches those outlined in the TCRP Project B-12 Research Problem Statement and the topics included in the survey of practitioners. The Congestion Management System strategies also include highway topics not covered by the TCRP Project B-12 Research Problem Statement.

One limitation of the Congestion Management System strategies is that the organization of topics is somewhat awkward from the perspective of the Handbook. Two other sources were consulted for possible classification systems. These were the workbook used for the 1994 FHWA training course on *Congestion Management for Technical Staff* and the 1995 FHWA report, *Guidebook for Congestion Management Systems: A Generic Process.* Although the topic organization in these two sources differed, they provided additional guidance.

All of these sources, along with the initial problem statement, the expertise of the team members, and the approval of the project panel, were used to develop the organizational structure for the updated Handbook. The result is that illustrated in Table 1-1.

Handbook Preparation. The heart of each topic area chapter is its comprehensive digest of travel behavior findings, backed up with case studies of selected transportation system changes, related actions, or urban design options. As fully outlined in the next section, this digest consists of three main parts—an exposition of the traveler responses to the system changes in question, a discourse on the underlying travel behavior factors, and an overview of related information. Topical digest preparation involved comparing, distilling, combining, supplementing, and structuring the findings from the literature to derive relationships and concise presentations of lessons learned on the travel behavior and related effects of the transportation system changes or built environment options addressed. Empirical findings were played against modeled relationships in an effort to broaden, strengthen, and test each finding. Judgments were made as to the degree of caution that should be used in applying the various research results.

The lessons thus derived have been synthesized in the form of generalized conclusions and guidance, including quantitative data and estimating parameters developed in accordance with consistency and commonality guidelines. Wherever possible the nature and sensitivity of response to each principal variable or configuration of systems change has been indicated. A comprehensive digest has thus been prepared of the literature-based travel behavior findings for each of the transportation system change and built environment alternatives topic areas chosen for coverage in the chapter/volumes of this TCRP update of the *Traveler Response* Handbook.

While each topic area chapter serves to distill and present the collective observations of the relevant literature reviewed, the interpretations offered are the responsibility of the Handbook authors. Assessments are provided to aid the user in judging the degree of confidence with which the findings presented for each transportation change can be applied to project likely travel demand results. Handbook users should note that the findings presented are intended only as generalized guidelines applicable under average conditions. In practical application, each individual project must be analyzed in the context of the specific site and conditions involved.

The case studies selected to complement each topic area chapter's digest of findings have been prepared according to a common approach. Each case study is designed to provide condensed case-specific traveler response and related information within the context of the system change, program action, or land use and site design option involved and the data collection and evaluation procedures originally employed. The standard approach has been to summarize the "Situation," the observed "Actions," the "Analysis," the "Results," and "More . . ." relevant insights. Case study intent has been to provide condensation while preserving the overall background, findings, and interpretations of the original sources without alteration of meaning. In some cases the Handbook authors have added calculations or interpretations, or have even carried out the basic assessment in conjunction with contributing agencies, and these instances are so noted.

USE OF THE HANDBOOK

This third edition *Traveler Response to Transportation System Changes* Handbook consists of these Chapter 1 introductory materials and the 15 published topic area chapter/volumes, plus the three future chapters, along with their digests of traveler response findings including supportive information and interpretation. Each topic area chapter also includes case studies and a bibliography consisting of the references utilized as sources.

Each topic area chapter begins with an overview and summary section that includes a description of the types of system and policy change covered. This section also includes an "Analytical Considerations" discussion, addressing findings-reliability concerns, and closes with the chapter's

"Traveler Response Summary."[1] The main digest which follows the "Overview and Summary" is provided in three major sections:

- "Response to [the System Change]," covering traveler responses to the various specific sub-types of system change or action encompassed.
- "Underling Traveler Response Factors," addressing the travel demand mechanisms involved.
- "Related Information and Impacts," providing cross-cutting summaries of selected user, travel demand, and impact characteristics, and also overviews of associated subtopics.

An identification of additional resources, the case studies, and references follow, and conclude each topic area chapter. Together, these components offer:

- A consolidated, interpretive source of information on how travel demand and use of transportation facilities and services are affected by the 18 different categories of transportation system change, program actions, and built environment alternatives.
- Encapsulated examples and case studies.
- Sources of additional information on the same and closely related subjects.

Appendix A of this Chapter 1, "Introduction," provides additional information on the derivation and application of elasticity measures, and Appendix B of Chapter 1 gives historical cost of living statistics and conversions useful for interpreting transportation system changes involving user costs. Known substantive errata, pertaining entirely to Chapter 15, are addressed following Appendix B.

Handbook Application

Applying the material in any handbook that attempts to provide useful generalizations and examples must be done with care and this Handbook is no exception. The subject at hand is complicated by the many confounding factors that may influence traveler response and by the diversity of urban environments involved. Some of these considerations are expanded upon in the final four subsections of this "Introduction" under the headings "Degree-of-Confidence Issues," "Impact Assessment Considerations," "Demographic Considerations," and "Concept of Elasticity." Concerns of special importance to individual topic areas are presented within the "Analytical Considerations" subsection of each respective chapter's "Overview and Summary." Issues specific to individual findings are brought up as part of the presentation of those findings.

Transportation planners and decisionmakers can use the information in this *Traveler Response* Handbook as a starting point to consider and evaluate transportation alternatives. Any specific situation must, however, in the end be examined in terms of the particular urban form, population, travel patterns, and transportation systems involved. No transportation system change can properly be considered in isolation from these measures and physical expressions of local conditions.

[1] Chapter 16, "Pedestrian and Bicycle Facilities," also contains an "Adult and Child Public Health Relationships Summary," placed at the end of the "Public Health Issues and Relationships" subsection of that chapter's "Related Information and Impacts" section.

The Handbook is structured to point the reader progressively to more detailed information internal to the document and then on to other studies, investigations, and texts. Given a specific transportation (or urban development) and travel demand question, a recommended progression within and beyond the Handbook would be:

- Select the most pertinent topic area chapter, a choice process that may be aided by the comprehensive four-level Table of Contents located at the beginning of this Chapter 1.
- Review the "Overview and Summary" section to understand context and data limitations, and to obtain a preview from the "Traveler Response Summary."
- Upon finding relevant topics in the "Table of Contents," or potentially useful information in the "Traveler Response Summary," proceed to the "Response to [the System Change]" section of the chapter for the full traveler response presentation for each sub-type of system change, with citations.
- Refer to any of the accompanying "Case Studies" which apply, for additional case example detail. Case studies are near the end of the chapter, ahead of "References."
- Consult the "Underlying Traveler Response Factors" section for interpretations useful in understanding the travel demand mechanisms and individual factors at play.
- See subtopics of interest within the "Related Information and Impacts" section. This section includes compilations, relevant to the chapter topic, ranging from user characteristics and trip purpose data to prior travel mode information and system usage characteristics, and also overviews of related experience and research findings.
- Check relevant cross-referenced material in other chapters, and also those updates provided in other chapters as described in connection with Table 1-1 (last paragraph of the subsection "Publication Timeline of This Handbook").
- Go outward from the Handbook—from either the main text, using the source material citations and the "References" entries linked to them, or from the "Sources" listing in each case study or the "Additional Resources" listing—to applicable papers, studies, and texts. Only the source literature can provide the breadth and detail of the original work.

Finally, after making use of the material in this Handbook and other literature sources, proposals at hand that pass initial screening must ultimately be studied within their own particular context and unique environment. The degree of appropriate study, depending upon the action contemplated, may range from design of a simple and low-cost pilot project with an accounting of the risks involved, to more detailed project designs employing user or prospective-user surveys and related analyses, to full-scale major capital investment studies inclusive of travel demand model applications for forecasting site- and alternative-specific traveler responses and related outcomes.

Handbook Organization

The remainder of this introductory chapter is devoted to additional instructive material offered to enhance use of the *Traveler Response to Transportation System Changes* Handbook. All subsequent Handbook chapters are devoted to the individual topic areas, each addressing one general type of transportation system change or related action except for Chapter 15, which covers "Land Use and

Site Design." The topic area chapters are arranged according to the transportation system change classification structure of the full third edition Handbook, encompassing 18 system change topics, as described earlier. Each topic area chapter is assigned, as illustrated in Table 1-1, to one of six broad system change categories. These categories constitute general sections, which simply serve to order the system change topics.

Chapter and page numbering is in conformance with the planned 18-topic, 19-chapter *TCRP Report 95* third edition.[2] Referrals in chapter text to one of the three "future" chapters may be encountered. These are further explanatory cross-references and do not detract from the use of the published chapter.

Topic Area Chapter Format

Table 1-2 illustrates the general format of each topic area chapter presentation, utilizing the "Vanpools and Buspools" chapter as an example.

The "Overview and Summary" section that each topic area chapter starts with begins with a road-map to the chapter itself. Next within the overview is a statement of the generally accepted objectives for undertaking the types of system changes or equivalent covered by the topic. This is immediately followed by a listing of the implemented or implementable types of change or option included. Next is a discussion of analytical considerations, designed to indicate the limitations encountered in the research and the corresponding level of confidence that can be placed in the conclusions.

With that background, the last item in the overview is a "Traveler Response Summary" section, highlighting the traveler response findings for the topic. (As previously detailed in Footnote 1, Chapter 16 also includes an "Adult and Child Public Health Relationships Summary," located within that chapter's "Related Information and Impacts" section.) The recommended approach to using either the "Traveler Response Summary," or the material which follows, is to do so only after first reading the initial three sections of the "Overview and Summary" for background. Moreover, any consequential use of findings previewed in the "Traveler Response Summary" should be accompanied by consideration of caveats set forth only in the more detailed presentations which follow.

The "Overview and Summary" of each topic area chapter is followed by the full Handbook survey of observed traveler responses for each type of system change (or program action or built environment option) addressed in the chapter. This "Response to [the System Change]" section of the chapter is accompanied by an "Underlying Traveler Response Factors" section which examines the role of both underlying travel behavior mechanisms and external factors in producing the traveler responses. Note that this sort of information is useful not only for a better understanding in general, but also for practical application in achieving an effective transportation service, facility, and urban design. Next is a "Related Information and Impacts" section which touches upon other subject areas pertinent to the particular system change topic, including environmental and cost considerations. It is important to be aware, as previously noted, that this section includes various cross-cutting compilations relevant to the chapter topic.

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[2] Chapter 18, "Parking Management and Supply," was referred to in the *Interim Handbook,* Web Document 12, as Chapter 17. Similarly, Chapter 19, "Employer and Institutional TDM Strategies," was referred to as Chapter 18.

Table 1-2 Topic Area Chapter Format Example (Vanpools and Buspools)

Format (Outline/Major Headings)	Example (Vanpools and Buspools)
[General Category]	Transit Facilities and Services
[Transportation System Change Topic]	Vanpools and Buspools
Overview and Summary	*A roadmap to the chapter, plus the following:*
Objectives of [the System Change]	*Vanpool/Buspool program focus, objectives*
Types of Programs	*A listing and definition of:* Vanpools—Employer-Sponsored Programs Vanpools—Third-Party Programs Vanpools—Owner Operator Buspool Programs
Analytical Considerations	*Limitations, caveats, data interpretation alerts*
Traveler Response Summary	*Overview of traveler response to changes/actions*
Response to [the System Change]	*A survey of the traveler responses to:* Employer-Sponsored Vanpool Programs Third-Party Vanpool Programs Buspools (Subscription Bus)
Underlying Traveler Response Factors	*Exploration of traveler response mechanisms:* [Travel Time Components] and Trip Distance Access Considerations Work Scheduling Implications Incentives and User Costs Preferences, Privileges and Intangibles
Related Information and Impacts	*A survey of related special and standard topics:* Extent of Vanpooling and Buspooling Demographic Characteristics of Riders Sources of New Ridership and Vanpooler Turnover Indicators of Market Potential Impacts on VMT, Energy, and Environment Revenue/Cost Considerations
Additional Resources	*Four sources of special interest highlighted*
Case Studies	*Four case studies provided*
References	*80-odd references listed*

The "Response to [the System Change]," "Underlying Traveler Response Factors," and "Related Information and Impacts" sections comprise what has been referred to in preceding discussion as the "digest." These three core sections are followed by a brief "Additional Resources" section highlighting compendia, manuals, or other documents of likely special interest to a reader delving further into the topic area in question.

Last in each topic area chapter, except for references, are the case studies. They provide condensations of papers, reports, and other information on system change applications selected for relevancy to the topic area and usefulness in illustrating and expanding upon the travel demand and related impacts reported in the preceding topic area presentation. They focus on case-specific traveler response and related information, necessarily within the context of the particular system studied. In structuring the case studies, the intent has been to include a description of the case study context, the system change action involved, some indication of the data collection and analysis methodologies originally employed, and a highlighting of the principal findings along with related useful information.

Bibliographic Format

In this third edition of the *Traveler Response to Transportation System Changes* Handbook—issued in both print and electronic versions, with each in a separate chapter/volume—the references pertaining to each topic area are kept in a list at the end of the topic area chapter in question. Duplication results, as compared to having a consolidated reference list, but use of one chapter at a time is facilitated. Single-chapter use should not be overdone, however, because of topic and concept overlap among chapters.

The citations in the text that provide the links to the list of references employ the so-called humanities style, giving author and date. This approach serves to alert the reader to the age of the source, and also allows the references to be alphabetically listed in bibliographic fashion.

Certain of the citation protocols derive from the non-academic origins of this Handbook, and are retained in this *TCRP Report 95* edition as a practical matter. In the text, citations are generally located at the *end* of groups of sentences or paragraphs based on the cited source material, but ahead of bulleted lists drawn from a single source. Where multiple paragraphs have been extracted from the same source, citations are repeated every so often, particularly where the continuity is not fairly obvious. Citations are not provided in the condensed "Traveler Response Summary" presentations which conclude the "Overview and Summary" section at the front of each topic area chapter. The Handbook user must look further, into the more detailed presentations which follow, for the applicable citations.

Findings drawn from source literature and reports have been added to with original information from individual contributors. Contributors of original information are cited and listed under "References," generally with an indication of their affiliation. Source documents and contributors are further supplemented with the practical and research experience of the Handbook authors along with their general knowledge of other studies and writings relevant to the topic. With the one primary exception of the "Traveler Response Summary" presentations, lack of a citation indicates that the information and observations offered at that juncture come directly from the professional experience and training of the Handbook authors.

Degree-of-Confidence Issues

Findings presented in this *Traveler Response* Handbook derive primarily from quasi-experimental and other field observations, supplemented with interpretations from additional sources such as travel demand model research, other cross-sectional studies, and stated preference experiments. Traveler response is expressed using such measures as elasticities, before-and-after market shares, and percentage changes or differences, with indicators of scale and guidance ranging from examples of volumes and passenger demand to simple feasibility indicators.

The confidence which can be placed in the generalizations drawn in each topic area digest concerning impacts of the transportation system changes varies among the types of change involved. The appropriate degree of confidence necessarily depends on the number of documented observations of a certain type of change or action, the design and statistical soundness of the associated analyses, confounding factors which may have affected the reported results, the extent to which impacts have been successfully modeled, and the consistency with which findings were obtained and reported.

Some transportation system changes examined here have had only limited application, or have been very infrequently subjected to systematic analysis, so that it is difficult to generalize to universal experience. In other instances, confounding factors or unique situations have influenced the results. Even where it has been possible to draw upon and compare numerous study findings, the validity of the inferences made is still dependent upon the quality of the data and analysis methods originally employed in deriving the reported conclusions.

As already indicated, an “Analytical Considerations” section has been included in each topic area chapter to provide a discussion of factors influencing the degree of confidence with which the traveler response findings and related conclusions for that Handbook topic area can be used. Circumstances range over the entire spectrum from instances where strong empirical evidence and theoretical basis exist to support the validity and widespread applicability of the conclusions derived, to situations where little hard data exists and conclusions offered are drawn primarily by inference or from very limited applications or theoretical studies.

In general, findings and conclusions provided with respect to impacts on vehicle miles of travel (VMT), energy consumption, and emissions are relatively more dependent on estimations and modeling applications than the associated traveler response conclusions. In this *Traveler Response* Handbook update, reduced emphasis has been placed on presenting energy conservation and air quality data, in light of the more extensive separate resources now available on the subjects of energy consumption, pollutant emissions, and sustainability.

The user of this Handbook will find that absolute-value data is often presented without rounding. This has been done as a matter of convenience, and should not be taken to always imply high levels of confidence. *There is little in this Handbook with real meaning (for travel demand assessment purposes) beyond two significant figures.* Reliability of elasticities is closer to one significant figure (if that) however useful elasticities may be for quick estimates.

Percentages have generally been rounded. When percentages and other rounded numerical values do not total exactly, for example, not adding to exactly 100 percent when representing the whole, it may be assumed that such minor discrepancies are attributable to rounding. Significant discrepancies carried over from source documents are marked with a “(sic)” notation.

Impact Assessment Considerations

The available observations of traveler response to transportation system changes are provided by assessments that run the full gamut from reports that are borderline anecdotal, to comprehensive studies carried out employing a pre-prepared and vetted study design. Full-scale travel behavior research evaluations are unfortunately limited in number for most system change sub-types, and scarcer yet are those that qualify as either true experiments or quasi-experimental before-and-after research. Moreover, even highly structured assessments do not always follow good evaluation principles (Pratt et al., 2000a, Higgins and Johnson, 1999, Committee on Physical Activity, Health, Transportation, and Land Use, 2005, Ogilvie et al., 2007, Parker et al., 2007).

The result is a virtual minefield that must be negotiated carefully by the user of available observations and studies, and indeed the user of compendia such as this one which must rely on available sources. If only the best and most sound of evaluations were to be reported, the data points would be too few. The choice has been made in developing this Handbook to use more studies and observations than just the most rigorous. It is therefore important that the Handbook user read caveats provided, and also pick up on available study design clues that can help determine how much reliance to put on any given finding. Three categories of problems to be alert for are highlighted here: issues of measurement and statistical significance, effects of confounding events and environments, and additional analytical concerns.

Measurement and Statistical Significance

Field observations of traveler response to transportation system changes are typically provided by user surveys, or by "before-and-after" counts of volume, passengers, or revenue. "Before-and-after" surveys and counts and the analyses based on them are essentially two-point-in-time longitudinal studies, with one set of observations before a system-change action or program, and the other afterward. In certain cases full regional travel survey protocols have been followed in before-and-after surveys of affected areas and "control" (unaffected) areas. In other cases there may be no "before" survey at all, with reliance placed on retrospective questions designed to elicit information on behavior prior to the system change. Related issues to be alert to include (Parker et al., 2007, Pratt, 1967, Higgins and Johnson, 1999, Pratt et al., 2000a, Brög et al., 2009):

- Inadequate count or survey sample size.
- Insufficient survey controls with the potential, especially in the case of self-administered surveys, to skew results.
- Incomplete system change and travel data, and data definitional problems, which may introduce bias or misunderstandings.
- Lack of adequate determination that the outcome was statistically significant.

Travel survey controls of importance include both sample selection and controlling for response rate bias. Survey response rate biases, particularly those encountered in self-administered surveys including post-card and internet applications, are perhaps the most troublesome of survey problems. For example, without designing in controls such as differential factoring, a transit on-board self-administered survey will tend to over-report travel by higher income riders (typically downtown-oriented and concentrated in certain sectors of a city), riders making work trips (primarily peak-period riders), and riders making longer trips. Even broad categories of travel such as the proportion of AM peak-period transit riding may be off by 25 percent or more without correction (Pratt, 1967).

Data completeness for a before-and-after evaluation requires a comprehensive, quantitative description of the "before" conditions and circumstance, the "before" usage or travel demand, the "after" conditions and circumstance, and the "after" usage or travel demand. If any of these critical elements are missing, then the scope of legitimate study conclusions possible is severely degraded. Travel demand data obtained in parallel for a control area where there was no change or action of the type under study can help in making adjustments for global exogenous events, such as changes in the economy or gasoline prices, giving increased confidence in analysis findings.

Transportation system change actions, provisions, and programs can affect travel choices on many dimensions including travel frequency, mode, route, and time of day. On a broader level, there may be effects on trip destination choice, and even housing and employment location choice, thereby impacting trip distribution. If data collection is limited to counts, these nuances cannot be rigorously explored. Even before-and-after surveys of travel response often have examined only one or two of these dimensions. This limitation makes difficult such assessments as examination of latent or induced demand or quantification of actual shifts among travel modes as contrasted, for example, to volume changes that simply represent shifts in route taken.

Data definitions may also hamper analysis. The "unlinked trip" method of tracking transit ridership—mandated for reporting ridership to the Federal Transit Administration (FTA) and its National Transit Database—is a case in point. An unlinked trip is a passenger trip made in a single transit vehicle, effectively the same as a passenger boarding. A one-way trip from home to work that involves one transfer, such as between two buses or a bus and train, produces two unlinked transit trips. Yet, those two unlinked transit trips serve only one person trip from the rider's perspective, have the social and environmental benefit of only one transit trip, and often generate only one transit fare. To fully understand whether transit route or system changes have attracted more ridership or the converse, the before-and-after number of "linked trips" must be determined. An example of a linked trip is a one-way trip from home to work with or without one or more changes of vehicle. An increase in unlinked transit trips may reflect nothing more than the effect of more forced transfers (Pratt et al., 2000a).

The "other side of the coin" in the linking of trips is seen in analysis of walking or bicycling to and from transit. Conventional regional travel survey processing assigns a single mode to "linked" multimodal trips, with mode designation done on the basis of a fairly standard hierarchy. This process typically causes certain information to be effectively lost, with non-motorized travel modes being most affected (Victoria Transport Policy Institute, 2007, Schneider, 2011). Thus, walking to a bus is subsumed into the bus trip and not counted in the walk mode, and if the bus is used as a feeder to urban rail transit, the bus trip is subsumed as well. Even in the National Household Transportation Survey (NHTS), walking and cycling trips made to access and egress transit are not entered as individual trip records in the primary trip data summarized by mode (Clifton and Krizek, 2004). Without specialized surveys and/or survey processing, use of affected modes will be undercounted.

Non-motorized travel analysis offers another classic example of a definitional problem that hampers evaluation and comparisons. Some key surveys (such as the NHTS) count an out-and-back "loop" walking or cycling trip done for recreation or exercise as two trips, while other equally prestigious surveys and research treat such activity as one trip, twice as long. The litany of analytical problems faced in particular by the non-motorized travel analyst is examined at length in the "Analytical Considerations" subsection of Chapter 16, "Pedestrian and Bicycle Facilities."

The use of full regional travel survey protocols in before-and-after surveys is an expensive transportation change/action evaluation approach that has been limited to date to use in assessments of individualized marketing of transit, walking, bicycling, and carpooling. The essentially voluntary travel behavior changes involved represent incremental shifts of mode in an experimental environment easily clouded by many uncontrolled factors, making reliable discernment of the travel demand changes a challenge (Brög et al., 2009, Parker et al., 2007). Survey issues include possible under-reporting by respondents of outcomes deemed to be undesirable and other biases that are particularly of concern if the survey is not well isolated, from the perspective of participants, from the transportation change/action involved (Ker, 2011). The same challenge applies, in varying degrees, to every transportation system change or intervention evaluation that might be undertaken using travel surveys. These issues are addressed in Chapter 16 as well, but within the "Individualized Marketing" discussion under "Response by Type of NMT Strategy"—"Walking/Bicycling Promotion and Information."

Confidence in survey findings can be increased not only by use of control groups, but also by employing "external evidence." If transit revenues, passenger counts, and individual-mode volume counts move in the same direction and with the same general magnitude as travel demand shifts identified in "before" and "after" surveys or retrospective studies, evidence of validity is provided.

A basic question in impact evaluations is, "Did something really change?" It is not enough to know that the final measurement of carpoolers, vehicles parked, transit riders, pedestrians, or vehicle emissions was some percentage more or less than in the "before" condition. It is also important to know the fluctuation around the average, so that the significance of the change relative to normal variation can be judged. There are time-honored statistical tests for determining significance, but they are all too often not applied, or perhaps applied only to some variables. For many "changes" or "differences" reported in the literature, it is simply not known whether they are meaningful or not (Higgins and Johnson, 1999).

Confounding Events and Environments

The other key question in evaluations of transportation changes besides "Did something change?" is "What caused it?" (Higgins and Johnson, 1999). The analyst who evaluates system change impacts must be especially cautious when interpreting results that may have been affected by confounding events or unique circumstances. Such events or circumstances may adversely affect the transferability of results from one location or time period to another (FHWA, 1974). Alternative explanations for travel changes that might otherwise be attributed to a transportation system change of interest may include (Higgins and Johnson, 1999):

- External Transportation Events—transportation system changes unrelated to the change of interest, such as new or closed facilities, altered levels of enforcement, transit service changes, transportation labor actions, construction delays, and altered parking charges, highway tolls, transit fares, or employer involvement in parking/commute cost subsidies.

- Other External Events—changes in the local/national economy or unemployment rates, changes in government regulations including taxes, social unrest, natural disasters, and special events.

- Effects of Testing—impacts of the experimental process itself on travel behavior, as when travelers learn more about their travel options as a result of initial surveys.

- Maturation Effects—gradual changes in the circumstances of travelers, most pertinent when a given sample is surveyed at two or more points in time, or regression toward the average of subjects chosen for their above- or below-average behavior.

- Measurement Inconsistencies—changes in the measurement process, specifically including alterations in survey procedures and questions, and drop-off in survey response rates and associated reliability.

An example of external events is provided by the two periods of fuel shortages which occurred during the 1970s, in 1973–74 and in 1979. Because of the drop-off in quasi-experimental "before-and-after" research following cessation of the Systems and Methods Demonstrations of the Urban Mass Transportation Administration (now Federal Transit Administration) in the early 1980s, and the uniqueness of some of the demonstrations, it remains necessary and useful to refer back to findings from 1970s investigations. The observed traveler responses to ridesharing and transit programs instituted concurrently with these fuel shortages may not be fully applicable, however, to times of normal gasoline supply (Pratt and Copple, 1981, Pratt et al., 2000a).

In the same way, unique circumstances in a particular city may influence system change results, sometimes in a markedly atypical manner, and other times by simply reinforcing or dampening impacts. The size and geography of cities serve to concentrate or disperse travel, affecting facility volumes or ridership. Cities bordering oceans or lakes have their radial travel concentrated in perhaps five major sectors or broad corridors, as in Chicago, or fewer in a mountainous urban area like San Diego. In extreme contrast, a flatlands pair of cities such as Minneapolis and St. Paul may have 15 separate broad corridors (eight for each city with one shared) over which radial travel is distributed (Deen and Pratt, 1992).

An example of results reinforcement is provided by New York, where it can be reasonably certain that modifications to transit fares during the 1990s were accompanied by especially positive results because of the then booming economy in New York City proper. Conversely, statistical analysis shows that patronage losses in the late 1980s in Dallas during a period of fare increases and service reductions were exacerbated by a local recession (See Chapter 12, "Transit Pricing and Fares").

Frequently, a particular system change is directly linked with other simultaneous changes which may affect the results. For example, transit fare reductions have often been accompanied by promotional campaigns and increases in transit service frequency and coverage. TDM programs inherently involve multiple actions. Under such circumstances it is difficult if not impossible to separate the impact attributable to each of the individual actions involved.

The fact that certain exogenous events can have impacted outcomes, for example earthquake destruction or collapse of a major bridge, may seem overly obvious. However, if not documented in connection with data presentations, they may raise questions or be overlooked in later uses and interpretations of the results affected. Factors such as weather conditions or facility maintenance clearly are subject to being overlooked if they have not been explicitly recorded as part of the data-gathering record.

The time required for use of a new service or facility to become established creates difficulties in before-and-after analysis design and in interpreting "after" survey results. Table 16-113, "Motorized and NMT Facility Usage Maturation Experience," in Chapter 16, summarizes examples of usage stabilization rates. This table shows that while new urban rail facility ridership appears to reach equilibrium in less than 2 years, High Occupancy Vehicle (HOV) facility usage may take 4 years on average, and non-motorized travel facility usage has been seen to take 7 or more years to mature. Among the eight cases set forth in the table, the average usage seen at the end of the first 12 months is only 55 percent of stabilized usage. Thus an "after" count or survey taken, say, 2 months after introduction of a new transportation service or facility may pick up only a modest proportion of the ultimate effect. On the other hand, a survey taken too long after a system change will produce results more likely to be confounded by exogenous events such as those enumerated above.

Additional Analytical Concerns

Some of the traveler response interpretations presented in this Handbook are based in part on travel demand model results, produced either by research models or forecasting models, as contrasted to observed results. The travel demand modeling efforts utilized are sometimes based on stated preference survey data but are more frequently based on revealed-preference cross-sectional survey data from a single point in time. Use of such survey data relies on the assumption that impacts over time of transportation system changes can be inferred from the response at a single point in time to differing system characteristics as observed in different locations in an urban area. This is an assumption that has neither been satisfactorily proved nor disproved (Mayworm, Lago and McEnroe, 1980).

Other interpretations are based on cross-sectional and other comparative analyses of one sort or another that involve no travel demand modeling per se. With or without models, additional concerns with cross-sectional or comparative analyses include (Deakin, 2002):

- Reliance of some aggregate studies on a small number of cases, effectively placing reliance on a very small sample.
- Existence of problems of scale and aggregation level, to the point where averages mask variations in characteristics.
- Substantive definitional inconsistencies affecting key variables, especially across different research agencies and study areas.
- Confusion of correlation and causality in interpretation of results, overlooking the fact that just because two or more parameters move in parallel, the one is not necessarily causing the other(s).

With respect to the final critical point above, *correlation does not prove causality* (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). Despite the benefit of structured analysis, certain of the more complex research studies are actually among the more naïve in terms of assumptions made and relationships accepted as meaningful. Concerns such as these listed here, along with presence of unaccounted for confounding events and local area individualities, can make validity of findings—to say nothing of comparison and transferability of findings among locales—both problematic and demanding of special care on the part of the analyst.

Depending on circumstances, deficient analytical approaches may result in either overstatement or understatement. Public opinion and oversimplified preference-survey-based evaluations, when inappropriately used as a forecasting tool, are notoriously associated with overestimates. For example, Madison, Wisconsin, 1970s bicycle commuting estimates made in this manner were only half fulfilled (Zehnpfenning et al., 1993). Even supposedly sophisticated forecasting studies of proposed toll roads and urban rail systems have an international historical record of overestimation, labeled “optimism bias,” and attributed to institutional factors (Committee for Determination of the State of the Practice in Metropolitan Area Travel Forecasting, 2007). Similar institutional factors may pertain to “smart growth” land development and TDM traffic mitigation impact estimates carried out for private developers and employers.

On the other hand, a systematic review of interventions to promote walking suggests that analytical inadequacies can be associated with implemented-action impact underestimation. Of 25 studies, all seven ranked highest for validity produced statistically significant findings, while under one-half of the 13 studies given intermediate rankings had statistically significant outcomes, and none of the five studies with the lowest rankings did. Moreover, the magnitude of the observed effectiveness that was reported declined with lesser analysis validity (Ogilvie et al., 2007). In the case of transportation changes evaluated with before-and-after studies, as already discussed, “after” evaluations done too soon after implementation may underestimate the long-run effects of the action.

Finally, attention must be paid to the effect of inflation whenever traveler response has been affected by user cost changes, such as transit fare, highway toll, and parking fee modifications. This is particularly important in the case of older data from periods before or during high inflation. The effect of inflation is pertinent whether traveler responses are observed or estimated.[3] Absolute changes in user charges should be interpreted in constant dollars. Unless a specific base year is provided for the value of dollar costs, the best assumption is that costs (and foreign currency conversions if applicable) are for the time of the event studied, if given, or otherwise for the time period preceding publication of the source material, the date of which is available from the citation.

The Handbook user may wish to convert costs to present day dollars, in order to have a better understanding of the scale involved. Appendix B, "Inflation and CPI Conversions," provides a table of conversions to 2011 dollars along with accompanying guidance. The more severe of the analytical problems introduced by inflation can be largely avoided by describing user cost changes in terms of relative change. The concept of elasticity, discussed further on, is particularly useful in this regard, as it is a relative indicator.

Demographic Considerations

Although the focus of this Handbook is on traveler response to transportation system changes, it is important to recognize that a number of factors external to the transportation system are crucial determinants of travel behavior. Among these factors, the most important are income, auto ownership, and organization of the built environment. The location and concentration of residences, employment, commercial activity, recreational areas, and other land uses are primary determinants of the number, purpose, and orientation of trips in an urban area (the trip generation and distribution). Lower worker or family income and lower auto ownership are associated with lower than average trip generation rates and higher than average transit usage (Pratt and Copple, 1981).

The concept of "captivity" is sometimes used to help explain the impact of low incomes and low auto ownership on mode choice. A traveler is considered to be a "captive" to a particular mode if he or she effectively has no alternative means of transportation. Captive transit riders are those who have no automobile available for their trip, and must therefore use transit or forego the trip. System changes designed to attract more transit riders are directed toward "choice" riders—people whose auto availability allows them to choose freely between transit and auto (Curtin, 1968).

At the other end of the scale are captive auto users, those trip makers who for some reason must use an automobile. A traveler may be an auto captive because of a need for the car at work, because a side trip requiring an auto is to be made, or for other reasons not necessarily well understood. The auto captive is not expected to be attracted by transit service enhancements and may be deterred from ridesharing, walking, or bicycling.

The concept of captivity suffers from some theoretical and practical difficulties. One problem is that it fails to adequately address the mode choice option of traveling as an auto passenger. Another concern is that the condition of captivity, being highly related to auto ownership, is often a matter of choice. Nevertheless, captivity is sometimes referred to in this Handbook, because it is a familiar term and is used in certain Handbook sources.

[3] When using travel demand models, it must be presumed unless otherwise stated that the cost expressed in the model pertains to the value of the dollar in the year of the survey upon which the model was based.

An advancement over the concept of captivity is the approach of distinguishing between "mobility choices" and "travel choices." If a person does not have a particular mode available for a trip, it is usually because of long-term mobility choices which were made in the past. Mobility choices include the choice of residential location (including proximity to transit service), number of automobiles owned, and employment location. The usual mode for the work trip can even be thought of as mobility choice, as it may affect auto availability for other travel.

Short-term travel choices cover the day-to-day decisions concerning trip frequency, distribution, time of day, mode, and route. In this framework, short-term travel choices are always made in the context of longer-term mobility choices (FHWA, 1974). The concept is particularly relevant to examining traveler responses to transportation system changes, because it recognizes not only the short-term impacts of changed travel options, but also the longer-term impacts related to residential location, workplace location, and auto ownership.

Concept of Elasticity

Elasticity measures provide a convenient tool for summarizing quantitative information about overall travel demand changes in response to certain types of system changes and are used extensively in this Handbook. For elasticity measures to be applicable, the transportation system change must generally be a relative one. In other words, it must involve a quantifiable percentage increase or decrease in the system parameter involved. (There are, however, procedures for addressing free transit, covered further on.) There are a number of elasticities of interest with respect to demand for transportation, including elasticities for changes in the overall amount of transit service, transit frequencies, transit fares, vehicular tolls, parking charges, and gasoline costs (Kemp, 1974). Elasticity estimates are available as well for comparative degrees of presence of certain built environment characteristics (see, for example, Ewing and Cervero, 2010).

Transportation elasticities are informally adopted from the economist's measure "price elasticity." Loosely speaking, price or service elasticity may be defined as the percentage change in the quantity of a commodity or service demanded by the public in response to a one percent change in price or service. For example, if transit service is measured by the number of bus miles operated, the transit service elasticity indicates the percentage change in patronage observed or expected in response to a one percent change in the number of bus miles. If the transit service elasticity is +0.6, a six-tenths-of-one percent patronage increase is indicated for each one percent increase in service.[4]

There are several different methods for computing elasticity. An expanded discussion of these methods and their application, along with comparative examples and illustrations, is provided in Appendix A, "Elasticity Discussion and Formulae." The most frequently used form of elasticity in transportation analyses is arc elasticity. There is also a more simplistic form encountered in mostly older transit fare analyses, known as a shrinkage ratio or factor.[5]

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[4] A negative sign used with an elasticity value simply indicates that the cause and effect operate in opposite directions. Price elasticities are almost always negative: when the fare, toll or fee goes up, usage normally goes down, and vice versa. Note that for arc elasticities (discussed next) and other closely equivalent elasticity formulations, the qualifier "calculated in infinitesimally small increments" applies to examples and applications such as the one given here.

[5] This more simplistic computational method has shown up again in domestic road value pricing investigations, but with different nomenclature such as "approximated point elasticities" or even simply "elasticity."

Arc elasticity is defined by a logarithmic formulation and, except for very large changes in price or service (P) and demand (Q), is closely approximated by a midpoint formulation which makes use of the average value of each independent variable (Webster and Bly, 1980, Mayworm, Lago and McEnroe, 1980, Litman, 2012):

log arc elasticity:

$$\eta = \frac{\Delta \log Q}{\Delta \log P} = \frac{\log Q_2 - \log Q_1}{\log P_2 - \log P_1}$$

mid-point (or linear) arc elasticity:

$$\eta = \frac{\Delta Q}{\left(Q_1 + Q_2/2\right)} \div \frac{\Delta P}{\left(P_1 + P_2\right)/2} = \frac{\Delta Q\left(P_1 + P_2\right)}{\Delta P\left(Q_1 + Q_2\right)} = \frac{\left(Q_2 - Q_1\right)\left(P_1 + P_2\right)}{\left(P_2 - P_1\right)\left(Q_1 + Q_2\right)}$$

where η is the elasticity, Q_1 and Q_2 are the demand before and after, and P_1 and P_2 are the price or service before and after.

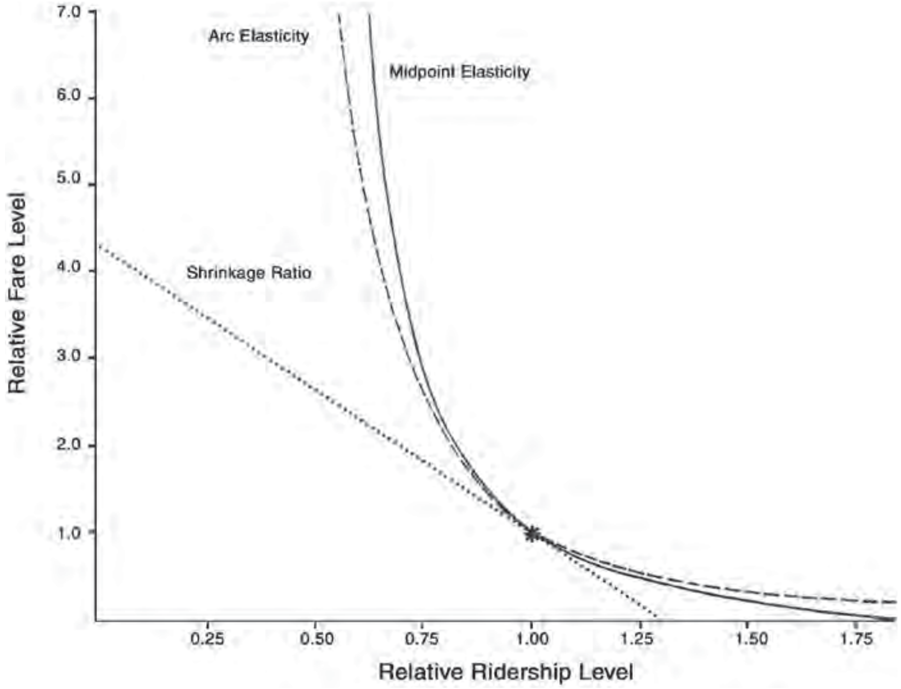
Arc elasticity is based on both the original and final values of demand and price or service. All elasticities involving free fares are of mathematical necessity calculated with the mid-point formulation. Otherwise, the logarithmic formulation has been used wherever elasticities have been calculated directly from available data in this updated Handbook, and the same was the case in the second edition. Certain values carried over from the first edition Handbook were computed using the mid-point formulation, and are so identified.

The shrinkage ratio or shrinkage factor has historically been used as a means of reporting response to transit fare changes, primarily fare increases. It is defined and discussed in detail in Chapter 12, "Transit Pricing and Fares," under "Response by Type of Strategy"—"Changes in General Fare Level."

There are certain conceptual problems with shrinkage ratios (discussed in more detail in Appendix A) which have led to the predominant use of arc elasticities in this Handbook and most contemporary works based on quasi-experimental data. Shrinkage ratios and equivalent computations of importance are reported, but arc elasticity conversions are given wherever possible. Figure 1-1 illustrates the differences between the two arc elasticity formulations and the shrinkage ratio using transit fare elasticity as an example.

It is essential to take into account that arc or linear elasticities and shrinkage ratios, being formulated differently, are not applied the same. Formulae to apply elasticities are provided in Appendix A. It is also important to note that there are inconsistencies and overlap in elasticity nomenclature that hold potential for significant confusion. Appendix A addresses this situation with an illustrated discussion of definitional differences and misinterpretations.

Figure 1-1 Elasticities of Different Types Calculated from a Demand Curve with an Initial Point Elasticity of –0.30



Note: The term "point elasticity" as used in the figure title refers to the derivative of the assumed underlying demand curve—it is not used here

Source: Mayworm, Lago and McEnroe (1980).

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Appendix A – Elasticity Discussion and Formulae

THE ELASTICITY CONCEPT

Elasticity is a convenient, quantitative measure of travel demand response to price, service, and certain other changes and differences which influence demand. Elasticity measures are found throughout the transportation literature and have been reported and used in various sections of this Handbook. When applied with caution, they provide a satisfactory means of quickly preparing first-cut, aggregate response estimates for a number of types of system changes, and for alternative approaches to land use and site design. When considering demand for transportation, there are a number of elasticities of interest, including elasticities describing traveler response to changes in the overall amount of transit service, transit frequencies, transit fares, vehicular tolls, parking charges, gasoline costs (Webster and Bly, 1980, Mayworm, Lago and McEnroe, 1980, Balcombe et al., 2004, Litman, 2012), and differing presence of built environment characteristics (Ewing and Cervero, 2010, Balcombe et al., 2004).

For elasticity measures to be applicable, the transportation system change or built environment difference must normally be a relative one. In other words, it must involve a quantifiable percentage increase, decrease or difference in the system parameter of interest. For example, while elasticity measures can be used to describe the response to a change in the overall amount of transit service, they cannot be used to describe the response to a new bus system.

Transportation elasticities are informally adopted from the economist's measure "price elasticity." The price elasticity of demand is loosely defined as the percentage change in quantity of commodity or service demand in response to a 1 percent change in price. For instance, a price elasticity of –0.3 indicates that for a 1 percent increase (decrease) in the price of a good or service, there is a 0.3 percent decrease (increase) in the demand for that good or service.

It would be more precise to say, however, that a price elasticity of –0.3 indicates an 0.3 percent reduction (increase) in demand in response to each 1 percent price increase (decrease), calculated in infinitesimally small (or vanishingly small) increments. (The order of the statement is not important, but the calculation in very small increments is.)

The negative sign signifies an inverse relationship between price and demand. In other words, it indicates that the effect operates in the opposite direction from the cause. For example, an increase in price results in a decrease in demand, and the corresponding elasticity is negative. Conversely, an increase in service promotes an increase in demand, and the elasticity is positive.

If a 1 percent change in a parameter causes a greater than 1 percent change in demand, demand is said to be elastic. If a 1 percent change in a parameter causes a less than 1 percent change in demand, then demand is said to be inelastic. Many, but not all, transportation system changes elicit responses that are so-called inelastic.

MEASURES OF ELASTICITY

There are three different methods commonly found in the transportation literature for computing elasticities:

- Point elasticity
- Arc elasticity
- Shrinkage ratio

Point elasticity is derived directly from the economist's definition of elasticity. Mathematically, it is described by the following formula (Webster and Bly, 1980, Mayworm, Lago and McEnroe, 1980, Balcombe et al., 2004):

$$\eta_p = \frac{dQ}{dP} \times \frac{P}{Q}$$

where η_p is the elasticity at price P, and Q is the quantity demanded at that price.

In practice, lack of information on the functional relationship between P and Q (the shape of the demand curve) precludes the computation of point elasticities from empirical data. Therefore, other formulations have been developed which allow the use of observed changes in price and associated demand. The measure which most nearly approximates point elasticity, and one frequently employed, is arc elasticity. It is defined by a logarithmic formulation and, except for very large changes in P and Q, is closely approximated by a mid-point (or linear) formulation that makes use of the average value of each independent variable (Webster and Bly, 1980; Mayworm, Lago and McEnroe, 1980, Litman, 2012).

log arc elasticity:

$$\eta = \frac{\Delta \log Q}{\Delta \log P} = \frac{\log Q_2 - \log Q_1}{\log P_2 - \log P_1}$$

mid-point (or linear) arc elasticity:

$$\eta = \frac{\Delta Q}{(Q_1 + Q_2)/2} \div \frac{\Delta P}{(P_1 + P_2)/2} = \frac{\Delta Q(P_1 + P_2)}{\Delta P(Q_1 + Q_2)} = \frac{(Q_2 - Q_1)(P_1 + P_2)}{(P_2 - P_1)(Q_1 + Q_2)}$$

where η is the elasticity, Q_1 and Q_2 are the demand before and after, and P_1 and P_2 are the price or service before and after.

Arc elasticity is based on both the original and final values of demand and price or service. When one of the values is zero, as in the case of adopting or terminating free use of transit, the mid-point arc elasticity formulation must be employed. Otherwise, the logarithmic formulation has been used whenever elasticities have been calculated directly from available data in this third edition Handbook, as was the case with the second edition. Similar values carried over from the first edition were computed using the mid-point formulation, and are so identified.

A third form of elasticity, historically used in reporting response to transit fare changes, is the shrinkage ratio or shrinkage factor. In its general-use "rule of thumb" formulation, it is defined as the change in demand relative to the original demand divided by the change in price relative to the original price, or in mathematical terms (Bly, 1976, Mayworm, Lago and McEnroe, 1980):

$$\eta = \frac{\Delta Q / Q_1}{\Delta P / P_1} = \frac{(Q_2 - Q_1)/Q_1}{(P_2 - P_1)/P_1}$$

More recently, this method of computation has been adopted by a number of domestic road value pricing studies. The "shrinkage" nomenclature is not used; instead such terms as "approximated point elasticities" are applied.

Shrinkage ratios present certain conceptual difficulties. For example, consider a specific experimental transportation price reduction or service expansion and the accompanying travel volume increase. Assume, for illustrative purposes, that the demand returns to its original level if the price is raised or the service reduced back to its original state as a second experiment. Logically, the elasticity in this hypothetical example should be the same for both experiments, and it is—if arc elasticity is computed. However, if the changes in price or service are moderately large, the corresponding shrinkage ratios will be different. Shrinkage ratio guidelines that are in common use are reported in this Handbook, but arc elasticity conversions are given where possible.

Note that this generalized "rule of thumb" formulation for shrinkage ratios is not the version derived and applied by the firm of Simpson and Curtin for describing and predicting transit fare change impacts. That formulation included a constant (Curtin, 1968), as described and examined in full in Chapter 12, "Transit Pricing and Fares," under "Response by Type of Strategy"—"Changes in General Fare Level"—"Urban Transit Overall." The Simpson and Curtin formulation has the same conceptual problems as described above, however.

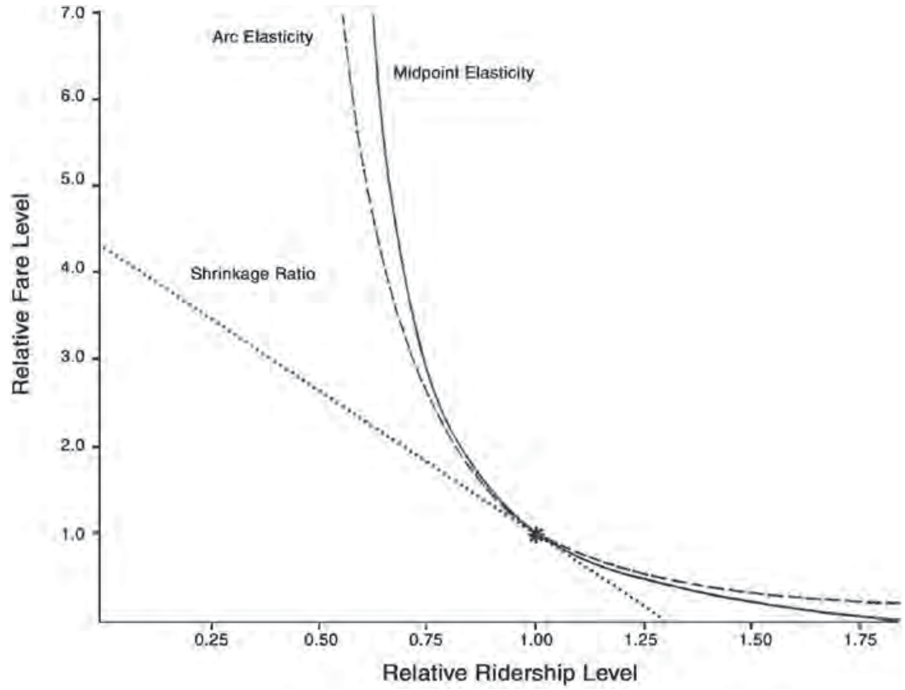
DIFFERENCES BETWEEN ELASTICITY MEASURES

When the percentage change in price or service is small, all the methods for computing elasticity give approximately the same value. Large changes, however, result in different values of elasticity depending on the formula used. Figure A-1 graphically illustrates the differences in arc elasticity, point elasticity, and shrinkage ratio values for an initial point price elasticity of –0.30 (Mayworm, Lago and McEnroe, 1980).

Table A-1 gives elasticity values for different fare changes, as specified in the first column, and an assumed *log arc* elasticity of –0.300. The tabulated elasticities are calculated using each of the three types of elasticity formulations presented above.

For both point and arc elasticities, an absolute elasticity value greater than 1.0 signifies an elastic relationship, while an absolute value less than 1.0 indicates an inelastic relationship. This is not necessarily the case for the shrinkage ratio, as the transit fare reduction example below illustrates (Dygert, Holec and Hill, 1977). The loss of revenue in the example shows that increased ridership was not great enough to offset the fare decrease in terms of revenue. This illustrates an inelastic relationship between fare and ridership.

Figure A-1 Elasticities of Different Types Calculated from a Demand Curve with an Initial Point Elasticity of –0.30



Note: The term "point elasticity" as used in the figure title refers to the derivative of the assumed underlying demand curve—it is not used here as a synonym from shrinkage ratio or factor.

Source: Mayworm, Lago and McEnroe (1980).

Initial fare = \$0.40
Final fare = \$0.25

Initial ridership = 1,000
Final ridership = 1,500

Initial revenue = \$400
Final revenue = \$375

Shrinkage ratio = –1.33
Log arc elasticity = –0.86

Table A-1 Values of Elasticity According to Different Methods of Computation

Percent Fare Change	Log Arc Elasticity	Mid-Point Arc Elasticity	Shrinkage Ratio
-50%	-0.300	-0.311	-0.46
-30	-0.300	-0.303	-0.38
-10	-0.300	-0.300	-0.32
+10	-0.300	-0.300	-0.28
+30	-0.300	-0.302	-0.25
+50	-0.300	-0.304	-0.23
+100	-0.300	-0.311	-0.19

USE OF ELASTICITIES IN THE HANDBOOK

Elasticities should not be taken or used as precise predictive measures. They simply serve to indicate the likely order of magnitude of response to system change, as inferred from aggregate data on the experience in other, hopefully comparable, instances. However, they can be very useful in providing first-order estimates of the changes in demand which may be expected for certain transportation price or service changes, or even certain differences in the built environment.

Elasticity Application Formulae

The formulae for applying arc elasticities to predict traveler response are not the same as for applying shrinkage ratios. Given a proposed transportation system change, to compute the new travel demand which may be expected given an arc elasticity value thought to be applicable, the equations to use are:

log arc elasticity:

$$Q_2 = 10^{\eta\left(\log P_2 - \log P_1\right) + \log Q_1}$$

mid-point (or linear) arc elasticity:

$$Q_2 = \frac{(\eta - 1) P_1 Q_1 - (\eta + 1) P_2 Q_1}{(\eta - 1) P_2 - (\eta + 1) P_1}$$

where η is the arc elasticity, Q_1 and Q_2 are the demand before and after, and P_1 and P_2 are the price, service, or other measure before and after.

Following is an example of arc elasticity application:

Assume that a transit operator with a daily ridership of 21,000 (Q_1) is interested in increasing fares from 35¢ (P_1) to 45¢ (P_2), and that the applicable fare elasticity (η), arc formula, is –0.40. The new ridership (Q_2), which could be expected following the fare increase, as estimated using fare elasticity, would then be computed as shown:

log arc elasticity:

$$Q_2 = 10^{-0.4(\log 45 - \log 35) + \log 21{,}000} = 19{,}000$$

mid-point (or linear) arc elasticity:

$$Q_2 = \frac{(-0.4 - 1.0)(35)(21{,}000) - (-0.4 + 1.0)(45)(21{,}000)}{(-0.4 - 1.0)(45) - (-0.4 + 1.0)(35)} = 19{,}000$$

Thus, the estimated decrease in daily ridership would be 2,000 passengers.

Source material constraints have precluded exclusive use of arc elasticities (or the closely comparable point elasticities) in this Handbook. Where elasticities derived using other formulations are given, the type is indicated, if known.

Elasticity Definitional Differences

The reader must be alert to major elasticity definitional differences among sources in the transportation literature. This is particularly important in the case of older studies of transit fare changes and newer studies of domestic road value pricing. Table A-2 provides illustrative examples of various extant definitional differences with respect to elasticity, as applied to transit ridership, and Table A-3 does the same for road value pricing:

In addition to definitional differences such as those listed in Tables A-2 and A-3, the user of elasticities also needs to be aware that shrinkage ratios or factors are sometimes called point elasticities. This confusion pervades even textbooks. A true point elasticity uses the derivative of the demand curve—the slope for the entire demand curve or function. One must have a mathematical function to work from in order to derive a true point elasticity, which is not the case with raw quasi-experimental data.

When point elasticity nomenclature is applied to what is otherwise referred to as a shrinkage ratio or factor, it is simply the elasticity for the demand curve at one particular point on the curve, irrespective of whether the whole curve is known or not. The problem with this method is that the elasticity is different at different points on the curve, causing the conceptual deficiencies noted earlier for shrinkage ratios. This limitation has led to growing acceptance of log or mid-point arc elasticities as the preferred approach for use with quasi-experimental data. Arc elasticities apply not to a single point, but to the entire portion of the demand curve under study.

The difficulties which may accrue from definitional and formulaic misunderstandings are not trivial. A notable example, which happens to derive from confusion between a particular formula, a shrinkage ratio rule of thumb, and arc elasticity results, led to a widely disseminated conclusion that transit riders at the outset of the 1990s had been found to react more severely to fare changes than found in the 1960s. Instead, the two landmark studies a quarter century apart actually found almost exactly the same average response to surface transit fare changes. (The two studies, the evolution of the earlier one into a non-equivalent rule of thumb, and the correct basis of comparison, are all detailed in Chapter 12, "Transit Pricing and Fares," under "Response by Type of Strategy"—"Changes in General Fare Level"—"Urban Transit Overall" [Simpson & Curtin formula and traditional rule of thumb] and "Transit by Mode" [study of 52 U.S. transit systems].)

Table A-2 Definitional Differences—Elasticity as Applied to Transit Ridership

***Traveler Response* Handbook**	**Mayworm, Lago and McEnroe (1980)**	**Bly (1976) Webster and Bly (1980)**	**Dygert, Holec and Hill (1977)**
shrinkage ratio	shrinkage factor	shrinkage ratio	arc elasticity*
fare or service elasticity*	arc elasticity* (log or mid-point)	fares elasticity* (or arc, or linear arc elasticity)	"Kemp…definition of arc elasticity"
(or log arc or mid-point arc elasticity)		service or headway elasticity	
point elasticity*	point elasticity*	point elasticity*	point elasticity*

Notes: The forms principally used in the respective publications are indicated by an asterisk (*). Note that the discussions of "arc elasticity" properties in Dygert et al. pertain only to what are termed shrinkage ratios/factors or growth ratios/factors elsewhere.
Sources: Sources for Table A-2 are as indicated in the column headings.

Table A-3 Definitional Differences—Elasticity as Applied to Road Value Pricing

Traveler Response Handbook	Cain, Burris and Pendyala (2001)	Yan, Small and Sullivan (2002)	Wilbur Smith Associates (2000)
shrinkage ratio or shrinkage-ratio-like	price elasticities elasticity	point elasticities… approximated elasticity price elasticity	elasticity
log arc elasticity mid-point arc elasticity	(not used)	(not used)	(not used)
point elasticity	(not used)	(not used)	(not used)

Sources: Sources for Table A-3 are as indicated in the column headings.

This example serves as a warning that full understanding of measures such as elasticities, including their historical antecedents and variations in terminology, is absolutely essential when making use of them.

ADDITIONAL ELASTICITY RESOURCES

Elasticity research and development continue apace. Two compilations that can serve as an excellent starting point for additional information are *The demand for public transport: a practical guide,* published in 2004 by TRL Limited in the United Kingdom, and *Understanding Transport Demands and Elasticities: How Prices and Other Factors Affect Travel Behavior,* by Todd Litman and available through the Victoria Transport Policy Institute (VTPI).

The demand for public transport: a practical guide provides extensive mathematical background for the approaches described above and also for more complex analyses allowing examination of dynamic processes and also situations requiring use of cross-elasticities. Dynamic processes, leading to gradually attained equilibrium states, are reflected in differential elasticity values for short-run, medium-run, and long-run outcomes. Cross-elasticities may be used to examine effects on competition of pricing and service changes, such as the impact of commuter rail pricing changes on a parallel rapid transit service, or the effect of parking price increases on transit ridership (Balcombe et al., 2004).

Besides mathematical background, the TRL guide offers extensive compilations of price and service elasticities, many of them presented in terms of short-, medium-, and long-run perspectives, as well as related values such as personal income elasticities for transit riding. Land use and auto ownership interrelationships are also covered. The focus is on the United Kingdom, but a number of compilations from other Commonwealth nations, Europe, and the United States are included.

Arguably the most important sets of findings in the TRL report, for users of the *Traveler Response* Handbook, are those drawing from analysis of the dynamic processes that reflect gradualness of response to actions traditionally examined through the lens of one-point-in-time elasticity measures. For example, in *TCRP Report 95,* Chapter 12, "Transit Pricing and Fares," a suggested overall bus fare elasticity value of –0.4 is offered. As Footnote 1 of Chapter 12 notes, such values are short-run elasticities, and recent investigations find longer-run elasticities to be higher. The TRL guide also sets forth a bus fare elasticity average of "around –0.4 in the short run." It pairs that value with elasticities of –0.56 for the medium run and –1.0 for the long run. It suggests time horizons of 1 to 2 years for the short run, 5 or so years for the medium run, and 10 or so years for the long run (Balcombe et al., 2004).

Understanding Transport Demands and Elasticities—How Prices and Other Factors Affect Travel Behavior presents compilations for a particularly broad range of transportation elasticity categories. Transit elasticities, parking price elasticities, fuel price elasticities, and travel time elasticities are just some of the various categories examined, but with emphasis on auto-operating cost/pricing elasticities in the Western world and particularly North America. Short-run and long-run values are provided where available. The elasticity compilations are accompanied by informative discussion of the factors that can affect travel demands and by an insightful exposition on factors that can impact price sensitivity and their relative effects. The "References and Resources for More Information" section is well supplied with web links and starts with helpful suggestions as to "Good summaries of transport elasticities" (Litman, 2012).

Thankfully, these two new works hew closely to the terminology employed in all three editions of the *Traveler Response* Handbook and the previous landmark elasticity publications of 1980 (Mayworm, Lago, and McEnroe, 1980, Webster and Bly, 1980). Table A-4 provides definitional comparisons between *TCRP Report 95, Traveler Response* Handbook, and the TRL and VTPI publications.

Finally, note should also be made of the *Travel and the Built Environment* elasticity research by Ewing and Cervero. Originally published in 2001 as *A Synthesis,* their revised and expanded 2010 version comes with the rigor of *A Meta-Analysis.* Transit trip, walk trip, and vehicle miles of travel (VMT) elasticities are provided for over a dozen built environment parameters selected as measures of local density, local land use diversity, local design, destination accessibility, and distance-to-transit service. The meta-analysis draws from and provides a tabular summary of over 50 quantitative studies found suitable for the analytical approach employed in the elasticity research. Additional studies were employed in the associated synthesis. Different elasticity formulae were used depending on the form of the original equations, but the researchers advise that the results may be interpreted as point elasticities (Ewing and Cervero, 2010). The updated elasticity findings, covering demand for both transit and non-motorized transportation (NMT), are summarized in Chapter 16, "Pedestrian and Bicycle Facilities" (see Table 16-42).

Table A-4 Definitional Comparisons among Recent Elasticity Compilations

***TCRP Report 95 Traveler Response* Handbook**	**TRL Guide Balcombe et al. (2004)**	**VTPI Litman (2012)**
shrinkage ratio	shrinkage ratio	shrinkage ratio or factor
fare or service elasticity,* parking or toll price elasticity, elasticity of travel, etc. (or log arc or mid-point arc elasticity)	fare elasticity,* travel time elasticity, service elasticity, petrol price elasticity, car ownership elasticity, etc. (or arc or linear elasticity)	transportation elasticity,* consumer demand elasticity, transit elasticity, etc. (or arc or mid-point arc elasticity)
point elasticity*	point elasticity*	(not used)

Note: The forms principally used in the respective publications are indicated by an asterisk (*).
Sources: As indicated in the column headings.

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Appendix B – Inflation and CPI Conversions

INFLATION AND THE VALUE OF THE DOLLAR

That which is known about actual direct impacts of the process of inflation on travel demand appears to be vanishingly small. As reported in Chapter 12, "Transit Pricing and Fares," two English studies examined the effects of inflation and concluded that in terms of ridership response to transit fare changes, the fare elasticity for decrease in the real value of fares due to inflation is the same as the elasticity for fare increases (Bly, 1976, Fairhurst and Morris, 1975). This seems logical, but no other investigation into the urban travel effects of inflation was encountered.

Be that as it may, the Handbook user needs to pay serious attention to the value of the dollar (or other currency) whenever examining the effect on traveler response of user cost changes, whether they be changes in transit fare, highway toll, parking fee, or whatever. The need here is basically one of accounting, to allow traveler responses to be considered in light of the real value of the user cost change. Real value is expressed in constant dollars, which implies the conversion of costs to a specified year. Obviously the specified year most easy to relate to is the current year, but "current year" is a moving target.

The effect of inflation on dollar values is pertinent whether traveler responses are observed or estimated. When using travel demand models, it must be presumed unless otherwise stated that the cost expressed in the model pertains to the value of the dollar in the year of the survey upon which the model was based.

For observed traveler response the best assumption for the user of this Handbook is normally that costs (and foreign currency conversions if applicable) are for the time of the event studied, if given, or otherwise for the time period preceding publication of the source material—the date of which is available from the citation. However, in certain cases, a different base year is identified for the value of dollar costs. For example, if a source was published in 1981, but the dollar cost basis is not circa 1980 but rather identified in the source as "1975 dollars," the Handbook authors have tried to make sure that information is conveyed and highlighted.

Note that it is important for time series cost data to be converted to and displayed in constant dollars calculated on the basis of any one single year, as opposed to showing the nominal historic values year by year. Use of a baseline in this manner avoids having inflation confound the interpretation of trends. Proper handling of this need is illustrated by compilations such as Table 18-37, "Portland CBD Trends in Daily Equivalent Monthly Parking Costs, in 1985 Constant Dollars" (in Chapter 18, "Parking Management and Supply").

The more severe of analytical problems introduced by inflation can often be largely avoided by describing user cost changes in terms of relative change. The concept of elasticity, covered in Appendix A, is particularly useful in this regard, as it is a relative indicator.

Table B-1 U.S. Consumer Price Index Data for All Urban Consumers (CPI-U) with Conversion Factors to 2011 Dollars

Year	CPI-U	Factor to 2011	Year	CPI-U	Factor to 2011
1946	19.5	11.533	1981	90.9	2.474
1947	22.3	10.085	1982	96.5	2.331
1948	24.1	9.332	1983	99.6	2.258
1949	23.8	9.450	1984	103.9	2.165
1950	24.1	9.332	1985	107.6	2.090
1951	26.0	8.650	1986	109.6	2.052
1952	26.5	8.487	1987	113.6	1.980
1953	26.7	8.423	1988	118.3	1.901
1954	26.9	8.361	1989	124.0	1.814
1955	26.8	8.392	1990	130.7	1.721
1956	27.2	8.268	1991	136.2	1.651
1957	28.1	8.004	1992	140.3	1.603
1958	28.9	7.782	1993	144.5	1.556
1959	29.1	7.729	1994	148.2	1.518
1960	29.6	7.598	1995	152.4	1.476
1961	29.9	7.522	1996	156.9	1.433
1962	30.2	7.447	1997	160.5	1.401
1963	30.6	7.350	1998	163.0	1.380
1964	31.0	7.255	1999	166.6	1.350
1965	31.5	7.140	2000	172.2	1.306
1966	32.4	6.941	2001	177.1	1.270
1967	33.4	6.734	2002	179.9	1.250
1968	34.8	6.463	2003	184.0	1.222
1969	36.7	6.128	2004	188.9	1.191
1970	38.8	5.796	2005	195.3	1.152
1971	40.5	5.553	2006	201.6	1.116
1972	41.8	5.380	2007	207.3	1.085
1973	44.4	5.065	2008	215.3	1.045
1974	49.3	4.562	2009	214.5	1.048
1975	53.8	4.180	2010	218.1	1.031
1976	56.9	3.953	2011	224.9	1.000
1977	60.6	3.711			
1978	65.2	3.449			
1979	72.6	3.098			
1980	82.4	2.729			

Note: To convert costs/prices to 2011 constant dollars, multiply the original dollar value by the conversion factor for the year of the original cost/price. For conversion to dollars of years beyond 2011, obtain the CPI-U for the year of interest, divide by 224.9, and multiply the result by the indicated conversion factor to 2011 dollars before application to the original cost/price.

Source: Bureau of Labor Statistics (2012), with conversion factors to 2011 by the Handbook authors.

The Handbook user may nevertheless wish to convert costs to present day constant dollars, if only to have a better understanding of the scale of expense and change involved. Absolute changes in user charges, along with time series data, should always be interpreted in constant dollars. To facilitate interpretation of transportation system changes involving user costs, the following section of this appendix provides a table of historical cost of living statistics along with factors for converting to 2011 dollars.

COST OF LIVING AND CONVERSIONS

Table B-1 gives the annual average "Consumer Price Index All Urban Consumers—(CPI-U)—U.S. City Average—All Items—1982–1984 = 100" for the years 1946 through 2011 (Bureau of Labor Statistics, 2012). The CPI-U is the broadest, most comprehensive CPI (Bureau of Labor Statistics, 2003).

The U.S. Bureau of Labor Statistics (BLS) warns that the CPI (Consumer Price Index) is not so broad an index as to consider the value of public goods, such as police protection and the like, and as such is not an ideal cost of living index. It is deemed, however, to be the best of several measures "for adjusting payments to consumers when the intent is to allow consumers to purchase, at today's prices, a market basket of goods and services equivalent to one they could purchase in an earlier period." It is also a good measure of inflation if that population and market basket is the perspective of interest (BLS, 2003). This orientation makes it an appropriate choice for quantifying change in the value of the dollar in the eyes of an average urban consumer, including the average consumer of urban transportation.

Various regional and local indexes are published, monthly CPIs are available, and the BLS seasonally adjusts CPI data. The BLS advises that the CPIs for individual areas should not be used to compare living costs among areas (Bureau of Labor Statistics, 2003). Use of regional or local CPIs will clearly improve the accuracy of assessments made using data from different points in time from a single locale. Following the BLS recommendation concerning comparisons among areas, only national CPIs should be used in multiple city analyses, including evaluations involving transfer of findings from one area to another. In light of the various confounding factors always present in travel demand assessments, it seems hardly worthwhile to worry about fine points such as issues of seasonal adjustments to the CPI, either. In any event, seasonal adjustments are irrelevant with respect to the CPI-U data selected for Table B-1, given that the CPIs presented are limited to annual averages.

In addition to annual average CPI-U data (BLS, 2012), Table B-1 provides conversion factors for going from dollar prices of any year to 2011 constant dollars. They are the result of dividing the CPI-U for each year into the 2011 CPI-U. When multiplied by dollar prices for any given year, the conversion factor for that year will translate those prices into 2011 constant dollars. For example, a 15¢ transit fare in 1950 equates to 0.15×9.332 or $1.40 in 2011 constant dollars.

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ERRATA: Chapter 15 – Land Use and Site Design

Discovery of an erroneous source tabulation* and substitution of original raw data lead to the following corrections to Chapter 15, "Land Use and Site Design," of *TCRP Report 95:*

In the paragraph on page 15-10 headed "**Transit mode choice and ridership,**" the second and third sentences should read: "The effect of density in contributing to volume of riders is illustrated by Arlington, Virginia's focusing of development on Metro stations. There key-station ridership, the second decade-plus after opening, rose 15 percent in 12 years, compared to an overall average change of 0 percent for other pre-1980 stations."

In the paragraph on page 15-32 immediately below the paragraph headed "**Density and Transit Choice,**" the last two sentences should be replaced with the following: "The volume effect of density is illustrated by the 'Arlington County, Virginia, Transit Oriented Development Densities' example under 'Case Studies.' Arlington's policy of focusing dense development on its Washington Metro stations is thought largely responsible for 1990 to 2002 ridership growth at the key Rosslyn, Court House, and Ballston stations of 9, 26, and 18 percent, respectively. During the same period, the ridership for other Metrorail stations opened prior to 1980 was, from the perspective of an overall average, static (Brosnan, 2000, WMATA, 2002)."

Within the "**Arlington County, Virginia, Transit Oriented Development Densities**" case study, on page 15-124 substitute the following for the last two sentences of the "**Results**" subsection (immediately in advance of the "**More . . .**" subsection): "Transit ridership has grown along with development at the three major stations. Between 1990 and 2002, weekday 24-hour Metrorail passenger entries grew from 13,600 to 14,800 at Rosslyn; from 5,300 to 6,700 at Court House; and from 9,500 to 11,200 at Ballston. During this same period, in comparison, overall change in ridership at the other 34 Metrorail stations open as of 1980 was negligible when computed as an average including stations with growth, stations exhibiting decline, and stations where ridership was stable."

Within the same case study, to the "**Source**" subsection (which becomes "**Sources**"), add the following source: "Washington Metropolitan Area Transit Authority (WMATA), 'Metrorail Passenger Surveys: Average Weekday Passenger Boardings.' Spreadsheet (June 6, 2002)."

At the end of the "**References**" section, add the same source.

Note: Given its relevance to Transit Oriented Development, the "Arlington County, Virginia, Transit Oriented Development Densities" case study is presented again in full, as a case study within Chapter 17, "Transit Oriented Development," including corrections and a Metrorail ridership update to 2006.

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*An error in the Metrorail ridership element of a chapter source led to erroneous ridership data and conclusions in the "Arlington County, Virginia, Transit Oriented Development Densities" case study presented in the 2003 printing of *TCRP Report 95,* Chapter 15, "Land Use and Site Design," and the corresponding electronic (pdf) version of Chapter 15, as well as in summaries within the main body of the chapter. This errata sheet covers the needed corrections to Chapter 15.

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation