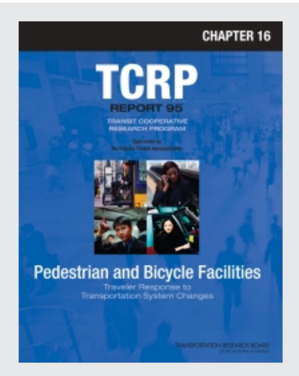

Traveler Response to Transportation System Changes Handbook, Third Edition: Chapter 16, Pedestrian and Bicycle Facilities

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AUTHORS

Pratt, Richard H.; Evans IV, John E.; Levinson, Herbert S.; Turner, Shawn M.; Jeng, Chawn Yaw; Nabors, Daniel; Texas Transportation Institute; Parsons Brinckerhoff, Inc.; J. Richrd Kuzmayak, L.L.C; Cambridge Systematics, Inc.; Vanasse Hangen Brustlin, Inc./VHB; Gallop Corporation; McCollom Management Consulting, Inc.; and K.T. Analytics, Inc.

TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 95

Traveler Response to Transportation System Changes

Chapter 16—Pedestrian and Bicycle Facilities

RICHARD H. PRATT
JOHN E. (JAY) EVANS IV
AND
HERBERT S. LEVINSON
Lead Chapter Authors

SHAWN M. TURNER
CHAWN YAW (C.Y.) JENG
AND
DANIEL NABORS
Contributing Chapter Authors

RICHARD H. PRATT, CONSULTANT, INC.
Garrett Park, MD
JAY EVANS CONSULTING LLC
Washington, DC
TEXAS TRANSPORTATION INSTITUTE
College Station, TX
PARSONS BRINCKERHOFF, INC.
Baltimore, MD
J. RICHARD KUZMYAK, L.L.C.
Silver Spring, MD
CAMBRIDGE SYSTEMATICS, INC.
Bethesda, MD
VANASSE HANGEN BRUSTLIN, INC. / VHB
Vienna, VA
GALLOP CORPORATION
Rockville, MD
MCCOLLOM MANAGEMENT CONSULTING, INC.
Darnestown, MD
HERBERT S. LEVINSON, TRANSPORTATION CONSULTANT
Wallingford, CT
K.T. ANALYTICS, INC.
Bethesda, MD

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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.

TCRP REPORT 95: Chapter 16

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NOTICE

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The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

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CRP STAFF FOR TCRP REPORT 95

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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 16, Pedestrian and Bicycle Facilities*

From a transportation and community perspective, objectives of pedestrian and bicycle facility improvements have evolved to include numerous aspects of providing viable and safe active transportation options for all ages, abilities, and socioeconomic groups. Pedestrian and bicycle facilities appear overall to benefit the full spectrum of society perhaps more broadly than any other provision of transportation. A challenge in non-motorized transportation (NMT) benefit analysis is to adequately account for all the different forms in which pedestrian and bicycle facilities provide benefit.

In this report, new as well as synthesized research is presented. This chapter examines pedestrian and bicyclist behavior and travel demand outcomes in a relatively broad sense. It covers traveler response to NMT facilities both in isolation and as part of the total urban fabric, along with the effects of associated programs and promotion. It looks not only at transportation outcomes, but also recreational and public health outcomes. This chapter focuses on the travel behavior and public health implications of pedestrian/bicycle area-wide systems; NMT-link facilities such as sidewalks, bicycle lanes, and on-transit accommodation of bicycles; and node-specific facilities such as street-crossing treatments, bicycle parking, and showers. Discussion of the implications of pedestrian and bicycle "friendly" neighborhoods, policies, programs, and promotion is also incorporated.

The public health effects coverage of this chapter, and associated treatment of walking and bicycling and schoolchild travel as key aspects of active living, have been greatly facilitated by participation in the project by the National Center for Environmental Health—part of the Centers for Disease Control and Prevention (CDC). This pivotal CDC involvement has included supplemental financial support for the Chapter 16 work effort. It has also encompassed assistance with research sources and questions, and draft chapter reviews by individual CDC staff members in parallel with TCRP Project B-12A Panel member reviews (see "Chapter 16 Author and Contributor Acknowledgments").

TCRP Report 95: Chapter 16, Pedestrian and Bicycle Facilities will be of interest to transit, transportation, and land use planning practitioners; public health professionals and transportation engineers; land developers, employers, and school administrators; researchers and educators; and professionals across a broad spectrum of transportation, planning, and public health agencies; MPOs; and local, state, and federal government agencies. This chapter is complemented by illustrative photographs provided as a "Photo Gallery" at the conclusion of the report. In addition, PowerPoint slides of the photographs in full color are available on the TRB website at http://www.trb.org/Main/Blurbs/167122.aspx.

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 18 topic areas, including essentially all of the nine topic areas in the 1981 edition, modified slightly in scope, plus nine new topic areas. 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://apps.trb.org/cmsfeed/TRBNetProjectDisplay.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.

REPORT ORGANIZATION

The *Handbook,* organized for simultaneous print and electronic chapter-by-chapter publication, treats each chapter essentially as a stand-alone document. Each chapter includes text and self-contained references and sources on that topic. For example, the references cited in the text of Chapter 6, "Demand Responsive/ADA," refer to the Reference List at the end of that chapter. The *Handbook* user should, however, be conversant with the background and guidance provided in *TCRP Report 95: Chapter 1, Introduction.*

An updated Chapter 1 publication, anticipated for 2012, will include a four-level table of contents for all 16 published chapters. An outline of chapters is provided below.

Handbook Outline Showing Publication and Source-Data-Cutoff Dates

General Sections and Topic Area Chapters (TCRP Report 95 Nomenclature)		U.S. DOT Publication		TCRP Report 95	
		First Edition	Second Edition	Source Data Cutoff Date	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 16 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 Investigators 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 and latterly of J. Richard Kuzmyak, L.L.C.; 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.

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 has provided pre-publication numerical quality control review throughout (limited to critical source materials in Chapter 16). 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 final chapter/volume. Editor Natassja Linzau has provided her careful examination and fine touch, while Publications Director Eileen Delaney and her team have handled all 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.

Continued recognition is due to the participants in the development of the First and Second Editions, key elements of which are retained. 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.

Richard H. Pratt, John E. (Jay) Evans, IV, and Herbert S. Levinson are the lead authors for this TCRP Report 95 volume: Chapter 16, "Pedestrian and Bicycle Facilities," the first coverage of Non-Motorized Transportation in the "Traveler Response" Handbook editions. Contributing authors for Chapter 16 are Shawn M. Turner, Chawn Yaw (C.Y.) Jeng, and Daniel Nabors.

Participation by the profession at large has been absolutely essential to the development of the Handbook and most especially this chapter. Sincere thanks are due to the Transportation Research Board (TRB) Pedestrian Committee ANF10 (Shawn Turner, Chair) and Bicycle Transportation Committee ANF20 (Jennifer Dill, Chair) for aiding this participation and serving as a forum for Chapter 16 resource material information exchange and chapter review solicitation. Chapter size dictated that most reviews be focused on individual sections. Chapter or section reviews from a transportation perspective were provided by Greg Griffin, Susan Horst, Kara Kockelman, Michael Langdon, John LaPlante, Meghan Mitman, Gina Mitteco, Anne Vernez Moudon, Laura Sandt, Robert Schneider, and Charles Zegeer. Comments, contributions, and advice received have substantially benefited the final product.

As acknowledged in the "Foreword," the Chapter 16 development effort was joined by the National Center for Environmental Health of the Centers for Disease Control and Prevention (CDC). Dr. Andrew Dannenberg arranged the CDC financial involvement, provided and oversaw technical assistance, and served as a Chapter 16 reviewer. Reviews were also undertaken by CDC staff members Amy Freeland and Christina Dahlstrom. Assistance with public health literature procurement was provided by the CDC reviewers and by Sarah Heaton. Dr. Arthur Wendel, following Dr. Dannenberg's retirement from the CDC, has kindly coordinated follow-up activities. Independent of the official CDC involvement, Dr. Laura A. Pratt reviewed Chapter 16 public health and statistical discussions in the final version, and throughout assisted with source material and statistical and epidemiological interpretations.

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 not feasible to list comprehensively here, many appear in the "References" section entries of this and other chapters. Special note is due of information procurement and interpretation contributions by Robyn C. Davies and Michael J. Langdon of the Department of Transport and Main Roads, Brisbane Australia; data assembly efforts by staff of the City of Boulder, Colorado; and of information assembly combined with a personal interview by Susan Horst, Whatcom Council of Governments, Bellingham, Washington. Posthumous acknowledgment, with highest regard, goes to the late Todd Heglund and the late Rodney E. Engelen, both retirees of Barton-Aschman Associates, Inc. These gentlemen provided historical perspective and, in the case of Mr. Heglund, personally archived reports and papers. The contribution of each and all is truly valued.

CONTENTS

16 – Pedestrian and Bicycle Facilities

OVERVIEW AND SUMMARY

Pedestrian and bicycle facilities form essential elements of the overall transportation system, whether utilized for walking or bicycling as the primary form of travel, or as the means of accessing other transportation modes. The first pedestrian facilities, of course, date back thousands of years. Bicycle advocates have been demanding paved facilities since the 1880s. For much of the 20th century in the United States, however, particularly during the great expansion of metropolitan areas into the suburbs after World War II, pedestrian and bicycle facilities received significantly less attention than was desirable.

U.S. Federal funding for non-motorized transportation (NMT) improvements was increased substantially in the 1990s, and interest in pedestrian and bicycle facilities grew dramatically. In the 21st Century, public health concerns have joined with transportation and environmental objectives as major forces supportive of "active transportation" enhancements (Centers for Disease Control and Prevention, 2010). The U.S. Department of Transportation has declared that walking and bicycling should be considered "as equals with other transportation modes" and adopted "complete streets" principles. Complete streets policy calls for "well-connected walking and bicycling networks" (LaHood, 2010). The importance of understanding the roles and potential of walking and bicycling in the satisfaction of both travel demand and the desire for recreation and exercise has expanded accordingly.[1]

This chapter examines pedestrian and bicyclist behavior and travel demand outcomes in a relatively broad sense. It covers traveler response to NMT facilities both in isolation and as part of the total urban fabric, along with the effects of associated programs and promotion. It looks not only at transportation outcomes, but also recreational and public health outcomes, which are primarily covered as part of the "Related Information and Impacts" discussion.

This "Overview and Summary" section presents:

- "Objectives of Pedestrian and Bicycle Improvements," which highlights goals and purposes of these applications.

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[1] Walking and bicycling, and the facilities they utilize, are together referred to as non-motorized transportation (NMT). "Active transportation" is an alternative term often employed in urban planning and public health circles. Both include "any self-propelled, human-powered mode of transportation." "Active transportation" is often meant to include public transportation, with its heavy reliance on walk and bicycle access. "Complete streets" are "roadways designed and operated to enable safe, attractive, and comfortable access for all users, including, but not limited to, pedestrians, bicyclists, motorists and transit riders of all ages and abilities." NMT trips made in the service of transportation needs, such as for commuting or going to retail establishments, are classed as "utilitarian" trips. That leaves pedestrian and bicycle trips made for recreation and exercise as the other primary NMT trip category (Federal Highway Administration, 2007, Centers for Disease Control and Prevention, 2010). Overlap of motivations—and thus purposes—for walking and bicycling is known to exist, but is poorly researched.

- "Types of Pedestrian and Bicycle Improvements/Programs," which categorizes and describes the characteristics of the various treatments and approaches, for purposes of organization.
- "Analytical Considerations," which discusses the limitations of available information and the conclusions which may be drawn from it.
- "Traveler Response Summary," which highlights key findings presented in the "Response by Type of NMT Strategy" section.

Following the "Overview and Summary" are sections on:

- "Response by Type of NMT Strategy," providing traveler response coverage of a variety of pedestrian and bicycle facilities and programs.
- "Underlying Traveler Response Factors," examining—from the perspective of travel behavior—influences affecting response to NMT facilities and programs.
- "Related Information and Impacts," addressing related issues such as NMT activity levels, safety, user health benefits, and economic considerations.
- "Case Studies," including one compilation of varied mini-studies, five selected examples of response to bicycle and pedestrian facility availability and implementation, and one example of NMT marketing.

An "Adult and Child Public Health Relationships Summary," similar to the "Traveler Response Summary" but health-focused, is provided within the "Related Information and Impacts" section at the end of the subsection on "Public Health Issues and Relationships."

Not covered by this chapter are the specific impacts of direct and indirect safety, operational, and design support for pedestrian and bicycle travel and facility development such as bicycle parking ordinances, safety education and enforcement programs, or construction design guidelines. Chapter 16 focuses on the travel behavior and public health implications of pedestrian/bicycle area-wide systems, NMT-link facilities such as sidewalks, bicycle lanes, and on-transit accommodation of bicycles, and node-specific facilities such as street-crossing treatments, bicycle parking, and showers. Discussion of the implications of pedestrian and bicycle "friendly" neighborhoods, policies, programs, and promotion is also incorporated. Related topics are addressed in Chapter 15, "Land Use and Site Design," Chapter 17, "Transit Oriented Development," and Chapter 19, "Employer and Institutional TDM Strategies."

Chapter 1, "Introduction," serves to provide guidance for effective use of this and all *TCRP Report 95* chapters. See especially the information and suggestions offered in the "Use of the Handbook" section of Chapter 1.

Objectives of Pedestrian and Bicycle Improvements

Bicycling, and to a lesser extent, walking, were—in the post-World-War-II half century—viewed mainly as recreational activities. It has been increasingly recognized, however, that walking for short trips and bicycling for medium-short trips represent efficient, non-polluting, inexpensive modes of travel (Goldsmith, 1992). Moreover, even in communities designed in the motor age, a large proportion of trips by auto and almost every trip by bus, rail, air, or boat begins or ends with non-motorized travel. Thus, from a transportation and community perspective, objectives of pedestrian and bicycle facility improvements have evolved to include numerous aspects of providing viable and safe active transportation options for all ages, abilities, and socioeconomic groups. NMT objectives include (LaHood, 2010, Centers for Disease Control and Prevention, 2010, U.S. Environmental Protection Agency, 2010, Litman, 2011a):

- Support for trips too short to be effectively served by motorized transportation.

- Reduction of vehicular trips and parking demand through
  – diversion of short- and intermediate-distance auto trips to non-motorized travel.
  – reduction in chauffeuring of unlicensed youth and elders.
  – enhancement of public transportation through access improvement.
  – diversion of automotive transit access trips to non-motorized access modes.

- Achievement of associated local and global environmental and security benefits through
  – pollutant and carbon emissions reduction.
  – conservation of oil and other energy resources.

- Provision of economic benefits through transportation and health care cost savings.

- Enhancement of mobility and safety, with attendant improvements in equity, for
  – unlicensed youth and elderly persons.
  – physically or mentally challenged individuals who cannot drive.
  – low income persons who cannot readily afford an automobile.
  – other persons without access to an automobile, temporarily or long term.
  – all members of society regardless of auto ownership, income status, or age.

- Enhancement of quality of life through
  – making available a broader array of viable and attractive transportation choices.
  – improving conditions for pedestrians and cyclists of all types and circumstances.
  – providing expanded, enjoyable recreation and exercise opportunities.
  – expanding opportunities for chance social and community interaction.
  – supporting more livable, vibrant, healthy, and sustainable communities.

Starting in the 1970s and brought to a head in the Surgeon General's 1996 report, *Physical Activity and Public Health,* inactivity has been identified as a public health crisis now roughly of the same magnitude as smoking (Committee on Physical Activity, Health, Transportation, and Land Use, 2005, Pratt et al., 2000). The inactivity of a majority of U.S. adults is estimated to lead to 200,000 or more premature U.S. deaths annually (Heath et al., 2006). About 1/3 of U.S. adults were obese in 2007–2008. Both adult and youth obesity percentages increased markedly in the 1980s and 1990s, more than doubling or even tripling—depending on age/gender category—in 25 to 30 years (Flegal et al., 2010, Committee on Prevention of Obesity in Children and Youth, 2005). Moderate intensity activity has been shown to be of substantial benefit, with brisk walking the most universally practical form. Relevant forms of active transportation include bicycling, in-line skating, skateboarding, and use of public transportation with its attendant walking for access and egress (Department of Health and Human Services, 2008, Besser and Dannenberg, 2005). The public health objectives of pedestrian and bicycle facility improvements include the following (Centers for Disease Control and Prevention, 2010):

- Expand opportunities for
  – safe and health-enhancing transportation choices.
  – convenient and affordable exercise.

- Achieve increases in exercise attainable from
  – walking and bicycling for utilitarian travel purposes.
  – walking and bicycling for pleasure.

- Achieve decreases in
  – excess body weight.
  – disease for which inactivity is a risk factor.

Clearly the goals and objectives for pedestrian and bicycle facilities are very diverse. The corresponding diversity of associated benefits leads to a situation where benefit analysis based on one objective alone, such as energy conservation, will lead to a severe understatement of advantage to the public welfare. This circumstance is further expanded on in the "Economic and Equity Impacts" discussion within this chapter's "Related Information and Impacts" section.

Types of Pedestrian and Bicycle Improvements/Programs

Area-wide, link-specific, and node-specific types of pedestrian and bicycle treatments are all addressed in this chapter. Area-wide approaches include providing comprehensive systems of pedestrian and bicycle facilities, pedestrian- and bicycle-friendly neighborhoods, policies and ordinances under girding NMT provisions, and active transportation promotion and information. Link-specific treatments include sidewalks, bike lanes, routes, paths, and connections to transit and activity centers. Node-specific treatments include intersection improvements and point facilities like showers and bicycle parking. In practice pedestrian and bicycle facilities can range widely in complexity and can involve many different simultaneous treatments. It is helpful to bear this in mind as the types of facilities and actions, and the responses to these approaches, are discussed.

Sidewalks and Along-Street Walking. Paved sidewalks are constructed alongside motorized vehicle travel ways with the intent of providing a safe, attractive environment for walking, separated from motor vehicles. ADA provisions such as avoidance of sidewalk obstructions and abrupt changes in cross-slope facilitate their use by the mobility disadvantaged and the general public. While sidewalks are found to the side of almost all streets in high-density urban sectors, they are not always consistently found in lower-density city and suburban areas. Where low-density residential area sidewalks are lacking, walking along low-volume, low-speed residential streets may serve as a generally inferior but workable substitute, as does use of paved shoulders in suburban and rural situations. Although it is not typically desirable for adult bicyclists to use sidewalks, there are exceptions, and such utilization does in any case occur.

Street Crossings. A range of traffic engineering approaches including crosswalk and related pavement markings, signs, warning beacons, and traffic signals, as well as crossing-related traffic calming, can help make crossing streets at grade less of a barrier for pedestrians and bicyclists. Many such improvements carry trade-offs between conveniences to motorists versus pedestrians and even vis-à-vis pedestrian safety. ADA requirements call for curb ramps. Marked crossings are most commonly located at intersections, but mid-block locations may be appropriate in some circumstances.[2] Where a reasonably safe and appropriate crossing solution cannot be provided at grade, the layout is amenable, and the typically high costs can be justified, pedestrian/bicycle grade separations may be employed.

Pedestrian Zones, Malls, and Skywalks. Pedestrian zones, malls, and skywalks, typically found in urban commercial cores, more extensively separate walkers from motorists and provide added walking space. Pedestrian zones are areas in which vehicle traffic is restricted and pedestrian travel is encouraged, generally resulting in a small-area system of pedestrian streets. The form of "Pedestrian Mall" now classified as "Traditional Pedestrian Streets" is for pedestrian use only except for off-hour use by delivery and service vehicles. Extensive landscaping and street furniture is typical. "Shared Malls" are similar but provide a narrow traffic-calmed passage for vehicles, normally a single lane in one or both directions, with or without parking. "Transit Malls" are likewise pedestrian oriented but share the right-of-way with exclusive transit vehicle lanes. Shelter for waiting passengers, and related amenities, are commonly provided. Skywalk systems connect between and through buildings above-grade to enable pedestrians to walk without traffic conflicts between business district activities. They typically utilize climate-controlled second-level pedestrian bridges, most often mid-block. Underground tunnel networks perform the same function below-grade. Pedestrian zone, mall, and skywalk installations are often intended as strategies for stabilizing or enhancing the viability of central business district (CBD) retail and office space (Robertson 1994).

Bicycle Lanes and Routes. Conventional on-road bicycle lanes are designated by signing and pavement markings, including lane striping that sets aside a portion of the roadway pavement width for preferential or exclusive use by bicyclists. An alternative provision is to have wider-than-normal shared-roadway right-hand lanes to give additional passing room for bicycles and vehicles, but to not actually stripe the lanes (AASHTO, 1999). Variations on the common right-side bike lane include left-side bike lanes and contra-flow bike lanes on one-way streets. Newer approaches include buffered bike lanes, with a marked buffer strip between bicycles and motor vehicles, and cycle tracks, where physical separation is employed. Physical separators may be created with raised medians, bollards, on-street parking, or by constructing a raised cycle track to introduce a grade differential. Cycle tracks may be one-way or two-way (NACTO, 2011). Another on-road approach gaining in acceptance is bicycle boulevards, a shared-roadway bicycle facility on low-volume, low-speed streets enhanced for cycling with preferential traffic calming, intersection crossing assists, pathfinder signing, and other treatments (Alta Planning + Design, 2009a). Other streets conducive to bicycling may simply be designated as bicycle routes. All such shared-roadway alternatives are designated with signs and may also receive shared-lane pavement markings, known as "sharrows," with the included chevrons indicating recommended bicycle positioning (NACTO, 2011). Pathfinder signing may obviously be used with any type or combination of bicycle (or pedestrian) facilities.

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[2] It is critical to note that under model U.S. vehicle codes pedestrians are in a legal crosswalk, even if it is unmarked, so long as (when unmarked) they are crossing *at an intersection* on the extension of one of the intersecting street's sidewalks or shoulders (Federal Highway Administration, 2005).

Shared Use, Off-Road Paths and Trails. Off-road paths or trails have a distinctive place in the hierarchy of non-motorized facilities, being totally separated from street traffic except at roadways. They are frequently located on old roadbeds in abandoned or "banked" railroad rights-of-way no longer used for their original purpose ("rail trails"), or similarly on canal towpaths. They may also be placed in linear and other parks, on river levees, and adjacent to vehicular roadways. Although commonly called bike paths, these shared use facilities are normally used jointly with pedestrians, joggers, and—when design and surface conditions allow—in-line skaters and other wheeled non-motorized conveyances. In this case, "shared use" means use by multiple NMT modes, but not "shared roadway" use in conjunction with motor vehicles.[3] Nevertheless, low-speed motorized wheelchairs and scooters for the physically disabled are generally allowed by law (AASHTO, 1999).

Pedestrian/Bicycle Systems and Interconnections. Pedestrian and bicycle systems and system expansions that provide system continuity through sheer size and good design are included in this category. Also included are pedestrian and bicycle facility segments intended to eliminate "missing links" and provide important NMT network connections. Examples include bridges for pedestrians and bicycles that cross major barriers such as freeways, railroads, or rivers. Other examples include short segments of sidewalks, pavement, or paths that join up unconnected sections or allow detour-free passage through traffic diversions or closed (or never opened) street segments such as may be encountered with traffic calming.

Pedestrian/Bicycle Linkages with Transit. Access to transit and facilitation of transit trips are important roles for pedestrian and bicycle facilities. Treatments include physical connections and bicycle storage at transit stops and stations. Transit oriented development (TOD), which ideally places the most dense development in closest proximity to transit service and provides pedestrian- and bicycle-friendly design throughout the community, is a model integration of pedestrian and bicycle treatments with public transit. Also within the scope of this topic is bicycle access/egress integration with transit service in the form of bike-on-bus and bike-on-rail programs allowing transit riders to bring their bicycles with them.

Point-of-Destination Facilities. Point-of-destination facilities encompass those necessities and amenities required at work and other non-home destinations to enable walking and bicycling to be workable and convenient transportation modes. They thus serve to eliminate barriers to NMT use. Examples are bicycle parking, secure from theft and preferably weather-protected, and shower and locker facilities for cleaning up and changing clothes at work. Included are workplace or activity center features, such as walkability and availability of convenience services, that reduce need to have one's car along. Bikesharing, providing short-term rentals of utilitarian bicycles, is also examined as a point-of-destination facility.

Pedestrian/Bicycle Friendly Neighborhoods. A variety of neighborhood land use and site design characteristics have been identified as having an impact on the amount and frequency of walking

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[3] Shared use, off-road paths are unfortunately referred to by any number of potentially confusing names, including but not limited to multi-use path or trail, bike path or trail, bikeway, sidepath, hiker-biker trail, greenway, pathway, bike/ped path, and walkway, not to mention design-specific terms such as rail-trail, towpath, and boardwalk (Patten et al., 1994, AASHTO, 1999). Note that although "path" is the preferred technical term for urban applications, regional and facility-specific uses of "trail" have been adopted here where known. Thus shared-use, off-road paths specifically located in urban areas such as Seattle, Minneapolis-St. Paul, and Washington, DC, are referred to as shared use, off-road "trails" to conform with local usage.

and bicycling. Included are development density, land use mix (diversity), design features, distance to transit, accessibility to goods, services, and other needs at destinations, and the overall neighborhood environment from both adult and child perspectives.

NMT Policies and Programs. Supporting policies, programs, and funding at the federal, state and local level are a key ingredient in implementing pedestrian and bicycle improvements and do have their own measurable influence on growth in use of non-motorized transportation modes. Included are encouraging, retrofitting, linking, and expanding pedestrian and bicycle facilities and accommodations of all types and making them work together as an integrated NMT system. Examples include city-level programs such as those in Portland, Oregon, Davis, California, and Boulder, Colorado; national-level programs most commonly associated at present with Northern European countries, but coming to the United States with adoption of Complete Streets requirements at the federal level; and schoolchild-focused programs such as Safe Routes to School (SRTS) activities.

Walking/Bicycling Promotion and Information. Not an "improvement" in the infrastructure sense, but an adjunct for encouraging more walking and bicycling activity for transportation and health, is the promotion of active transportation and the provision of information both on NMT options available and benefits. Included are mass market information and promotions focused on inducing mode shifts to active transportation, group-targeted information and promotion with the same objectives, and similar activities focused on introducing new facilities to the public and encouraging their use. Also included is one-on-one personal promotion tailored to the interests and needs of the individual, known as "individualized marketing," a voluntary-behavior-change approach to concurrent assistance with and encouragement of walking, cycling, and transit use choices (Brög and Ker, 2008). Finally, physical activity promotions and interventions used by public health practitioners to encourage walking and bicycling for exercise and its health benefits are covered.

Analytical Considerations

Well into the 1990s, NMT travel data and travel demand studies were quite limited and mainly descriptive in nature. NMT research focused primarily on safety and capacity investigations, while travel demand and behavioral aspects of walking and cycling received relatively little attention (University of North Carolina, 1994, Schwartz and Porter, 2000). Since then, NMT information and insight has received a remarkable infusion from physical activity research spurred by public health concerns (Clifton and Krizek, 2004). Substantial progress has been made in establishing existence of a significant connection between physical activity and the built environment. In the process, advances have been made in evaluating what aspects of the transportation system, community design environment, and active transportation encouragement policies tend to be associated with increases in walking and bicycling and how much so (Handy, 2004, de Nazelle et al., 2011). The process of making sense of the multitudinous new findings is moving forward.

Comprehensive evaluation of NMT facility impacts and active transportation policies potentially involve numerous complex factors, yet remain relatively undeveloped compared to motorized transportation analyses (Victoria Transport Policy Institute, 2007, Committee for Determination of the State of the Practice in Metropolitan Area Travel Forecasting, 2007). The presence or absence of pedestrian and bicycle facilities can affect travel choices on many dimensions: frequency, mode, route, and time of day. On a broader level, the presence of such facilities may influence destination choice, and even housing and employment location choice, thereby impacting trip distribution. Facility availability for exercise and recreation may induce more physical activity, just change where it takes place, or both. Such interrelationships are poorly understood, and deficiencies in data collection and analysis remain widespread (Clifton and Krizek, 2004, de Nazelle et al., 2011, Kuzmyak et al., 2011). It has been stated, for example, that walking is "the least understood major mode of transportation in the United States" (Agrawal and Schimek, 2007).

Users of this chapter should be aware of a number of specific walking and bicycling data and analysis issues encountered in the practice of NMT research and planning and which limit the degree to which quantitative conclusions can confidently be offered. The remainder of this subsection addresses such issues broadly. Additional specifics are introduced at points throughout the chapter where of special relevance.

National and Regional Non-Motorized Transportation (NMT) Data

Derivation of walking and bicycling activity and demand response information from national and regional NMT data, such as household travel information from the National Household Transportation Survey (NHTS) or a regional travel survey, presents a largely different set of issues than does use of data from counts and surveys of NMT facility users. These two major data sources are addressed separately here, followed by discussion of NMT trip purpose versus motivation identification. Purpose identification is an issue that affects all types of survey questions and applications seeking to classify NMT trips and understand reasons for NMT trip making and mode selection.

Modal Definitions for Multi-Modal Trips. There are several aspects of survey-based household travel information on NMT trips that are crucial to keep in mind. One is the matter of modal definitions and priorities. Conventional travel survey processing assigns a single mode to any trip made up of individual segments, i.e., to "linked" multi-modal trips. This mode selection is done on the basis of a hierarchy that normally gives the *least priority* to NMT travel modes or else employs some other identification of a single "primary" mode (Victoria Transport Policy Institute, 2007, Schneider, 2011). Thus, bicycling to a commuter rail station (for example), if it is picked up at all, will be subsumed into the commuter rail trip and not be counted in the bicycle mode. Walking to or from a bus or a parking lot a few blocks away has been almost never identified in *processed* regional or national travel survey data. To get at this type of NMT activity, one must typically utilize specialized surveys such as transit mode-of-arrival surveys, parking facility user interviews, individual building-occupant or visitor/patron surveys, pedestrian and bicyclist interviews, and travel surveys specifically structured to garner quantitative travel data on all configurations of NMT trips.

Since 2001, the NHTS has served as an example of a standardized survey where NMT transit access information is at least asked about and retained in publicly available data files. Even in the NHTS, however, walking and cycling trips made to access and egress transit are not entered as individual trip records in the trip data identified by mode (Clifton and Krizek, 2004). As in those regional surveys which do obtain raw data on NMT access to transit, extra analyses requiring special interest, effort, and expertise are necessary to isolate and evaluate NMT travel linked to transit use. The NHTS does not obtain information on NMT travel in connection with auto use, such as walking between remote parking and the office (Agrawal and Schimek, 2007). To summarize, the processed data and documentation of most traditional large-scale travel surveys—the usual source of regional data and statements about proportions of trips made by walking and cycling—understate overall NMT activity to a substantive degree. Only trips made exclusively by walking or bicycling are identified as NMT trips in the standardized data compilations and reporting of such surveys, and in many cases information on the NMT component of multi-modal trips is never obtained at all.

Poor Survey Respondent NMT Trip Recall. A second important consideration in using travel-survey-based information is the extent to which survey respondents may not recall or understand they should report NMT trips, particularly when not prodded to do so. The trips least well recalled are non-work trips and short trips. Walk trips in particular are predominantly both of these, and thus tend to be underreported (Victoria Transport Policy Institute, 2007, Agrawal and Schimek, 2007). Non-work vehicle trips are sometimes adjusted upward in regional studies on the basis of screenline information, but this is a procedure rarely if ever attempted for NMT trips. Presently available count information is typically insufficient for such use. The gradual shift from trip-based to activity-based surveys has helped survey respondent recall, but the problem has not been eradicated.

Use of Global-Positioning-Systems (GPS) devices for regional surveys holds future promise for addressing poor trip recall effects. Work remains, however, on determining whether and which differences between survey-reported and GPS-recorded travel inventory results reflect survey-respondent recall problems or GPS-recorded trip misreporting (Bricka et al., 2011).[4]

Changes in survey methodology necessarily have an adverse effect on the validity of comparisons over time. For example, walk trip shares from the NHTS cannot be directly compared with those from the predecessor National Personal Transportation Surveys (NPTS) because of significant walk trip reporting increases obtained through trip recall prompts instituted in the 2001 NHTS protocol (Hu and Reuscher, 2004) and maintained in the 2009 NHTS survey. Also, whereas the NPTS did not survey the trips of children under age 5, the NHTS does so (Liss et al., 2003).

A less crucial but nevertheless troublesome survey respondent recall problem (affecting all travel modes) is the tendency to report trip start and end times to the nearest 5 or even 15 minutes. This tendency can warp trip-survey-based calculations such as estimation of average walking speed. The 2001 NHTS reports walk times and distances (Agrawal and Schimek, 2007) that suggest an average walk speed of only 2.2 miles per hour (mph). The reason for this dubious value may lie in imperfect trip start and end time reporting. The comparable value from the 2009 NHTS is 2.8 mph (Kuzmyak et al., 2011), more reasonable, but suggesting instability in the calculation inputs.[5]

Limited Non-Work and Child Trip Data. A third consideration is that some surveys address only travel to and from work, most notably the widely used decennial U.S. Census travel data and its replacement, the yearly American Community Survey (ACS). As noted in a Victoria Transport Policy Institute publication, referring to U.S. weekday travel, "Only 7% of walking trips and 8% of

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[4] Survey-reported versus GPS-recorded differences seen in a 265-sample analysis of 2009 Indianapolis regional-survey GPS-trial results do not fully conform with conventional wisdom. Trip totals were lower for survey-reported than GPS-recorded records for lower-income families, as would be expected, but the same discrepancy was also found for busy professionals and volunteers. Among groups with work-trip reporting results most closely matching between methodologies were non-Caucasians, middle-income workers, and persons commuting via transit and NMT. More non-work trips were obtained from survey responses than GPS readings for the elderly and retirees, including persons reporting walk and bicycle trips. In Indianapolis, dependence was placed on GPS readings for determining the beginning and ending of trips and workplace orientation (Bricka et al., 2011), unlike the 2007 Portland, Oregon, studies of bicycle trip route choice described later, which asked each participant to key trip beginning, ending, and purpose information into the GPS devices (Dill and Gliebe, 2008).

[5] The 2009 NHTS travel diary sample size of 150,000 households is, to its benefit, well over twice the 2001 NHTS sample size of 64,000 including localized sample add-ons (Kuzmyak et al., 2011).

cycling trips are to work, a far smaller portion than for motorized travel, so surveys that focus on commute trips are particularly likely to under[-emphasize] non-motorized travel" (Litman, 1999). School travel is necessarily omitted in surveys that obtain only work-trip information, and even when sought, there are concerns that travel by children is underreported (Victoria Transport Policy Institute, 2007).

Even when data have been available for non-work or recreational walking and bicycling, effects of trip purpose acting in combination with other factors have received only spotty attention. Cross-classifications involving purpose have only rarely been developed in pedestrian and bicycle trip data mining, a limitation highlighted in the "Factor Combinations Involving Trip Purpose" discussion of the "Underlying Traveler Response Factors" section.

A related issue is that some regional travel survey processing procedures have called for discarding (or setting aside) some or all trips with the same origin and destination, typically the home. This protocol may limit the utility of such surveys for analysis of walking or cycling that takes place purely for recreation or exercise, or at lease cause such trips not to be included in standard travel compilations. An example of the latter, involving non-motorized recreational trips starting at and returning to the home without an intermediate stop, is provided by the "Travel Behavior Inventory"—the regional survey for the Minneapolis-St. Paul area. In the 2000 survey, such trips were recorded in the household data along with distance covered, and have been used for university research, but were not entered in the trip-data files (Filipi, 2011). Depending on the particular survey design, ability to analyze chauffeuring of children and other non-drivers who might conceivably walk or bike—were adequate facilities to exist—may also be affected.

Bureau of Transportation Statistics (BTS) reporting on NMT data limitations, in addition to touching on many of the other survey issues raised here, observed that travel by preschoolers is rarely obtained. Moreover, trips by children of approximately grade school and junior high age are often obtained from adult proxies, reducing the likelihood of picking up all travel (Schwartz and Porter, 2000). The NHTS has at least attempted to record the trips of children of all ages starting with the 2001 survey (Liss et al., 2003). Nevertheless, many research studies reflect the limitation of having investigated only the travel or exercise of working age adults.

The NHTS series of surveys, covering 2001 and 2009 so far, provides a rich resource at the national level of U.S. non-work travel by all modes including walking and bicycling (Agrawal and Schimek, 2007). It also includes trips by children of all ages (Liss et al., 2003). In working with the NHTS it is essential to take into account that it is a *7-day-a-week* survey representing an average day, not an average weekday. Of sample days, 29 percent are weekend days (McGuckin and Srinivasan, 2005). Trip purpose distributions from the full spectrum of NHTS trip records reflect the inclusion of weekend travel, whether for motorized or non-motorized travel modes.

Lack of Consistency in Trip Counting Protocols. Also requiring close attention is a lack of common protocols in travel-survey-based information, especially when walking and bicycling for recreation and exercise is involved. For example, there appears to be no consensus protocol for defining a one-way trip equivalent for so-called "loop trips" that begin and end at the same point (if such trips are counted at all). Loop trips from the home, and sometimes from work, are typically encountered when the trip purpose is recreation/exercise. Despite the terminology, they include simple out-and-back trips using the same routings in both directions but involving no destination activity at the farthest-out point.

The NHTS splits such loop trips into two one-way trips by asking the survey respondent to identify—as a "destination"—the farthest point reached (Agrawal and Schimek, 2007). Other surveys, such as the National Highway Transportation Safety Administration (NHTSA) and BTS 2002 summer survey and the 2007 GPS-based survey of cycling in Portland, Oregon, have treated the entire loop as a single one-way trip for purposes of trip reports (NHTSA and BTS, 2002, Dill and Gliebe, 2008). Thus, survey findings based on an approach similar to the NHTS report twice as many recreational/exercise trips for a given amount of activity, and half the average trip length, as compared to studies using the Portland GIS-study approach. Large differences among trip length reportings for recreational/exercise trips suggest that this is likely a pervasive definitional problem,[6] and there may be others like it.

A related issue is what constitutes a walk trip that should be recorded at all. "Tours," series or chains of work-related or non-work trips made starting at and ultimately returning to the same location, present a special problem. The nature of activity required to define the end of one trip and the start of another has not been well defined, a deficiency that remained unsolved for the 2001 NHTS. (Does buying a newspaper on the way to lunch count as a trip-ending/beginning?) Even simple one-leg trips present a problem. (Is crossing the street to visit a neighbor a trip?) It has been suggested that the questioning process include a request to treat each change of address location as a trip (Clifton and Krizek, 2004).

Most-Recent Trip Versus Trip-Day Travel Data. Travel-diary and activity-diary surveys focus on a set period, most often a "survey day" during the working week, and so produce information on a typical weekday's trips. More abbreviated surveys may ask about specific types of trips made on the previous day. Some NMT survey information is, however, obtained for the most-recent walk or bicycle trip. For example, the 2002 summer survey performed by NHTSA and BTS utilized a variant of the "most recent trip" inquiry methodology in that it recorded NMT data for the day (within the last 30 days) of most recent walking or bicycling activity (NHTSA and BTS, 2002). Such surveys overemphasize trips by persons who walk or bicycle less and underemphasize trips by persons who do so more frequently yet have only one trip covered in the survey. This approach can skew data ranging from age distributions to trip purpose percentages to trip length averages.

There may be reasons for finding out about the walking and bicycling of persons who engage in these activities less frequently. If one is trying to use such a survey to describe trip making by a representative population, however, there are built-in biases to address. The nature of such biases has apparently not been investigated quantitatively, but it has been suggested that longer recreational trips—such as hikes—may be overemphasized.

Self-Reported Information and Perceptions. Public health professional involvement in walking and exercise research, in many cases representing a first attempt at epidemiological consideration of the transportation and land use environment, has introduced certain additional issues to be aware of. On the one hand, health researchers are bringing badly needed added attention and rigor to statistical designs, along with new analysis techniques and a broad knowledge base concerning

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[6] A circa 2005 survey of bicyclists by a large metropolitan planning organization (MPO) apparently fell into this inconsistency trap. Although questions on the survey instrument inquired about one-way bicycle trips, interviewers were instructed to treat out-and-back recreational and exercise trips as a single trip. Trip lengths were compared with 2001 NHTS results, and the conclusion was drawn that MPO-area recreational and exercise bicycle trips were over twice as long as the national average. This was likely an inadvertent apples and oranges comparison, given that (as described above) loop trips surveyed in the NHTS are split in two, whereas in the survey in question they were apparently not, at least not if they were identified as recreational/exercise trips.

such matters as the reliability of self-reported socioeconomic characteristics, actions taken in daily life, and health status. On the other hand, certain self-reported information—while perhaps useful in analysis of perceptions relevant to behavioral intervention—comes with questions related to its use as independent variables for understanding travel behavior.

A case in point, which comes from both health and transportation research, is asking a survey respondent if some place or activity, such as shopping, is within walking distance. It would seem that such indicators could vary considerably in their quantitative basis: For example, what would be perceived as "beyond walking distance" for an obese person would likely be quite different than for a fit individual. Moreover, various studies suggest that factors in the environment can affect distance perception.

Self-reported distance walked, expressed in terms of travel times, has been subjected to quantitative investigation vis-à-vis estimated actual travel times. The study in question surveyed individual perceptions of proximity to various types of businesses and facilities in Minneapolis and its inner and outer suburbs. Actual locations were geocoded, allowing perceived travel times to be compared to both airline and transportation-network distances and corresponding travel times estimated using average walking speeds. Both perceived and actual travel times were grouped into 1-to-5, 6-to-10, 11-to-20, 21-to-30, and over-30 minutes categories. Perceived travel times matched the corresponding estimated-time category only 37 to 38 percent of the time (Horning, El-Geneidy, and Krizek, 2008).

Results of surveying or analyzing perceived values such as travel distance need to be treated with suitable caution. Moreover, with regard to findings derived from modeling, it also needs to be kept in mind that the strength of other variables modeled concurrently may be affected by inclusion of variables based on perceptions.

Facility Counts and Research Surveys

Transportation planners of motorized facilities and services rely on widely accepted vehicle and passenger count methods for measuring use and validating estimating models. The available procedures include periodic statistically controlled street and highway counts, vehicle classification counts, full-time highway count stations, and transit passenger counts and rider surveys (Shunk, 1992, Kell, 1992, Cambridge Systematics et al., 2011). Walking and bicycling have been afforded no such consistent data collection and processing systems. Each agency has tended to conduct any NMT counts, surveys, and analyses in its own way, and there has been little national sharing of data (Jones, 2009).

National Perspectives. A 2004 review of NMT data collection in the United States found many communities and agencies following at least part of an organized pedestrian and bicycle data collection process, although many did not. Among agencies collecting data, it was a challenge to formalize results and make them publicly available. There was no uniform, national NMT data format to rely on. Of 29 pedestrian and bicycle data collection case studies developed by the authors, only 2 were supportive of evaluations that could contribute directly to traveler response evaluation (Schneider et al., 2005).

Recognizing the need, the National Bicycle and Pedestrian Documentation Project (NBPDP) was initiated in 2002 as a voluntary cooperative effort by Alta Planning + Design and The Institute of Transportation Engineers (ITE). This effort has sought to establish a "consistent national methodology" and assemble counts and other information into a starter database. The taking of annual counts is encouraged, focusing on one 2nd-week-of-September weekday in the peak periods (7–9 AM, 4–6 PM) and one weekend in the midday (12–2 PM). It must be understood, however, that the NBPDP (at least as of January, 2009) is unfunded, with no resources to conduct quality assurance/quality control on incoming data (Jones, 2009). Related limitations include automated pedestrian and bicyclist counters that are more difficult to properly deploy and less reliable than the motorized-vehicle equivalent, requiring calibration to manual counts (Lindsey et al., 2006, Schneider, Arnold, and Ragland, 2009), and sometimes uncritical acceptance of counts, surveys, and observations contributed by NMT advocacy groups.

Effects of Exogenous Events and Circumstances. The occurrence of exogenous influences and events is a potential problem for any transportation data collection effort. As discussed in the "Natural or Artificial NMT Volume Variability" discussion to follow, special events may strongly affect pedestrian volumes. Such events include athletic contests, concerts, and any happening that draws large crowds to areas with pedestrian accessibility. In some cases events affect bicycle volumes as well. Shared use trail volume modeling in Indianapolis included a "state fair in session" variable in the Monon Trail model to address a key special event impact (Lindsey et al., 2006).

Exogenous influences and events that obviously or possibly caused NMT-count, survey, comparison, demand-model, or long-term-outcome abnormalities are noted where relevant throughout this chapter. Such instances include sharp growth in university enrollment and employment, lack of hard surfaces in an urban path system, urban Interstate bridge collapse at a CBD cordon, earthquake destruction, weather conditions, and a mass-transit strike. Some of these real-life examples may seem overly obvious, but if not documented in connection with data presentations, they can raise questions or be overlooked in later applications and interpretations of the data affected.

An ever-present exogenous circumstance is the area type context, in terms of land use and demographics, for individual facility improvements and other actions. A new sidewalk or bicycle connection (or walking/cycling encouragement program) in a dense, urban, mixed-use area may promote a significant mode shift that is in part thanks to having many people living and working in close proximity to the improvement. Adding the same facility or taking the same action "in a low-density suburban area with separated land uses may produce a minimal mode shift" because residences and activity destinations are simply too far apart for most trip makers to contemplate walking or bicycling. New facilities in such environments may increase recreational walking and bicycling, and increase safety, but utilitarian travel may continue using the auto (Schneider, 2010).

In the case of heavily recreational shared-use-path volumes, trail use research in Indianapolis suggests that neighborhood demographic makeup may be more important than land use and design in influencing trail usage, although both were found significant (Lindsey et al., 2006). In any case, such findings highlight "the difficulty of drawing general conclusions about the pedestrian and bicycle volume impacts of pedestrian and bicycle facilities in different [. . .] contexts" (Schneider, 2010). Important land use context information is reported where known, and effects of land use are examined in the "Pedestrian/Bicycle Friendly Neighborhoods" discussion within the "Response by Type of NMT Strategy" section.

Natural or Artificial NMT Volume Variability. Pedestrian and bicycle counts tend to exhibit much higher variability than observed for equivalent vehicle or transit passenger volumes. Walking and cycling are more affected by the day-to-day and season-to-season weather than other travel modes, making conduct of "typical day" counts more problematic. Commercial and sports/entertainment area pedestrian volumes, reflecting as they do what is going on close at hand, can be strongly affected by special or localized events and situations including conventions, opening or failure of popular stores, and local economic conditions at the time. NMT facilities exhibit significant hourly variation, often making designation of standardized peak periods meaningless (Bruce, 2002a and 2004a and b, Jones, 2009). This variability notwithstanding, it is not uncommon to limit NMT counts and surveys to fixed one-or-two-hour peak periods, raising concern about the reliability of such data gathering.

A count variability example is provided by pedestrian crosswalk counts presented in this chapter's first case study, "Special Mini-Studies in Montgomery County, Maryland" (within the case study, see "More—Volume Variability"). Counts taken on parallel crosswalks illustrate how strongly pedestrian volume characteristics reflect the events of the day and/or the nature of nearby land development. Counts one year later illustrate how much difference there can be between two counts at the same location, for whatever reason.

Pedestrian activity is much more localized than transit or automobile passenger flows. Comprehensive surveys circa the 1970s in Chicago's Loop found State Street pedestrian volumes between Madison and Washington Streets to be 4 to 5 times the volumes three blocks up the street, and over 7 times the pedestrian volumes 5 blocks over to the west. Similar phenomena were recorded in 6 other major U.S. cities coast to coast (Pushkarev and Zupan, 1971, Wilbur Smith and Associates, 1970, Levinson, 1982). (For more detail, see "Related Information and Impacts"—"Facility Usage and User Characteristics"—"Sidewalks and Other Provisions in Major Central Business Districts"—"Central Business District Pedestrian Volume Characteristics.")

There has been little study of variability in bicycle volumes. Perhaps as critical as variability in the case of bicycle volumes is the small proportion of all travel, and even of NMT travel, that bicycling today represents in the United States. The previously noted BTS study points up the possible inadequacy of sample sizes for specific examinations of travel by lesser-used modes such as bicycling (Schwartz and Porter, 2000). Errors in measuring and estimating bicycle volumes will be magnified in the context of describing changes from low-activity base-case conditions.

NMT Facility Survey Design Issues. Intercept surveys of NMT facility users, in addition to encountering the same traffic flow variations noted above, introduce other methodological issues. NMT/active-transportation survey instrument definitions and application designs have less commonality than typical for transportation surveys. This lack of standardization perhaps occurs because a broader range of professional backgrounds is reflected in their design, a range encompassing not only transportation planners and traffic engineers, but also parks, recreation, and public health professionals. A case in point involves determination of the purpose of active transportation trips. There appears to have been a tendency to obscure utilitarian purposes of travel by asking survey questions in such a way that "motivation" has superseded trip "purpose." This particular problem, not limited to individual-facility studies, has sufficiently widespread implications that it is afforded a separate discussion under the "Trip Purpose Versus Motivation" heading.

NMT facility observations and intercept surveys taken "on-line" (on-facility), i.e., at a point on the main walkway or path, may bias analyses if one is attempting to derive conclusions about trip-based use and usage characteristics. In such an on-facility intercept survey, trips in categories associated with longer trip lengths are more likely to be intercepted, and thus overemphasized in summaries relative to categories associated with shorter trip lengths. This phenomenon will adversely affect discernment of usage characteristics such as trip purpose percentages, trip length, NMT travel-mode mix, child versus adult proportions, and even gender proportions. Classification counts and surveys taken on-facility reflect the mix of user traffic at points along the facility, useful for operational analyses of facility traffic, whereas interception of persons starting or ending facility use allows analysis without trip length bias of the mix of users visiting the facility. The latter method, as employed in year 2000 Indiana trails surveys, provides actual trip-based user data in the manner of an attraction survey.

For example, proportions of trips for commuting and recreation, by adults, and—especially on shared-use facilities—by bicyclists, will probably be over-reported in on-facility intercept surveys. Use for running errands, by children, and by pedestrians will be underreported. If trip-length data were obtained, it should be possible to compute bias corrections, but use of such an approach is presently rare. The only direct approach to avoiding this bias entirely is to conduct intercept surveys of persons entering or exiting the facility, the methodology used in the year 2000 Indiana University trail use studies (in the "Case Studies" section, see "Six Urban, Suburban, and Semi-Rural Trails—Indiana Trails Study").

The Monon Trail of Indianapolis, included in the Indiana trail entry/exit interviews, was reexamined just under 4 years later using field observations taken in accordance with the on-facility intercept approach. The on-facility observations showed a 165 percent higher proportion of bicycle-mode users, shifting the reported majority user from pedestrian to bicyclist, and a 24 percent higher proportion of male users, shifting the reported majority user from female to male (Indiana University, 2001, Lindsey et al., 2006). The passage of time, seasonality, and interview versus field observation approaches to data gathering may have had some effect. The major differences fit, however, with the expectation that the proportion of longer trips would be boosted by the choice of an on-facility survey approach.[7] (A full numerical comparison is provided in Table 16-107 of the "Related Information and Impacts" section, under "Facility Usage and User Characteristics"—"Off-Road Shared Use Paths"—"Path User Mode Distributions" and "Mode-of-Access Distributions.")

Public Opinion and Preference Surveys. Public opinion and preference surveys, as contrasted to carefully structured and modeled stated preference survey experiments, have been largely discredited as a basis for direct estimation of motorized transportation facility usage. This type of public survey has nevertheless commonly been used in the active transportation community to determine motivations and estimate the degree of increased bicycling and walking likely with improved NMT facilities. Typically, potential improvements are described and the persons surveyed are asked if the changes would lead them to walk or cycle. Findings from such surveys are often contradictory, and frequently exaggerate the potential of prospective improvements. For example, 1970s surveys of residents in Madison, Wisconsin, found 21 percent willing to bicycle to work if there were better facilities. After bicycle lanes and paths were provided, it was found that the share of bicycles in traffic had risen from 4 percent to 11 percent: a very substantial increase but about half that projected (Zehnpfenning et al., 1993).

Before and After Surveys. "Before-and-after" surveys and the analyses based on them are essentially two-point-in-time longitudinal studies, with one set of observations before an action such as facility improvement, and the other afterward. They do not track individuals, however, unless a panel-survey approach is used. The introduction to this "Analytical Considerations" discussion highlights the many dimensions in which presence or absence of pedestrian and bicycle facilities can affect travel choices including trip frequency, mode, route, time of day, destination, and distribution. The limited number of before and after studies available of response to pedestrian and bicycle facility improvements generally examined only one or two of these dimensions at most, or utilized volume as the travel measure (see the various strategy assessments within the "Response by Type of NMT Strategy Section").

This limitation makes difficult such assessments as quantification of latent or induced demand, frequently discussed in the context of motorized facilities, but also a factor of interest to planning

[7] This assumes that male trail users make longer trips on average than female users, primarily because a lower proportion of females typically choose to bicycle.

non-motorized improvements. Introduction of pedestrian and bicycle facilities may inspire individuals to undertake walk or bicycle trips not made previously by any mode, as well as to shift from motorized to non-motorized modes. On the other hand, NMT volume increases observed in connection with individual facility improvements may largely represent shifts from alternative walking or cycling routes by people already using active transportation. Travel choice sensitivities, discussed further in the "Underlying Traveler Response Factors" section (see "Behavioral Paradigms"), suggest that such route shifts are a major contributor to usage of new facilities, especially within dense networks.

Before-and-after surveys may have other analytical problems, such as inadequate sample size, various forms of potential survey response bias, and exposure to exogenous influences that may distort outcomes. A full discussion of such challenges is provided in connection with individualized marketing. (Within the "Walking/Bicycling Promotion and Information" subsection of the "Response by Type of NMT Strategy" section, see "Individualized Marketing"—"Critiques of Home/Community-Based Individualized Marketing Assessments.") It is important to stress that the challenges listed there are not unique to individualized marketing. Indeed, the same or similar issues are encountered in before and after analyses of all types of NMT facility improvement and program actions, and are rarely as well addressed as has been done in a number of individualized marketing assessments.

A before-and-after survey problem potentially troublesome in NMT facility improvement evaluations is the exceptionally long time it may take to fully establish usage patterns for a new facility. Data on this subject is scarce, but time-series counts in Melbourne and Seattle suggest that in the first year of all-new facility availability, weekday usage may be only 15 to 40 percent or so of fully stabilized usage. Complete establishment of usage patterns may take 7 or 8 years (Davies, 2007, Moritz, 1995 and 2005a and b). Motorized facility trends suggest usage at the end of two years may be an acceptable albeit incomplete indicator of long-term travel response, but NMT facilities appear to require more time for usage to become established. "After" surveys taken too soon will fail to pick up usage by people requiring more time to take advantage, while attempts to defer such surveys until further demand stabilization has taken place may run afoul of the confounding events that come with the passage of time. Available usage stabilization information is provided in the "Time to Establish Facility Use" subsection of the "Related Information and Impacts" section.

Trip Purpose Versus Motivation

The challenge of determining the purpose of trips made on NMT facilities, already noted, is applicable to both national/regional surveys and facility surveys. Much active transportation may fall into a large gray area where the pedestrians and bicyclists involved are actually killing two birds with one stone—deliberately choosing to exercise while also accomplishing utilitarian NMT travel (trips for "transportation"). When asked, under these circumstances, to provide a single-choice answer to a trip purpose survey question, the interviewee is faced with a dilemma regarding what to answer. Especially in surveys of shared-use paths and other facilities attractive in their own right, there may be an inclination to ask purpose of path use or "trail visit" in such a manner that "motivation" overrides conventional trip purpose (in the transportation planning sense), obscuring utilitarian purposes of travel. Even purely trip-oriented surveying of trip purpose may be producing unclear results. Exercise or recreational motivation appears to be not infrequently reported as a purpose when there was in fact a utilitarian trip involved, even commuting to work.

Identified Cases of Motivation Versus Purpose Confusion. Two studies in particular illustrate "exercise" or "recreational" purpose reporting when there was actually a utilitarian trip involved.

Interviewers on the Iron Horse Regional Trail in the San Francisco East Bay area made specific note of a tendency for interviewees to give "recreation" as a trail trip purpose when, in fact, they had actual utilitarian destinations but were choosing trail use as an exercise opportunity (East Bay Regional Park District, 1998). The Indiana Trails Studies of 2000 asked users about both "main" and "other" purposes of visiting the trail. On the Monon Trail in Indianapolis, among those users who volunteered an answer to the other-purpose question, 12 percent reported "commute." Another 3 percent reported various utilitarian secondary purposes ranging from dining to business (Indiana University, 2001). Additional context and information is provided in the "Case Studies" section (see "Six Urban, Suburban, and Semi-Rural Trails—Indiana Trails Study"—"More . . .").

Reporting of Both Motivation and Purpose. One example encountered provides insightful information on both purpose and motivation. The source is a post-graduate student survey on the Goodwill Bridge NMT crossing of the Brisbane River, in Brisbane, Australia. Although 82 percent of bridge walkers and 72 percent of bridge bicyclists were found to be making a commute to work or school in this weekday-peak-periods survey, 56 percent of walkers (including 59 percent of commuters) and 60 percent of bicyclists (including 58 percent of commuters) reported an exercise motivation for using the bridge (Abrahams, 2002). (For more detail, see Tables 16-24 and 16-25 and the accompanying discussion in the "Response by Type of NMT Strategy" section under "Pedestrian and Bicycle Systems and Interconnections"—"River Bridges and Other Linkages"—"Goodwill Bridge, Brisbane, Australia.")

NMT Modeling and Research Procedures

In *TCRP Report 95: Traveler Response to Transportation System Changes*, the focus is on observed traveler response relationships. Demand model findings add important additional insight, however, and also serve to fill gaps in the observed response record. Thus the limitations of NMT demand models, along with research procedures and coverage, are relevant.

Common Research Model Limitations. A fairly large number of research models have actually been developed in the last 10 to 15 years in attempts to investigate and describe factors affecting the choice of walking and/or bicycling. The results have contributed greatly to the understanding of NMT travel choices. Most of the research by university and other research organizations has, however, not been of a scale allowing use of regional transportation network data for describing the en route travel characteristics and options affecting choice of travel between individual origin and destination pairs, or even to develop and use accessibility measures employing these characteristics. At the same time, relatively few regional agencies have had the transportation network information required to fully describe pedestrian and bicycle facility availability and quality along individual links of the transportation network.

Most research modeling has focused on developing and using models exclusively employing neighborhood and other "trip-end" area descriptors—including socio-demographic information and sometimes proximity measures—as contrasted to models taking into account NMT network characteristics specific to individual trips (e.g., Kitamura, Mokhtarian, and Laidet, 1994, Saelens et al., 2003, Krizek and Johnson, 2006, Cao, Handy, and Mokhtarian, 2006). A few studies have used GIS information to identify specific features encountered en route, such as need to cross a busy street or percentage of arterials with sidewalks (e.g., Troped et al., 2001, Moudon et al., 2007). Fewer still have more fully employed regional study network data, either to develop accessibilities or to explicitly examine conditions via minimum and/or chosen paths (e.g., Kockelman, 1996, Broach, Gliebe, and Dill, 2009a and b and 2011). Reliance on local-area descriptors dulls ability to describe NMT facility availability and features in a context relevant to specific travel desire lines.

This lack of full spatial demand and supply representation may be causing underemphasis in model results on effects of facilities, and overemphasis on factors that *can* be described well with "trip end" data—such as socio-economic factors or attitudes, for example.

It is mainly research and subsequent applied models developed for or by regional agencies that have made use of transportation network data (e.g., Reiff and Kim, 2003, Kuzmyak, Baber, and Savory, 2006, Lawrence Frank & Co., SACOG, and Bradley, 2008), but these also are few in number. Limitations in network information on NMT facilities have led to use of surrogates, such as having street intersection density stand in for pedestrian and bicycle system interconnectivity. The street intersection density variable has generally worked well for regional models (Reiff and Kim, 2003, Lawrence Frank & Co., SACOG, and Bradley, 2008), but would fall short in describing any NMT network not closely aligned to the street system.

The lower speeds and lesser range of walk-mode trips cause pedestrians to be highly exposed to microscale features of the immediate transportation and land use environments. This circumstance places extra demands on the scale of analysis, with Census-tract levels of detail not up to the task (Clifton and Krizek, 2004). The same can be said of traffic analysis zones (TAZs) and perhaps even blocks. Land use, transportation, and public health research in greater Seattle at the land-parcel-level of detail has produced fruitful results, discussed at several points in this Chapter, but even that research has not managed the full integration of fine parcel-level detail with regional transportation model spatial representations of travel demand and facility networks (Moudon et al., 2007, Lee and Moudon, 2006a).

These limitations of research-scale and applied NMT travel demand models lead to concern that NMT network characteristics, such as NMT system connectivity, may often have been described in a manner inadequate for identifying the nature and full importance of system effects on choice and use of NMT modes of travel.

Cross-Sectional Studies and Causality Issues. The vast majority of the new body of research consists of cross-sectional analyses, although a few new "before and after" type evaluations have been added by transportation and health researchers, and some true experimental trials have been run on interventions to promote active-transportation-based exercise. In working with cross-sectional studies—found in both physical activity research and travel demand modeling—it is essential to keep in mind that correlation does not prove causality. Which caused what may not even be readily evident. Correlation between built environment characteristics and rates of walking and bicycling activity does not necessarily prove the environment directly caused the degree of activity (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). One example of a confounding issue is that of "self-selection": Did an environment favorable to walking and cycling cause more NMT activity, or did the environment simply attract persons predisposed to walking or cycling? (For more on "self-selection," see "Underlying Traveler Response Factors"—"Choice of Neighborhood/Self-Selection.")

Deficient Research Methodology. There is always the concern that a deficient analytical approach will result in overstatement, as in the case of the 1970s Madison, Wisconsin, example noted previously in connection with "Public Opinion and Preference Surveys." Indeed, supposedly sophisticated forecasting studies of proposed toll roads and urban rail systems have an international record of overestimation in the past, attributed to the institutional climate, and labeled "optimism bias" (Committee for Determination of the State of the Practice in Metropolitan Area Travel Forecasting, 2007).

The equivalent can happen in reverse, however, in active transportation research. As part of a systematic review of interventions to promote walking, studies by public health professionals were ranked by Scottish Physical Activity Research Collaboration (SPARC) investigators on a seven-point scale reflecting seven procedure-validity criteria. Examination of 25 studies on promotions of walking found that all studies ranking "6" or "7" for validity, seven studies in all, produced statistically significant findings. Not quite half of the 13 studies that ranked "5" had statistically significant outcomes. None of the five studies with lower rankings reported statistically significant results. Moreover, the median increase in time spent walking isolated in the seven top-ranked studies was 54 minutes, the median increase for the 13 mid-ranked studies was 32 minutes, and the median increase for the five studies ranked lowest for validity was 0 minutes (Ogilvie et al., 2007). Similar relationships have been seen, but within a much smaller sample of studies, in research on effects of sidewalk presence and condition on exercise by children (Davison and Lawson, 2006).

Insufficient Second-Order-Effects Research. Questions about the nature and importance of second-order effects remain to be resolved. A number of examples suggest existence of more nuanced or complex relationships than have been fully investigated to date. Illustrating this point is a paired-neighborhood study which found more walking and cycling in the non-auto-oriented neighborhood, an expected and desired outcome from a transportation perspective, but a level of physical activity overall that was so slightly higher as to not be statistically significant. Other types of exercise were being substituted for active transportation, a secondary effect that appeared to diminish public health implications (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). Another study reported in a synthesis update found, among persons doing at least some walking, that total time spent walking was less in areas with more physical activity facilities (Saelens and Handy, 2008). Findings such as these have to be regarded as needing further replication before full acceptance, but they serve to underscore that there has been little exploration of possible second-order effects and counterbalancing outcomes.

Deficient Research Coverage. One area of interest in particular stands out as having so little available travel demand and response information as to render impracticable any substantive treatment in this chapter. It is the effect of ADA-compliant pedestrian and multi-use facilities (or lack thereof) on the travel and mobility of people with disabilities. The importance of having facilities which people with disabilities can readily use to get from one place to another is fairly self-evident. Obvious benefits include enhanced mobility with attendant social and economic benefits, a better life for the affected persons, and reduction in need for special social services such as costly door-to-door paratransit. The transportation and active-living public-health literature utilized as a basis for this chapter was not, however, found to contain data or research focused on impact of ADA-compliant pedestrian and multi-use facilities—or even presence or lack of sidewalks—on trip-making or exercise by people with disabilities. Thus, despite its importance to a consequential segment of the population, there has been no basis for inclusion of a full discussion. A few perceptive observations found in the literature, and one special-purpose capital cost recovery estimate, have been provided.

A second area of interest not quite so devoid of research, but only beginning to receive attention in empirical studies, is the effect of "tour" composition on the choice of whether to use or not use active transportation. Advanced travel demand modeling investigations indicate that people are influenced in their travel mode choice decisions by all the travel requirements they encounter during any chain of trips made on a tour of activity stops. Travel data keyed solely to individual trips (links) between pairs of activity stops is effectively divorced from information on other elements of a tour. Since most past travel surveys available for analysis were "summarized using trips as the unit of analysis, this can lead to some problematic interpretations of pedestrian and bicycle mode choice." An example is use of trip length as an indicator of walking or bicycling likelihood. In many cases trips shorter than a mile, and thus seemingly obvious active-transportation candidates, are components of much longer tours—perhaps 10 miles or more in total length. An auto may be needed for the full tour even though individual trips within it could theoretically be taken by walking or bicycling (Schneider, 2010). Research available on this issue has allowed only limited examination here, found mainly in the "Underlying Traveler Response Factors" section (see "Trip Factors"—"Walk Trip Distance, Time, and Route Characteristics"—"Walk Trip Speeds and Lengths").

Traveler Response Summary

In this summary of traveler response to pedestrian and bicycle facility implementation and programs, both highly positive and neutral results will be found. However, the general indication is that the phrase "if you build it they will come" does apply to pedestrian and bicycle facilities and programs that are well planned, especially facilities that are well oriented to utilitarian travel patterns and points of activity. Of special interest is that the more robust positive results tend to occur when a systems approach encompassing enhancement of connectivity is followed. This will be seen especially in the summaries and corresponding subsections for "Pedestrian/Bicycle Systems and Interconnections" and "NMT Policies and Programs."

In addition to traveler response impacts there are public health effects, again, generally either positive or neutral. Those effects are summarized separately, at the end of the "Public Health Issues and Relationships" subsection, located within the "Related Information and Impacts" section. That digest is titled "Adult and Child Public Health Relationships Summary."

Sidewalks and Along-Street Walking. Neighborhood sidewalks perform a "land service" function, just as do local streets. As with local streets, their usage is often light but important to fronting dwellings. Illustrative pedestrian-volume intersection counts from three San Francisco Bay Area counties range from roughly 12,000 pedestrians/day at a location on one side of the San Francisco central business district (CBD), to some 2,200/day at a suburban intersection with low-rise apartments near ethnic gathering spots, to 300–350/day at an exurban intersection with a town hall and dwellings, and on down to 20–25/day at partially developed office/commercial intersections in suburban and exurban locations. The average individual sidewalk at these locations would be handling roughly 1/4 of these volumes assuming four-way intersections with sidewalks on all sides.

Four quantified cases of neighborhood sidewalk improvement effects show pedestrian volume increases ranging from 46 percent to 400 percent, with a median increase—among case study averages—on the order of 60 percent. Not known from these before-and-after investigations is whether the added pedestrian volumes represent additional walking in the form of new walk trips, more frequent walk trips, or lengthened walk trips, or whether and to what extent the added volumes come from walk trips diverted from other routes or destinations. In one California five-site Safe Routes to School (SRTS) evaluation, however, additional walking activity by schoolchildren in response to new sidewalk construction was probed and explicitly demonstrated.

Directness of sidewalk routing is sought by pedestrians. Local deviations producing as little as 12 percent extra walking distance have been observed to engender short-cutting by most pedestrians, while 6 percent local indirectness may be tolerable. At a larger scale, route directness has been shown to be an indicator of higher walking activity.

Studies in Austin, Texas, found walking for its own sake (exercise/health, pleasure, and dog-walking) to vary least across neighborhood types, although traditional gridded neighborhoods did have the most. Walking for shopping was five times as prevalent in traditional neighborhoods as in late modern neighborhoods of roughly similar socio-economic makeup, with early modern neighborhoods in between. Closeness of stores was a major factor. Quality of commercial area sidewalk connections and presence of low traffic volumes and speeds were stronger indicators of walking for shopping than residential street sidewalk completeness. At least for able-bodied adults, narrow and pleasant low-volume streets appear to have offered suitable compensation for lack of continuous sidewalks.

In other cities, five out of six adult-focused cross-sectional walking studies found presence of neighborhood sidewalks or sidewalks in general to be positively related to walking activity, although typically not the strongest indicator. In one of these cases the relationship only held for recreational walking and in one case it explicitly held for utilitarian, recreational, and health-related walking. In addition, three U.S. child-oriented active transportation studies found walking to be positively related to sidewalk availability, while two Australian studies found walking by children to be negatively related to heavy or problematic traffic.

A comparative analysis in the Seattle area, the Austin studies, and San Francisco Bay Area shopping district research, along with less formal reportings, all underscore the importance of customer-friendly commercial area sidewalk facilities. The Seattle area analysis examined 12 shopping districts and their surrounding neighborhoods, six suburban and six urban—controlled for density and land use mix—using 16-hour shopping area pedestrian cordon counts. The six suburban examples, with large blocks and averaging 8 miles total of discontinuous, incomplete sidewalks, averaged just 12 pedestrians/hour per 1,000 residents. The six urban examples, with small blocks and averaging 38 miles of sidewalks, averaged 38 pedestrians/hour cordon line flows per 1,000 residents.

It is well established that traffic calming reduces traffic crashes. Very limited evidence suggests it also encourages more walking and bicycling along the treated streets, with increases of 60 to 70 percent or so in NMT traffic observed.

National surveys report that some 11 to 14 percent of bicycle trips are made mostly on sidewalks. A majority but not all of the limited available research suggests this is undesirable from an adult bicycle crash rate perspective. Two studied instances of attracting cyclists off of sidewalks and onto bike lanes suggest different diversion outcomes. In the central San Francisco example, bike lane installation caused sidewalk usage to drop from 52 percent of 71 2-hour PM peak cyclists to 7 percent of 94 cyclists. In a Fort Lauderdale beachfront installation of bike lanes, sidewalk usage stayed within a percentage point of 44 percent. Bicycle lanes may be less effective where there are fewer commuters and large proportions of less skilled cyclists and/or where the bike lanes are substandard.

Public health physical activity research has directed extensive attention onto effects of sidewalk system availability, often finding significant and positive relationships with walking sufficiency, exercise, and normal body weight. Public health research—as noted in the introduction to this "Traveler Response Summary"—is summarized at the end of the "Public Health Issues and Relationships" subsection of the "Related Information and Impacts" section (see "Adult and Child Public Health Relationships Summary").

Street Crossings. Reports of pedestrian and bicyclist response to street crossing provisions present a mix of quantitative research and less formal reporting, but the findings overall largely demonstrate that provision of safe and attractive crossings is an essential element of having an attractive overall NMT system. A before-and-after study of 11 sites in four U.S. cities, all signed for 25 mph, found the proportion of pedestrians crossing at the crosswalk locations to have increased by a range of less than 1 percent up to 12 percent (city averages) in response to new crosswalks. There was also a statistically insignificant increase of somewhat less than 1 percent in pedestrians overall. A larger study of marked crosswalks without traffic controls, in comparison with unmarked and uncontrolled intersection crossings, found the proportions of the young and elderly crossing four or more lanes who used the crosswalks to be 76 and 81 percent, respectively, as compared to 66 percent for all types of pedestrians. Unfortunately, the four-or-more lane uncontrolled crossings category represents precisely the type of facilities found to have higher crash rates within marked as compared to unmarked crosswalks at higher traffic volumes and speeds.

Individual cases where walking volume changes were observed provide indication that an urban-design highway intersection with tight curb radii is more attractive to pedestrians than a rural design with free right turns and "pork-chop" corner islands, and that an urban traffic circle with comprehensive pedestrian provisions is more attractive than a complex conventional intersection. A systems approach to traffic signal placement as part of one-way street revisions in a London entertainment district, with attention to pedestrian desire lines and provision of an increased number of signals along with selective sidewalk widening, was followed by a 9 percent increase in overall pedestrian flow.

Based on GPS tracking of bicyclists in Portland, Oregon, it was estimated—in the context of a 3.5 mile trip—that cyclists will deviate by 16.5 percent to avoid *each* unsignalized major arterial crossing. Comparable deviation values for other conflict situations include 2.5 percent per unsignalized minor arterial crossing, 11.5 percent for each unsignalized left turn from a major arterial, and 4.5 percent for each unsignalized left turn from a minor arterial. Modeling of surveyed shared use trail utilization in Arlington, Massachusetts, found *perceived* need to cross a busy arterial for trail access cut usage of the trail in half, but the effect could not be isolated for *measured* need.

Three of four research efforts examining the effect on walking and bicycling to school of necessity to cross multiple, busy, or major roads found negative impacts. California Safe Routes to School studies found the travel choice effectiveness of intersection improvements to be only moderately less than the impact of paved sidewalk projects. Crossing signalization was the most effective intersection treatment, with before-and-after child pedestrian counts showing a 24 percent increase in schoolchild usage of 2 intersections that had been newly signalized.

Studies in England made under 1960s conditions found usage of pedestrian grade separations to be highly sensitive to pedestrian crossing time relative to at-grade alternatives. Virtually no one used an overcrossing requiring 25 to 50 percent more crossing time than the at-grade route. Given equal travel time via either the grade separation or an at-grade route, underpasses were found to be chosen by 95 percent of pedestrians, while overpasses were chosen by 20 to 70 percent.

Pedestrian Zones, Malls, and Skywalks. Traditional CBD pedestrian streets (malls) have been greatly affected by long-term business activity trends, especially retail trends. Many in the United States were superimposed in the 1960s and 1970s on downtowns in decline. However meritorious, they were often unable to stem the tide toward suburban shopping. Loss of activity led to a deserted feeling, and many were removed or redesigned to reintroduce street traffic lanes and provide a better balance of pedestrian space with pedestrian flows. In other cases, pedestrian streets have been and are highly successful. In the Downtown Crossing pedestrian zone in Boston, the volume of visitors to the area went up by about 10 percent over a 2-year period. Weekday mode shares for worker and shopper trips into and in the pedestrian zone shifted from 48 to 54 percent walk, 37 to 39 percent transit, and 11 to 6 percent auto.

Transit malls have had a higher success rate in the United States than purely pedestrian malls, with four out of five completed transit malls covered in a 1970s study report still extant in the 21st Century. On the Nicollet Mall in Minneapolis, average 11- to 12-hour pedestrian counts *per side* for the six blocks central to retail activity were 12,400 to 12,800 in 1958, well before the 1967 introduction of the transit mall, and 13,600 in 1973 after transit mall development. Introduction of parallel skywalks, starting in the mid-1970s, reduced usage into the low 7,000s as measured in 1976 and 2002. The Nicollet Mall attracted 38 to 46 percent of the immediately parallel pedestrian flow on a September day in 2002. The block-wide corridor centered on the Nicollet Mall is estimated to have been attracting—as of 2002—an 11-hour pedestrian flow averaging 15,600 to 18,700 per side (skywalk traffic included), contrasted to the 12,400 average per side in 1958, an increase of some 25 to 50 percent.

Comparable data is not available for other transit malls, but simulation-aided pedestrian estimates circa 1980 led to a conclusion that the Portland, Oregon, transit mall had focused pedestrian activity on the mall area and nearby sections of cross-streets. Total mall pedestrian volumes were estimated to be 75 percent bus patrons at the time. In contrast, 16 percent of surveyed Nicollet mall pedestrians were headed to or from a bus stop.

Two much newer major mall installations, on opposite sides of the Atlantic, utilize context-sensitive combinations of mall facility types. The Oxford, England, installation of June 1999 involves Cornmarket and two other streets, while the New York City trial—now assured permanency—involves Broadway through Midtown Manhattan. Oxford central area pedestrian flows increased 8-1/2 percent between 1998 and 2000, and Broadway pedestrian flows past Times and Herald Squares gained an average of 8-1/2 percent, roughly double the annual upward trend since 1999.

No studies have been encountered that explicitly examine the relationship between presence or extent of skywalks or underground walkway systems and prevalence of walking. Skyway system bridge crossings in the three- by four-block core of the Minneapolis downtown have averaged about 10,000 per day from the 1970s to the present, with recent volumes on the remainder of the now-vast 82-bridge system averaging about 1/3 as much. Choice of Skyway over parallel crosswalks in Minneapolis and St. Paul ranged in 1975 from 46 percent in June to 68 percent in November, averaging 61 percent over 12 months. A parametric estimate based on these Minneapolis and St. Paul sidewalk versus Skyway choice differentials by season suggests that induced walking may represent 9 to 30 percent of total annual observed Skyway traffic, with a maximum likelihood estimate of 15 percent. At a time when the extent of the St. Paul Skyway system was four blocks north-south and east-west, the median CBD walk journey via sidewalks was found to be approximately 2-2/3 blocks, while the median for walks making use of the Skyway system was some 3-1/3 blocks.

Bicycle Lanes and Routes. Bicycle lanes have been found to reduce cyclists concerns about conflicts with traffic and to attract riders from nearby parallel roads, as well as potentially tapping latent demand. GPS route tracking studies in Portland, Oregon, indicate that the average cyclist making a utilitarian trip will go 31 percent out of their way to use a bike lane instead of having to ride in mixed traffic on a street with moderately heavy volumes. The corresponding value for bicycle boulevards was found to be 45 percent out of the way. (The research did not encompass cycle tracks.) The user makeup of bicycle lanes, as compared to other types of facilities, may possibly be tilted toward use by adults commuting to work. In-depth before-and-after evaluations in Davis, California, and Toronto, Ontario, suggest that the introduction of bike lanes on a single street or multiple streets results in increased cycling along those streets, but with a substantial portion of the increase attributable to shifts in route choice.

The average weekday increase in counted bicyclists on streets receiving bicycle lanes—across four North American cities with usable before-and-after data—is 48 percent, with a range from 23 percent in downtown Toronto to 70 percent in San Francisco. The bicycle count on St. Kilda Road in

Melbourne, Australia, almost doubled in the first year after bicycle lane installation. After 10 years, however, it had increased by a factor of 12 (to 511 cyclists in the AM peak one hour). Two separate studies that examined commute travel mode shifts in response to bicycle lanes, in Minneapolis-St. Paul and Chicago, found average bicycle mode share increases of 64 percent and 91 percent, respectively, with bicycle lane introduction. The response in Chicago was almost certainly amplified by publicity and bicycle parking enhancements. The response in Minneapolis-St. Paul represented a 1.38 percentage point shift in corridor work-trip bicycle share.[8]

Availability of both weekday and weekend before-and-after data from Oriental Blvd. in Brooklyn indicates that the relative weekday impact of bicycle lane implementation was some 7 to 8 times the weekend increase in bicycling, skating, and scooter use. California SRTS studies found no statistically significant evidence of an effect on bicycling to school with bicycle lane installation. These and a number of other bicycle lane and route studies with relevant data could be the beginning of a still very tentative thesis that bicycle lanes offer relatively little attraction for increased cycling at times or by groups likely to be characterized by presence of youngsters and high proportions of cyclists with modest skill levels.

Four progressively comprehensive national-level studies using aggregate cross-sectional data support existence of a strong correlation between bike lane mileage in a city and work-trip bicycling. A 90-city study, utilizing 2006–2008 journey-to-work travel data, has estimated a highly significant statistical relationship between commuter cycling and both bike lanes and bike paths. Typical of this study's findings, one of the research models estimates 2.5 percent more bicycle commuters for each 10 percent more bike lanes and 2.6 percent more for each 10 percent more bike paths. In a Seattle area study that addressed cycling for *all* purposes, a perception of bike lane and/or trail presence was found to have a positive relationship to actual bicycling activity, but not objectively measured presence of a bike lane. Objectively measured closeness of an off-road trail proved significantly positive, however.

Cycle tracks, now extensively deployed in the Netherlands and Denmark, have only a short history in the United States. A before-and-after study in Copenhagen found 18 to 20 percent bicycle (and moped) count increases on streets with cycle track installations, as compared to 5 to 7 percent increases on streets with conventional bike lanes added. A comparative study in Montreal encompassing 6 street pairings found 2-1/2 times the bicycle volumes on cycle tracks relative to mostly parallel streets with no bicycle facilities. Early results from Portland, Oregon, indicate high levels of preference for cycle track and buffered bike lane installations.

In California, Palo Alto's early development of a bicycle boulevard saw 85 to 97 percent bicycle count increases with 35 and 54 percent declines on nearby multi-lane streets. Bicycle volume increases on streets in Vancouver, British Columbia, converted to "Bikeways" (a.k.a., bicycle boulevards), found weighted-average 2-to-5-year cycling increases per Bikeway of 76 percent, 272 percent, and approximately 333 percent, easily exceeding upward secular trends in cycling of roughly 18 percent per year. Surveyed residents fronting a Portland bicycle boulevard report bicycling rates markedly higher than average, and a variety of bicycle trip purposes. Analysis of travel mode shifts in response to implementing signed bicycle routes or "on-street bikeways" found an average increase in three cities of 20 percent in corridor bicycle commuting, with a range from –1 percent in Salt Lake City to +37 percent in Austin, Texas.

[8] "Percentage point(s)" refers to an absolute difference in percentages, rather than a relative difference.

Shared Use, Off-Road Paths and Trails. The GPS route tracking studies in Portland indicate that the average cyclist making a non-recreational trip will go 55 percent out of their way to use an off-road trail instead of having to ride in mixed traffic on a street with moderately heavy volumes, or 26 percent out of their way even if the alternative is a quiet street. The Portland studies indicate a hierarchy wherein conventional bicycle lanes are preferred over all categories of undifferentiated streets except maybe quiet streets, bicycle boulevards are preferred over bike lanes, and off-road trails are preferred over bicycle boulevards, thus according off-road paths highest preference. Earlier studies produced inconsistent findings on bike lane versus shared use path cyclist preferences. Various surveys have indicated willingness to incur extra travel in order to bicycle on off-road shared use paths, including 67 percent extra in the case of Minneapolis respondents bicycling for all purposes—including recreation and exercise—on weekends as well as weekdays.

The most recent national-level study—making use of aggregate cross-sectional data for 90 out of the 100 largest U.S. cities—found bike path prevalence to be significantly related to commuter cycling, and with about the same degree of positive effect as bike-lane prevalence. Each 10 percent more bike path miles per 100,000 residents was associated with 2.6 percent more bicycle commuters per 10,000 residents. Many shared use paths follow natural features and fail to offer direct commuting routes, and may thus appear less attractive as a facility type unless indirectness is explicitly taken into account. Shared use paths serve all NMT users, including pedestrians, joggers, and riders of various non-motorized wheeled vehicles representing all ages and a broad spectrum of capabilities. On six urban, suburban, and semi-rural trails in Indiana, trail users (as distinguished from spot-count path traffic) ranged from 11 to 54 percent walkers, 5 to 20 percent runners, 23 to 77 percent cyclists, and 1 to 13 percent in-line skaters and others.

In 2000, when the six studied Indiana trails were relatively new, they attracted August weekday volumes ranging from 170 (Pennsy Trail in Greenfield) to 1,620 (Monon Trail in Indianapolis), with corresponding weekend-day volumes of 190 to 2,350. On the 30-mile Interurban Trail of Ozaukee County, Wisconsin (north of Milwaukee), fully opened in September 2002, the 14-hour, 7-day trail traffic volume in August 2004 was 4,400 per week, averaged across 2 locations. A summer 2003 survey found 25 percent of respondents countywide to have made use of the trail. The corresponding rate for a March 2005 survey was 53 percent.

The Seattle-area shared use Burke-Gilman and Sammamish River Trails were opened in the late 1970s, joined in 1993 into a 27-mile trail, and then gradually extended closer to downtown. Average 3-to-4-station weekday volume counts grew (not steadily) from 410 in 1980 to 2,190 in 1995, dropped to 1,690 in 2000, and rose again to just over 2,000 in 2005. Corresponding Saturday counts were 1,940, 3,640, 2,080, and 2,290. Possible reasons for the post-1995 drop include weather, reaction to trail crowding and high-speed cyclists, and increased recreational opportunity competition from newer trails. In 1985, 54 percent of survey respondents reported use of a car for trail access on weekdays, while the Saturday proportion was 59 percent. A 50 percent decline for Tuesday respondents from 1985 to 2000 in this proportion, and a 22 percent decline for Saturday respondents, meshes with the postulate that some earlier recreational users of the trails may have shifted to newly opened facilities. Weekday trip purposes evolved in a continuous shift from 10 percent work/school commute and 90 percent recreation/exercise in 1985 to 48 percent work/school and 45 percent recreation/exercise in 2000, with continuation of the shift toward commuting in 2005.

Two individual studies that examined work commute travel mode shifts in response to implementing shared use off-road paths obtained a range of results. Bicycle commute share increases along four new trails in Minneapolis-St. Paul averaged 43 percent, starting with corridor shares that were already 4 to 5 times the norm, and represented a 1.38 percentage points gain. Off-road trail commutershed bike shares in Austin, TX, increased by an average of 0.88 percentage points, up 24 percent. Work commute mode share outcomes for the off-road paths in the other cities were not statistically significant. The research examined neither walk trips nor non-work purpose trips, and in the cities without significant outcomes, the paths tended to either not be part of an overall bike facility network or else parallel to pre-existing facilities. A review of five other before-and-after studies of cycling activity by residents living nearby new or modified paths likewise produced mixed results. No significant changes in levels of cycling were identified in two studies, one of which examined a 1-mile path, but two other studies did find more cycling, and in the 5th study there was an identifiable increase within 1 mile of the path but only after a promotional campaign. Among local or regional cross-sectional studies examining walking or bicycling activity levels vis-à-vis off-road path proximity or availability, four out of six established a positive relationship.

The primary tributary area of an off-road trail has been estimated at 1/2 mile from the facility for commuter cyclists on the Burke-Gilman Trail, and appeared to be 1/2 to 3/4 mile to each side for *all* users of the Minuteman Trail in Arlington, Massachusetts. On the other hand, decay functions fitted to percentages by access distance of all-purpose cyclists in Minneapolis did not flatten out until about 3 miles from the trail. The functions for work/school and shopping trips dropped off more sharply than the function for recreational trips.

Pedestrian/Bicycle Systems and Interconnections. In Portland, Oregon, bikeway system extent (bike lanes, bicycle boulevards, and off-road trails) was increased from 78 miles in 1991 to 256 miles in 2004, a 228 percent increase. Bike facilities were improved or added on four central area bridges. Extrapolation from bridge counts suggests a 210 percent increase in bike trips over the same time span. In the 1990–2000 decade, the citywide bike mode share for work purpose trips increased from about 1 to 3 percent, a comparable increase. In 2005–2008, bridge bicycle counts increased even more rapidly, despite a slowing in system expansion. Possible explanations include a lag effect, gas price increases, individualized marketing, and feedback effects. The bridge bicycle traffic counts from 1991 through 2008 exhibited an exponential growth rate of 9.6 percent per year, producing a fivefold increase overall, with 16,700 weekday four-bridge bicycle crossings in 2008.

With development starting circa 1985, Brisbane, Australia's shared use path system extended some 7-1/2 miles from the central business district (CBD) in one corridor by 1995 and in three corridors by 2000. A major new pedestrian-and-bicyclist-only bridge was opened in 2001. Walk to work shares for travel to the CBD and the CBD fringe increased almost threefold from 1986 to 2006, reaching 17.4 percent walk. (Housing expansion in the core may have contributed to the increased walking.) Bicycling shares, from within roughly 7-1/2 miles, increased sixfold, reaching 3.0 percent bike. Usage over a 2-week period of the new NMT bridge across the Brisbane River ranged, 5 months after opening, from 4,726 (25 percent cyclists) on a Saturday up to 10,854 (18 percent cyclists) on a Tuesday. The prior travel choices of weekday peak period bridge users, 8 months after opening, included 40 percent previously walking or bicycling via an upstream vehicular bridge less safe for NMT users. Prior modes, with multiple responses allowed, were 59 percent walk or bike, 45 percent bus, train, or ferry, 19 percent car, and 6 percent other. Many multi-modal trips were involved, both before and after, and the change from motorized modes was often for the innermost, cross-river leg of the motorized trip only.

Example bike and walk bridge volumes range from 350 users a day on a former rail bridge between Lewiston and Auburn, Maine; to 2,120 pedestrians and 940 cyclists on the NMT-only Stone Arch Bridge in Minneapolis, a former rail bridge across the Mississippi River; 4,000 to 5,000 cyclists and walkers a day on a new NMT-only bridge over Town Lake in Austin, Texas, where the parallel highway bridge with 3-1/2 foot sidewalks was formerly used by only 700 to 1,000 per day; and nearly 2,400 pedestrians and roughly 4,400 cyclists per day on Burrard Bridge in Vancouver, British Columbia, after safety and traffic flow improvements to the highway bridge's bicycle provisions.

A market survey focused primarily on adjacent neighborhoods found the Burrard Bridge improvements were accompanied by a 6 percent decline in reported cross-bridge walking versus a doubling of reported cross-bridge cycling.

When the NMT-only Millennium Bridge in York, England, was opened in 2001, use of walking and cycling routes on both banks grew between 1999 and 2002 by 73 percent for walkers and 31 percent for cyclists, with some route expansion involved. Utilitarian trips went up by 141 percent, going from 25 to 38 percent of the NMT total. Surveys on the Brisbane NMT bridge in Australia and a new harbor-crossing bridge with path in Charleston, South Carolina, have found a majority of walk/bike bridge commuters to be combining intentional exercise with their commute trip.

Closure of a 3-mile gap between Seattle's Burke-Gilman Trail and the Sammamish River Trail saw 1990–1994 before-and-after weekday bicycle count increases of 84 percent at the closest-in end of the gap and 227 percent at the other end. Corresponding weekday pedestrian count changes were –19 percent and +163 percent, respectively. The pedestrian count outcomes seem to reflect an overall increase combined with redistribution to the new and to the previously less accessible sections of the combined trails. Connection across a missing link in Brisbane's Centenary Bikeway was accompanied by a 142 percent weekday (164 percent weekend) 2006–2007 cycle traffic increase at the nearest count station, and corresponding 54 percent and 59 percent increases calculated as weighted averages for the 3 count stations within 4 kilometers to each side of the former gap. Post-2007 annual increases were substantially higher than the almost negligible increases prior to the late 2006 interconnection.

Scattered evidence, mostly circumstantial, gives indication that smaller-scale neighborhood and facility linkages are also of substantial importance. Analysis of Seattle neighborhoods found that when neighborhood pedestrian connectivity and vehicular connectivity were about the same, the walk mode share averaged 14 percent. Where pedestrian connectivity was inferior, the walk share was 10 percent, and where pedestrian connectivity exhibited greater directness than vehicular connectivity, the walk share averaged 18 percent.

Pedestrian/Bicycle Linkages with Transit. Of person trips in the United States, 1.7 percent in 2001 and 2009 involved walking to and/or from bus or rail transit service. This amount represents 16 percent (almost 1 in 6) of all walk trips. Walking is an essential component of all but a small fraction of transit trips. Surveys of transit riders have consistently shown transit mode share and walk to transit share to each have a strong inverse relationship to the distance from the stop or station. Rules of thumb suggest 1/4 mile is the outer limit within which most people are willing to walk to a bus stop and 1/2 mile is the rough equivalent for rail transit. Survey-based studies have shown these rules to be reasonable but not quite comparable. Research in the Miami-Dade area of Florida and Orange County, California, has found a 1/4 mile distance to encompass 80 to 90 percent of persons walking to bus service, while 1/2 mile is barely past the median walking distance to studied West Coast rail transit stations.

The ultimate in deliberate placement of dwellings close to transit stops and stations is found in good Transit Oriented Development (TOD) design. It has been amply demonstrated that transit prime mode shares in TODs and most transit-adjacent developments exceed the transit shares found in nearby non-TOD areas. Walk mode-of-access shares in TODs are mostly within the 70 to 100 percent range, with 90 to 100 percent most common.

There are essentially no reported empirical attempts to isolate changes in transit use or walk or bike mode of access in response to transit access improvements, except in the rather obvious (but important) case where breaching an access barrier has extended a station's tributary area. One may either infer effect from the strong inverse relationship to access distance or model the effect using behavioral models developed for the purpose. Orange County, California, found that when a residential area was 80 to 100 percent within 1/4 mile of a bus stop, as measured along roadway centerlines, the work commute bus mode share was 7.9 percent. This dropped to 3.1 percent when the coverage was 40 to 80 percent, and 0.5 percent when the coverage was 10 to 20 percent. The researchers concluded that providing better pedestrian connectivity would increase coverage and thus bus shares.

Application of access-choice behavioral models produced estimates that walking to Chicago-region Metra commuter rail stations could be increased by 7.2 percent if pedestrian system improvements were implemented. It was also estimated that bicycle parking and access enhancements would raise the Metra bike access mode share from 2.1 to 3.2 percent for home-based trips originating within 2 miles of the station, with one-half the added bicycle access coming from the drive-and-park mode. More dramatic increases were estimated for bicycling to Chicago Transit Authority subway/elevated stations, but with some 80 percent of the shift coming from the walk access mode.

Revealed preference modeling has identified relatively limited importance for socio-economic characteristics in choice of access mode to rail transit, except as expressed in auto availability, which diminishes likelihood of choosing either walk or bike access. Larger numbers of auto park-and-ride spaces at stations have also been shown to dampen walking. Walk mode-of-access shares have been found to universally decline with distance, and except for blocks particularly close to stops and stations, the same pattern is seen for bike access. One or two built-environment measures of neighborhood pedestrian/bicycle friendliness have shown significance for increasing walk access share in 4 out of 5 walk mode of access models. Nearby presence of streets with higher posted traffic speeds entered one bike access model (and its companion walk access model) as a negative factor.

Transit access survey results from 14 U.S. cities and national transit share data suggest that bicycle trips taken in conjunction with transit use constituted, circa the year 2000, on the order of 1/10 of 1 percent of all trips taken in the United States. That would be roughly 1 for every 10 bike-only trips. Relatively little empirical study has been done on this aspect of travel. A stated preference experiment focusing on transit access identified bike lockers as a significant incentive to bike-and-ride instead of driving to transit or all the way. Lockable covered parking was 40 percent as effective. Relative to bike lanes, lockers were 3 times more important for frequent cyclists, but slightly less important for infrequent cyclists.

Bus and rail systems that offer full-scale bike-on-transit programs have found that 3/4 or more of riders arriving by bicycle are taking advantage of the bike-on-transit service. The Phoenix, Arizona, area bike-on-bus program is in this category. It started with a 1991 demonstration, by FY 2000–2001 already served 2,400 weekday bike boardings (a 1.9 percent share of annual passenger boardings), and in FY 2008–2009 served over 4,600 weekday bike boardings (a 2.2 percent annual share). The median share for U.S. bike-on-transit programs circa 2000 was 0.7 percent of passenger boardings.

Among the most heavily used U.S. bike-on-transit services is that of Caltrain commuter rail on the San Francisco Peninsula, reflecting a need for many of its commuters to reach Silicon Valley jobs not within easy walking distance of suburban stations. In a 2007 AM peak period, 924 cyclists boarded with their bikes, 7 percent of all Caltrain passengers. Bike-on-transit, aside from a higher-income component on urban rail systems, is a mobility option heavily used by the transportation disadvantaged, including students. In a survey covering three Florida "Bikes-on-Bus" programs, with 0.25 to 1.61 percent bike-on-bus shares, 78 percent of users reported annual incomes below

$30,000 in 2004 dollars. The median access distance via bike was 1 mile, while the median egress distance by bike was 1/4 mile.

Point-of-Destination Facilities. Point-of-destination facilities are provided at a workplace, school, shopping area, or other attraction to make it more feasible or easier to use non-motorized transportation. The obvious example is bicycle parking. Quantitative empirical data on impacts is extremely limited. Nevertheless, an overall importance of destination facilities for engendering more utilitarian bicycling—and also walking—is apparent.

When Portland, Oregon, created four "Bike Central" locations offering showers, changing facilities, and bicycle storage for a modest fee, a before-and-after study found users of the service increased their average frequency of commuting by bicycle from 3.1 days per month before to 15.5 after. They drove, or rode transit, less. "Bike stations" perform a similar function. A 2009 survey covered eight stations in seven cities, ranging in capacity from 40 bikes (Auckland) to 300 (Chicago). Average percent occupancy, where known, ranged from 28 percent (Seattle) to 88 percent (San Francisco, Caltrain terminal). A Riverside, California, company with about 650 employees, subject to a trip reduction ordinance, installed bike lockers, provided changing facilities, offered access to tools for cycle repairs, and also offered financial incentives to bicycle commuters worth about $2.00 per day cycled. The 10 percent bicycle commute mode share achieved was 10 times the regional average.

Research utilizing stated preference experiments offers additional insight. One such study, based in Edmonton, Canada, estimated large effects for secure bicycle parking provisions (equivalent to a reduction of en route cycling time of 27 minutes) and smaller effects for showers (equivalent to 4 minutes). A study combining U.K. National Travel Survey and stated preference data estimated that with a starting workplace commute trip bicycle mode share of 5.8 percent, the bike share would increase to 6.3 percent with outdoor bike parking, 6.6 percent with indoor secure parking, and 7.1 percent with that plus showers.

An empirical study of workplace destination amenity effects on combined walk and bike work trip mode shares found that measures such as high walking accessibility to convenience services, high appearance of safety around the workplace, and high workplace and vicinity aesthetic appeal, were each associated with NMT work trip shares higher by 0.7 to 1.5 percentage points. This was an environment where observed overall NMT mode share averages were within or close to the range of 2 to 4 percent. San Francisco travel demand modeling found an urban vitality measure to be, for both work and other trip purposes, an indicator of higher mode shares for walking, walk-transit combinations, and ("other" trip purposes only) bicycling.

Bikesharing, involving the shared use of a publicly available bicycle fleet, may be considered both an origin and a destination facility and service. Implementation of this relatively new development appears to be following a typical technology adoption curve and is presently in the "innovators" or "early adopters" phase of market penetration. Estimates of impact vary widely, ranging from 44 percent cycling increases (Lyon, France, first year) to 70 percent (Paris, France) and even a tripling where initial shares were small (Barcelona, Spain, first year). These were major, comprehensive programs, and it is not altogether clear to what area coverage the mode shift reports apply. In Minneapolis, 1/3 of first-year subscribers previously rode a bicycle less than once a month. If the service had not been available, 46 percent would have walked or used their own bike, 20 percent would have used transit, 19 percent would have driven, 6 percent would have ridden in an auto or taxi or made other arrangements, and 9 percent would not have made the trip. About 1/3 used the bikesharing service to access public transit, the same order of magnitude (in terms of proportion) as first- and second-year reports for bikesharing in Paris.

Pedestrian/Bicycle Friendly Neighborhoods. Some of the more notable travel impacts of urban land use structure and design relate to their effect on use of active transportation, specifically, the decision to walk, to cycle, or to do one or both in conjunction with taking public transportation. A meta-analysis of over 50 studies found that the built environment descriptors most closely related to walking were intersection and street density (measures of connectivity), land use diversity, and local access to jobs. Land use mix, neighborhood design measures, and distance to a transit stop were important to transit use. Elasticities were derived, and all were in the lower inelastic range when each was examined in isolation. However, the combined effect on active transportation use of an array of supportive built environment characteristics could be quite large. (For a brief explanation of elasticities see Footnote 12 in the "Response by Type of NMT Strategy" section—"Street Crossings" subsection. For a full explanation, see Appendix A in Chapter 1, "Introduction.")

Other research has found greater density, higher mix of land use, aesthetics, street connectivity, enhanced accessibility or proximity, traditional neighborhood design, and related infrastructure and conditions such as sidewalks and safety to be positively correlated with walking or with both walking and bicycling activity. For children the list is shorter, with distance to school critical. Closeness of schools to homes correlates significantly with walking and cycling to school, with some 20 studies finding distance to school inversely related to choice of active transportation for school access. Overall, the relationships of neighborhood characteristics to walking and bicycling to school appear to be either logical, or insignificant, while generally weaker (distance to schools excepted) than those for adults. Partially conflicting studies have, on balance, found street connectivity and destination proximity to be positively related to physical activity of children.

Disaggregate studies that separately account for intensity of transit service and other density-related parameters find a weak association between density of development in and of itself and propensity to walk or ride transit. This effect may be taken to imply that when other factors are analytically controlled for, the presence of more residents or jobs per unit area only slightly increases walk and transit mode shares. However, and importantly so, density produces conditions that are themselves strongly conducive to use of active transportation. Suitably organized dense development leads to and supports higher levels of transit service, brings activities into closer proximity, and fosters land values that induce priced parking, all characteristics that lead to additional walking, bicycling, transit use, and lower vehicle miles of travel (VMT). Low walk and transit use elasticities for density do show that density not well integrated into the urban fabric, such as apartments in the middle of auto-oriented suburban sprawl, will not have large beneficial effects on either walking or bicycling for transportation or on transit use.

Diversity and design are both more strongly related to prevalence and mode choice of walk trips than density per se. Where there are more local opportunities to meet daily needs there will typically be more walking, with the relationship strongest and more often identifiable in the case of utilitarian walking. There is a general lack of consistent evidence that destination proximity is associated with recreational walking. Choice of walk versus auto access to transit is an aspect of travel behavior particularly sensitive to land use characteristics, and it has been found to be highly responsive to land use mix in particular. Positive land use mix elasticities for walking to transit have been estimated to lie in the elastic range, at +1.1, very sensitive.

Bicycling appears to be an individual choice only moderately associated with the local land use and design environment, although shared use trail proximity and certain commercial use groupings had significant positive relationships in Seattle area research. Companion studies found the neighborhood environmental measures most related to walking to be closeness to grocery stores, restaurants, and retail; lack of office building dominance; and density of the individual's home parcel. Numerous studies support the importance of proximity of retail stores to higher rates of utilitarian walking, for example, walk trips were determined to be more than twice as likely for Minneapolis-St. Paul households less than 1/8 of a mile from the nearest retail as compared to those greater than 3/8 of a mile from retail. Various neighborhood walkability scores have been shown in the Puget Sound Area and in Canada to be positively related to walking activity, including walk mode shifts observed in longitudinal panel survey observations of response to changed residential location and neighborhood environment.

NMT Policies and Programs. Major exemplary illustrations of translating policy into city-wide bicycle or NMT programs in the United States are provided by Portland, Oregon; Davis, California; and Boulder, Colorado. Brisbane, Australia, provides an additional “new world” example.

The NMT policies and programs in Portland, Oregon, have been heavily focused on bicycles, although pedestrians have benefited. The City of Portland has since the mid-1970s pursued policies designed to reduce auto use, particularly in the central area. Portland Bicycle Master Plan implementation did not move full steam ahead, however, until the 1990s. Results, including a 10-year tripling of work trip bicycle shares and a 17-year quintupling of central-area bridge crossings, were described previously under “Pedestrian/Bicycle Systems and Interconnections.”

Also focused heavily on bicycling have been the NMT policies and overall program in Davis, California, a university town long known as the U.S. bicycle capital. Today Davis has systems of bicycle lanes and separated shared use paths that total close to 50 miles each, in an area of 10 square miles. Davis provides a unique sequence of lessons. The bicycle program reached its zenith in the latter half of the 20th Century, and now effects of program maturity and even decline may be observed, as citizen involvement and numerous university support programs have withered and/or disappeared. Increased in-commuting is also a factor. The circa 1970 Davis bicycle mode share for trips to work neared or may have exceeded 30 percent, but stood at 14 percent in the year 2000. The student share for commuting to campus approached or reached 80 percent circa 1970. Student bicycling shares to campus were 48 percent in 2007, but with much of the drop having been taken up by use of free bus service.

Boulder, Colorado, is also a university town but, as a suburb of Denver, it serves as well as a home for major employers. The policy and program focus differs from Portland and Davis in that it addresses in one Transportation Master Plan (TMP) goal the enhancement of all active transportation modes: pedestrian, bicycle, and transit. Off-road shared use paths and pedestrian/bicycle undercrossings of highways have been major NMT development program components. Travel mode shares of residents shifted, between 1990 and 2006, from 18.2 to 18.9 percent walk, 9.1 to 13.6 percent bike, and 1.6 to 4.0 percent transit, for an overall growth of 26 percent in the active transportation share. For employees working in the city, the active transportation share for commute trips has increased by 16 percent and for midday-trips by 30 percent.

In Brisbane, Australia, the “Brisbane Active Transportation Strategy” derives from national pedestrian and cycling strategies. Relevant components of Brisbane’s strategy, together with state government agency internal initiatives preceding strategy and master plan adoption, have undergirded metropolitan area NMT facility investment initiatives. Again, results were described in the “Pedestrian/Bicycle Systems and Interconnections” summary. Urban area walk trip mode shares for work trips to the CBD and its fringe have close to tripled between 1986 and 2006, while corresponding bicycle shares have sextupled.

Comparisons with European programs raise issues of transferability to American situations, but are nevertheless instructive. Most north-central European countries reported circa 1995 walk and bike mode shares that, combined, were 5 to 6 times higher than found for 1995 in the United States, including walk shares 3 to 5 times higher and bicycle shares 10 to over 25 times higher. North-central European NMT shares reflect major gains from low points set in the 1970s, with reversals of earlier declines correlating well with shifts in policy and funding toward substantial support for walking and bicycling. Perhaps the most direct countering of arguments that higher bicycling shares in north-central Europe relative to the United States are primarily attributable to higher urban densities and correspondingly shorter trips is provided by comparison of mode shares stratified by trip length. For example, bicycle shares for trips 1-1/2 miles or less in length during the 2000–2005 period were 2 percent in the United States (and United Kingdom), 14 percent in Germany, 27 percent in Denmark, and 37 percent in the Netherlands. (An unstudied aspect of this comparison is that U.S. trip tour lengths may be longer, even when individual trips are short, with corresponding mode choice effects.)

The dominant school-focused active-transportation program effort in the United States is the Safe Routes to School (SRTS) program. Quantified results for infrastructure improvement approaches are limited and mainly from California. Counts taken before and after sidewalk improvements on the approaches to California elementary schools showed a weighted-average five-site 46 percent increase in schoolchild walking. Similar counts at intersection signalization projects indicated a weighted-average two-site 24 percent increase. Results for other crossing improvements were inconclusive.

Other SRTS approaches involve various forms of encouragement. An intensive pilot program of outreach, encouragement, and aid to schools and parents in Marin County, California, is reported to have resulted in a 21-month, 64 percent increase in walking at surveyed schools and more than a doubling of bicycling. (Results exhibited some anomalies and 12-month results averaging a 17 percent increase for walking and 54 percent for cycling offer a more conservative perspective.) A walking increase of 6 to 12 percent was achieved with a possibly less-intensive pilot program in three Arlington, Massachusetts, schools.

Two programs in England that depended mostly on coordination and encouragement proved ineffective. Daily tracking of student walking and cycling, with recognition and perhaps awards, appears to produce results. A school in Brampton, Ontario, Canada, achieved a 1/4 reduction in auto drop-offs in this manner and a primary school in Dorset, England, obtained a 16 percent increase in walking/cycling rates. A Boulder, Colorado, elementary school more than doubled walking and bicycling and reduced school-area traffic by 36 percent with a trip-tracking challenge combined with walking school buses (WSBs) and other actions. Research in Dorchester County, England, estimated a 26 percent shift from auto use among case study WSB participants, while a Seattle inner-city school achieved a school-wide 37 percent increase in walking with three WSBs. Participant turnover proved a major consideration for Dorchester WSBs and Nelson, New Zealand, cycle trains (CTs) as students "graduated" from supervised walking in WSBs to supervised cycling in CTs, and from both to independent walking and cycling.

Walking/Bicycling Promotion and Information. Results of a broad mass-market walking and cycling information and promotion program in England were inconclusive, similar to the outcome of a larger number of studied public-transit mass-marketing efforts in North America. However, "Ride to Work Day" events may attract the uninitiated: In Melbourne, Australia, high first-time female cyclist participation was achieved and over 1/4 of first-time riders reported riding to work at least once in the course of a survey week 5 months later. One group-targeted information and promotion program achieved approximately a doubling in walk trips, while another increased time spent walking by 64 minutes per week, both as measured against control groups in the short term. Information and promotion marketing focused on cycling via a new NMT facility, an obscure rail-trail in Western Sydney, Australia, was accompanied by a significant increase in overall cycling (from 17 to 28 minutes per week) by persons living nearby who already had a bike available. In transit marketing, similar programs offer only very limited evidence of longer-term gains.

"Individualized marketing" delivers information on environmentally friendly travel modes tailored to needs of individual participants willing to receive project outreach. Household-based dialogue marketing applications encompassing personalized encouragement and addressing all purposes of travel are the most common. Evidence from England and Portland, Oregon, indicates that the travel mode shifts encouraged are in fact larger for discretionary and other non-work travel than for commute trips. Statistics from an audited large-scale application in South Perth, Australia, provide a representative scaling of target area population involvement. Among some 18,600 target-area households, 72 percent proved possible to contact by telephone and also agreed to the initial interview. Of households thus interviewed, 5 percent were regular users of environmentally friendly modes with no need for further information and another 12 percent were regular users desirous of additional walk, bike, or transit facility/service guidance. Regular users received small rewards as encouragement along with any information requested. All other "interested" households accounted for 46 percent. They received targeted information and incentives to try shifting modes. That left 37 percent of interviewed households that were not interested.

Representative target area results based on averages for projects in six sectors of Perth, Australia, the combined outcomes of the Federal Transit Administration's four-city Individualized Marketing Demonstration Program (IMDP) projects in the United States, and an average of two of the annual programs in sectors of Portland, show a range of 1 to 4 percentage points gain in walk trip mode share. They also show a 1 to 2 percentage points gain in bicycle share and also in transit share. Corresponding auto driver or drive-alone mode share declines are in the 3 to 6 percentage points range. Overall average U.K. results are encompassed by these same ranges. The mode shifts obtained in the IMDP projects translate into relative gains of 20 to 25 percent, in their U.S. context, for each of walk, bike, and transit use.

Australian studies have determined that individualized marketing effects tend to be greater for large-scale programs involving more than 5,000 households per application. Small-sample studies of programs in cities with poor transit service and non-motorized transportation facilities suggest that impact may be reduced by half in such circumstances, but contrary results have been seen. Nine projects done in conjunction with rail transit improvements in Portland (1 project) and Germany (8 projects) have averaged first-year transit ridership gains of 48 percent in individualized marketing target areas as compared to about one-half that in control areas receiving only the transit improvements. A number of long-term surveys across three continents have found substantial retention of mode shifts after 1 to 4 years, indicating durability of impact.

Despite some controversy, the national government transportation agencies in the United Kingdom and Australia have each concluded that the benefits of household-based individualized marketing programs are sound and cost-effective. Employer-based and school-based individualized marketing has been less studied and so far shows less promise than the household-based approach. Assessments of U.S. programs with expanded information and activity menus have not allowed robust conclusions on effectiveness of the add-ons. Nevertheless, an augmented large-scale program in Bellingham, Washington, is notable for obtaining absolute shifts of +4 percentage points for walking, +3 percentage points for cycling, and –6 percentage points for driving alone, paired with a slight transit mode share increase and a –1 percentage point auto passenger decrease.

External evidence in the form of pedestrian and bicycle count and transit ridership data lend support to the significance of household-based individualized marketing outcomes. The 2005 project in Portland estimated a 7 percent relative gain in walk mode share based on survey analysis and also saw a 7 percent gain in target area walk counts. Counts obtained for Portland's 2007 and 2008 programs showed target area bicycle volume net increases of 8 to 14 percent after adjustment for substantial citywide bicycling increases. Target area transit ridership data in Seattle, Washington, and Cambridge, Australia, show 11 and 16 percent 9-month and first-year increases, respectively, in parallel with individualized marketing.

Seeking to increase physical activity is a major thrust of contemporary public health policy, and public-health-based interventions to promote active transportation have been tried. Although vaguely similar in concept to transportation-oriented individualized marketing, applications to date have been research-oriented and of much smaller scale. Self-reported walking increases of 1/2 to 1 hour per week were documented in a typical example, but long-term impacts beyond a few weeks or months are in doubt except for one intensive-support example. Additional summarization is provided in the previously cross-referenced "Adult and Child Public Health Relationships Summary" that concludes the "Public Health Issues and Relationships" subsection within the "Related Information and Impacts" section.

RESPONSE BY TYPE OF NMT STRATEGY

This section focuses on the response of urban travelers making utilitarian trips, along with candidates for recreation and exercise, to a wide variety of pedestrian and bicycle improvements and strategies. The facilities and improvements addressed include sidewalks; at-grade and grade-separated crossings; pedestrian zones, malls, and skywalks; bicycle lanes and routes; shared use paths and trails; and system interconnections. Also covered are linkages to transit; point-of-destination provisions; pedestrian- and bicycle-friendly neighborhood design; policies and programs; and promotions and information.

Some closely related user and usage characteristics data is provided. Most such information is located either within the "Underlying Traveler Response Factors" section, to the extent that it helps illuminate walking and cycling choice mechanisms, or within the "Related Information and Impacts" section. The latter section includes global data on Non-Motorized-Transportation (NMT) use overall and representative facility-specific pedestrian and bicycle volume information. Reference should also be made to the "Related Information and Impacts" section for additional information and interpretations from public health and other diverse perspectives.

Sidewalks and Along-Street Walking

Changes in volumes of walkers or walk activity levels in direct response to specific sidewalk improvements are documented here to the extent they are available. This information is bolstered with research on the effects, on overall walking levels, of sidewalk availability and street traffic intensity. Findings on prevalence of walking in pedestrian-friendly versus less attractive walking environments are examined both in this subsection—which focuses on sidewalk availability, traffic, and street characteristics issues—and later in the "Pedestrian/Bicycle Friendly Neighborhoods" subsection, where a broader view is taken.

Pedestrian Volumes Overview

It is useful, before examining traveler response data for sidewalks, to understand the nature and scale of NMT volumes encountered. Walking, the primary candidate for sidewalk use, can of course occur with or without paved sidewalks or paths. People also walk on roads, shoulders, and unpaved areas. A majority of walkers do, however, use paved sidewalks or paths. A survey of Florida residents found that 67 percent of walking trips were on sidewalks or dedicated footpaths (NuStats International, 1998). A national survey found that 45 percent of respondents used mostly sidewalks while about 6 percent used mostly bicycle/walking paths or trails in their foot travels. Another 33 percent walked primarily on paved streets, roads, and shoulders (NHTSA and BTS, 2002). More background information on where people walk and in what numbers is provided in the "Related Information and Impacts" section under "Facility Usage and User Characteristics," starting with the "Frequency of Facility Usage by Facility Type" discussion.

One of the tabulations presented in the "Facility Usage and User Characteristics" subsection (see Table 16-98) presents volumes from illustrative intersection counts in San Francisco Bay Area counties. Total 2-hour AM plus 2-hour PM intersection pedestrian volumes covering all crosswalks, on both streets, range from 4,925 (roughly 12,000/day) at a "South o'Market" San Francisco central business district (CBD) intersection, to 900 (some 2,200/day) at a Santa Clara County (Silicon Valley) intersection with low-rise apartments near ethnic gathering spots, to 135 (300–350/day) at an exurban Napa County intersection with a town hall and dwellings, and on down to nine pedestrians (20 to 25/day) at partially developed office/commercial intersections in suburban Santa Clara County and Napa County locations (see Table 16-98 for sources). A rough conversion of these representative intersection pedestrian volumes to average individual sidewalk volumes, for purposes of understanding typical magnitudes, may be accomplished—where sidewalks on both sides exist—by dividing by four.

Observed pedestrian volumes run even higher than the one San Francisco CBD example, but volumes in the lower ranges are much more prevalent. Toward the fringes of any sidewalk system, pedestrian volumes are usually diminishingly small. Neighborhood sidewalks are in one sense like local roads, providing a land service function. Thus, most urban and a number of suburban jurisdictions require sidewalks as part of any new street construction. Portland, Oregon, requires sidewalks on any new street, excepting only cul-de-sacs with less than 5 dwellings and streets with severe natural constraints (Federal Highway Administration, 2004). Seattle requirements call for sidewalks in connection with platting of *any* new street. In addition, the city requires that sidewalks be provided in connection with platting or developing six to 10 or more units, depending on zoning, or any units at all in the case of designated areas or streets (City of Seattle, 2008).

Individual Sidewalk Provision Examples

Availability of pedestrian counts before and after sidewalk improvements has improved, but remains limited. Virtually all examples are descriptive analyses with no statistical tests, no control-area counts, and too-frequent reliance on informal reporting. Table 16-1 summarizes examples encountered with apparently solid before and after observations, along with some less formal accountings. The final entry is from Safe Routes to School studies.

Table 16-1 Summary of Before and After Studies of Individual Sidewalk Provision or Improvement Examples in Various Locations

Study (Date)	Process (Limitations)	Key Findings
1. Aboelata et al. (2004)	A badly degraded 1.5-mile sidewalk encircling Evergreen Cemetery in the Latino community of Boyle Heights in Los Angeles was converted into a rubberized jogging path. (Analysis approach not reported.)	Daily use rose from roughly 200 to over 1,000 people using the path for jogging, walking, and socializing. The increase probably includes some diversion from other facilities — doctors are said to advise use of the soft path surface.
2. Investigation by the Handbook Authors, 2002-06 (see Montgomery Co. case study — "Results- Sidewalk Improvements")	A rural-section 2-lane state highway in suburban Garrett Park, MD, with a badly degraded sidewalk on 1 side for 4 blocks and none for 1 block, was rebuilt with curbs, street trees, and sidewalks on both sides for 4 blocks and 1 side for the 5th block. (3-hour winter counts, 1 day each.)	The AM peak period child pedestrian count 1 block from a school crossing decreased from 11 to 6, perhaps because of safety patrol termination. The adult and teenager count increased from 5 to 21 persons (up 320%). Thus the total 3-hour pedestrian count increased from 16 to 27 (up 69%).
3. Harkey and Zegeer (2004)	One mile of partly commercial arterial in University Place, WA, was rebuilt from 5 lanes, gravel shoulders and no sidewalks to 4 traffic lanes with bike lanes, wide sidewalks, a median, and 2 mid-block crosswalks. (No sidewalk counts.)	Few pedestrians walked or crossed the arterial without sidewalks or cross-walks. Usage after improvement is suggested by the 3,200 monthly pedestrians on the midblock crosswalks. Crashes decreased 60% (no change in ped. crashes despite walking increase).
4. Painter – 1996 as summarized by Cao, Mokhtarian, and Handy (2007) and Heath et al. (2006)	Before and 6-weeks-after study of pedestrian volume changes seen with street lighting improvements along three poorly lit streets and a footpath in London, with descriptive analysis. ("Fair execution.")	Volume increases (presumably after dark): Site 1 (footpath), males +50%, females +64%; Site 2, males +44%, females +45%; Site 3, males +34%, females +48%; Site 4, males +101%, females +71%; overall increase of 51%.
5. Boarnet et al. (2005a and b) (for more see "NMT Policies and Programs" — "Schoolchild-Focused Programs" in this "Reponse by Type of NMT Strategy" section)	Of 10 CA schools surveyed to ascertain 2002-03 SRTS impacts, 5 had received sidewalk improvements. Parents were asked retrospective questions about changes in walking and cycling to school. Counts were made 2 days running of child pedestrians at project sites, before and after improvement. (Survey obtained parent perceptions, not expressed in numbers. Count dates relative to school year not reported.)	Walk/bike increases were more likely to be reported for children passing via sidewalk improvements (17%) than for study control subjects (3%). The increases were higher than for traffic controls (16% vs. 4%) or other crossing improvements (12% vs. 6%). Before-and-after-improvement counts showed a weighted average 5-site 46% increase in child pedestrians, with a ±82% reduction in the proportion walking in the roadway or on the shoulder.

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column.

Four out of the five cases in Table 16-1 (all except the 3rd entry) offer quantified observations of pedestrian usage shifts. All cases show increased pedestrian activity accompanying the sidewalk improvements. Using overall averages (of all pedestrians studied, or all examples, within each individual study) pedestrian count increases ranged from 46 percent to 400 percent. The four quantified cases have a median pedestrian volume increase, among case study averages, of roughly 60 percent. The 400 percent increase in the 1st Table 16-1 entry cannot be disregarded as an anomaly, given that the adult and teenager increase in the 2nd entry was 320 percent. The 5th and final entry in Table 16-1, one of the four cases with quantified observations, pertains to situations where there was no sidewalk at all in the "before" condition. The increase observed is slightly below the median sidewalk improvement increase, but probably not significantly so, especially considering that the counted population (children only) differed from other cases (see Table 16-1, column one, for citations and cross-referencing).

Despite analysis limitations, it is fairly obvious that improved and new sidewalks do attract and serve more pedestrians. What is not known from the before-and-after counts alone is whether the added pedestrian volumes represent additional walking in the form of new walk trips, more frequent walk trips, or lengthened walk trips, or whether and to what extent the added volumes come from walk trips diverted from other routes or destinations. Diverted walk trips are not associated with either shifts in travel mode or additional walking. Nevertheless, even diverted trips represent some benefit gained by the users, whether added safety, a more pleasant walk, or greater convenience. Where there are increased pedestrian volumes it is likely that some degree of additional walking has been induced.

The final entry of Table 16-1 includes research evidence that the 46 percent average increase in child pedestrians observed in response to sidewalk improvements at five California 2002–2003 Safe Routes to School program sites did indeed reflect additional walking (Boarnet et al., 2005a and b). Additional evidence of additional walking is provided by the cross-sectional and comparative analyses summarized in Table 16-2 below, as part of the "Sidewalk Coverage and Traffic Conditions" discussion.

Sidewalk Indirectness Effects

A discussion is provided in the "Underlying Traveler Response Factors" section, under "Trip Factors"—"Walk Trip Distance, Time, and Route Characteristics," on the relative importance of travel time in pedestrian and bicycle utilitarian travel choices. The consensus is that time (or distance) is particularly important for the potential or actual pedestrian, with distance minimization as the dominant factor in route choice for utilitarian pedestrian trips (Weinstein et al., 2007). This sensitivity to time/distance manifests itself both within segments of trips and with respect to the overall trip from origin to destination. Pedestrians notice sidewalk indirectness and seek to avoid it if they can. This phenomenon is addressed in design literature, but generally without quantitative support.

Five quantified examples of pedestrian response to trip segment indirectness are presented in the "Special Mini-Studies in Montgomery County, Maryland" case study, under "More—Sidewalk Indirectness." In the one example where count data were obtained, 80 percent of pedestrians were found to walk in the street behind parked cars in preference to incurring a 27 percent deviation involved in walking around via the sidewalk. Four supplementary examples look at what sidewalk deviations are avoided (or were avoided before the pedestrian traces were paved) by cutting across grass or parking. The deviations, measured as percentage of existing (or original) sidewalk distance, range from 17 down to 12 percent for the segment involved in the deviation. The median deviation encountered, unacceptable to many or most pedestrians, was 15 percent. It is of interest to note that in the instance of the 17 percent deviation, caused by a zigzag sidewalk, a substantial

Table 16-2 Summary of Research Findings on the Relationships of Sidewalk Prevalence and Street Traffic Characteristics with Walking Activity

Study (Date)	Process (Limitations)	Key Findings
1. Cao, Handy, and Mokhtarian (2006) (see this section for more information)	Models were utilized to reexamine a 6-neighborhood Austin, TX, data set to explore built environment and residential self-selection effects on walking for its own sake (strolling) and utilitarian walking to the store. The 2 neighborhoods with the worst commercial pedestrian access had the only 100% complete residential sidewalk systems. (Some evidence of survey bias; perceived measures of environment dominated analysis.)	The proportion of strollers was modestly higher in older traditional neighborhoods, and no significant difference was found in mean strolling rates. Frequencies of walking to stores, even after accounting for self-selection, were positively related to pedestrian connections to stores, store quality, and store closeness, and negatively related to residential and retail area traffic. Self-selection was on the basis of walk access to stores but affected all walking.
2. Schneider (2011) (see "Underlying ... Factors" — "Environmental Factors" — "Ambiance" for more information)	Interviewed San Francisco Bay Area pharmacy shoppers. Socioeconomic and trip data obtained for 959 tours were augmented/used in 3 mode choice models. (Sidewalk coverage of 91% may have given insufficient variability for variable calibration.)	Sidewalk coverage not statistically significant in the one-shopping-district to/from mode choice model, full-tour model, or the within-shopping-districts model, but in the latter, number of driveway/alley crossings per mile was a significant negative for walking.
3. Moudon et al. (2007) (see "Ped…cycle Friendly Neighborhoods" for more information)	Cross-sectional analysis of walking activity, socio-demographics, attitudes, and objectively measured environmental variables covering 608 adults in King County, WA. (Only major-road sidewalks were documented/taken into account.)	Major road sidewalk length was found significantly related to walking in one of two modeling approaches (about 9% more walking per sidewalk-mile within 0.62 miles). Neighborhood measures such as store proximity were generally more important.
4. Lee and Moudon (2006a) (see "Ped…cycle Friendly Neighborhoods" for more information)	Similar analysis to above study, also making use of public health and physical activity survey data and GIS-based physical features augmentation, but covering city of Seattle respondents only (438) and all city sidewalks. (Self-reported minutes and frequency of walking.)	Sidewalk extent positively but not significantly related to minutes of walking (odds ratios from 1.05 to 1.12), with no consistent relationship to utilitarian walking frequency, but statistically significant relationship to frequent recreational walking (odds ratio 1.12). Some proximity measures more important.[a]
5. Giles-Corti and Donovan – 2002 [Prev. Med.] as summarized per SR 282	Cross-sectional survey and analysis of Australian adults using measures of activity accessibility, neighborhood perceptions, and transportation features. Examined utilitarian walking (UW), recreational walking (RW), and walking as recommended for health (WH). (Used self-reported walking and perceived sidewalk availability measures.)	UW 65% higher, RW 41% higher, and WH 65% higher with perceived presence of sidewalks. UW 3 times more with perceived access to shops, less with beach access, and more in presence of lots of traffic. RW more with beach access and favorable perception of neighborhood. WH more with high access to public open space and favorably perceived neighborhood.
6. Reed et al. – 2006 as summarized in Saelens and Handy (2008)	Analysis of Sumter County, SC, survey of amount walked per week and perceived presence of sidewalks in neighborhood. (Relationships not significant in race-stratified models.)	Persons walking 1 to 149 minutes/week were found more likely to report presence of sidewalks than persons not walking at all. No relationship found for walking more than 150 min./week.

Table 16-2 (Continued)

Study (Date)	Process (Limitations)	Key Findings
7. Kitamura, Mokhtarian, and Laidet (1994) and SR 282	Cross-sectional analysis of travel behavior, built environment characteristics, and attitudes surveyed in 5 diverse San Francisco Bay Area neighborhoods using incrementally expanded regression models. (Aggregate facility measures.)	Number or share of NMT trips positively related to North S.F. location, rapid transit and bus access, sidewalks in neighborhood, high density, and closeness of nearest park (thought to have actually served as a disaggregate land use mix indicator).
8. Van Lenthe, Brug, and Mackenbush – 2005, as summarized in Saelens and Handy (2008)	Related walking by adults in 78 Netherlands neighborhoods to various environmental conditions perceived by professional observers.	Higher likelihood of walking was associated, for adults under 50 years of age, with less traffic noise, and for older adults, with greater proximity to food shops.
9. Krizek et al. (2007) (see "Related Info and Impacts" — "Public Health Issues…" for a study description)	NMT Pilot Program Evaluation Study asked about neighborhood sidewalks and determined walk mode shares. (Any relationship between the two is circumstantial evidence: the study authors themselves did not infer causality.)	Some 97% of Minneapolis respondents agreed there were sidewalks on most streets in their neighborhood, versus 59% to 63% in the 4 other communities surveyed. The 2006 Minneapolis walk mode share was 17.6% compared to 6.6%-11.8% for the other 4 areas.
10. U.S. EPA – 2003 as summarized per SR 282	Utilized 2 surveys of the Gainesville area of Florida to examine various density and pedestrian environment variables along with NMT travel times to school.	Choice of walking to school positively influenced by sidewalk availability and shortness of time to school from home. Choice of cycling significantly influenced only by bicycle travel time.
11. Ewing et al. – 2004 as summarized by Davison and Lawson (2006)	Utilized objectively measured cross-sectional data to model the effect on walk/bike school access of sidewalk characteristics, bike lanes or paved shoulders, accessibility, and density.	Student walk-to-school shares showed a significant positive relationship with main road sidewalk availability and a negative relationship with estimated walk/bike travel time to school.
12. Fulton et al. – 2005 as summarized in Saelens and Handy (2008)	Utilized survey of U.S. parents to relate area type, perceived sidewalk availability, and perceived play safety to usual mode of travel to school. (Used perceived and self-reported measures.)	Active transportation to school was more likely in non-rural areas, in areas perceived to have sidewalks, and when the child felt safe playing in the neighborhood. The safety variable was not significant in the full model.
13. Timperio et al. – 2004 as summarized by Davison and Lawson (2006)	Conducted cross-sectional analysis of various area conditions. (Used parental perceptions of conditions and parental reporting of walking and cycling.)	Lesser walking/cycling was, among Australian 5-6 year olds, associated with parental perceptions of heavy traffic and poor public transportation.
14. Carver et al. – 2005 as summarized by Davison and Lawson (2006)	Cross-sectional analysis of parent and child perceptions of various facilities and environmental conditions. (Used self-reported physical activity measures as well as perceived environment measures)	Australian adolescents (male, female, or both) were found to walk/bike more where traffic was less problematic, roads were perceived to be safe, and there were fewer unattended dogs and more good places to be active.

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

[a] See text Footnote 21 in the "Shared Use, Off-Road Paths and Trails" subsection for a brief explanation of odds ratios.

Sources: As indicated in the first column. The notation "SR 282" is shorthand for Committee on Physical Activity, Health, Transportation, and Land Use (2005) together with Handy (2004).

proportion of short-cutting pedestrians and cyclists appear to be satisfied with a 6 percent deviation relative to a possible but grassier straight-line routing.

Trip origin to destination indirectness was examined as one of many explanatory variables in a set of walking activity research models developed for the Seattle area (King County). Route directness from home to the nearest grocery store and from home to the closest school both proved to be significant variables in two out of three final models, with directness being associated with more walking overall per week (Moudon et al., 2007). More background on this analysis is given in Table 16-2 and in the "Pedestrian/Bicycle Friendly Neighborhoods" subsection under "Diversity."

Sidewalk Coverage and Traffic Conditions

Assessing importance of broad-area sidewalk system coverage and improvements is generally done by means of empirical investigation of static situations, including paired-community descriptive comparisons of walking conditions and activity, and through survey-based cross-sectional modeling.[9] Such research often covers other environmental factors that potentially affect walking, thus sometimes addressing effects of traffic conditions. Traffic conditions are typically expressed in a general way, but some of the studies support inferences about traffic effects on streets where there are no sidewalks and pedestrians must share the street space with motorized vehicles. Table 16-2 summarizes a wide selection of broad-area studies, starting with eight cross-sectional analyses relating adult walking activity to built environment factors, followed by one descriptive analysis, and closing with five studies relating child and adolescent walking to the physical environment.

The 1st Table 16-2 entry pertains to Austin, Texas. The research done on walking in Austin neighborhoods stands out for its examination of "strolling" (walking for its own sake) separate from utilitarian walking (to meet a travel need). It is also notable for analytical refinements accomplished in waves of research extending over more than a decade. Most of the Austin analyses draw from a 4-page 1995 mail-out/mail-back survey that achieved a 23 percent response rate. This provided 1,368 completed questionnaires covering walking behavior, neighborhood perceptions, and attitudes. The built environment was also quantified through site visits, geographic information systems (GIS), and network analysis.

Six neighborhoods were studied. Two are traditional, laid out on more-or-less of a grid just beyond the downtown, with stores focused on sidewalks. Another two are early modern, immediately post-World-War-II, located somewhat farther out and more reliant on auto-oriented strip commercial for shopping. The last two are late modern 20th Century, 10 to 15 miles from downtown, with retail layouts requiring walking though parking lots for access. The late modern neighborhoods, however, have the only complete residential sidewalk systems. Residential sidewalk systems are only partial in the four older neighborhoods. One each of the traditional and late modern neighborhoods have a large park with extensive walking trails. Residential street widths are 26 feet in the traditional neighborhoods, 26 to 30 feet in the early modern developments, and 36 to 40 feet in the late modern locales. Despite efforts to match populations in the research, some differences were found. Residents of the early modern neighborhoods reported, for example, being somewhat older (Cao, Handy, and Mokhtarian, 2006, Handy, Clifton, and Fisher, 1998). The 1st entry in Table 16-2 pertains to a reexamination of the Austin data. Table 16-3 summarizes the measured walking activity.

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[9] An attempt at city-wide before-and-after analysis of pedestrian system improvements has been underway as part of the five-city Nonmotorized Transportation Pilot Program Evaluation Study, with findings publication scheduled for after a 2010 follow-up survey (Krizek et al., 2007).

Table 16-3 Walking Trips for Strolling and Shopping in Six Austin Neighborhoods

Neighborhood Type (One Pair Each):	Traditional	Early Modern	Late Modern
Strolling Trips			
Percent strolling at least once in 30 days	83%	77%	78%
Average trips/30 days for those who strolled	12.7	12.1	11.2
Average trips/30 days for all respondents	10.5	9.2	8.4
Walk Trips to Store			
Percent walking at least once in 30 days	62%	43.5%	21.5%
Average trips/30 days for those who walked	6.3	4.3	3.9
Average trips/30 days for all respondents	4.2	1.9	0.8

Source: Cao, Handy, and Mokhtarian (2006), with elaboration by the Handbook authors.

Almost every walk activity parameter presented in Table 16-3 progresses steadily downward from traditional to late modern neighborhood types. However, statistical significance (taking into account all six neighborhoods individually) is exhibited only by the walk trips to store statistics, which decline dramatically, and by the percentages who strolled. As can be seen, walking for its own sake varied least among neighborhood types. Reasons for engaging in strolling were varied, but exercise/health, pleasure, and dog-walking predominated (Cao, Handy, and Mokhtarian, 2006, Handy, Clifton, and Fisher, 1998).

Findings of the six-neighborhood Austin studies indicated that persons highly rating "stores within walking distance" as important in their choice of residence location (so-called "self-selection") were walking for its own sake more frequently. Ambient environment impacts on walking were all statistically modeled taking into account both self-selection and demographics. In decreasing order of importance, perceptions of traffic and personal safety combined with light traffic volumes, shade from trees, and opportunity to see people were all significantly and positively related to strolling. Utilitarian walking to stores was significantly related to residence closeness to the nearest store, perceived quality of commercial area pedestrian facility connections, perceived advantage of walking (including parking hassle avoidance), usefulness and quality of stores, commercial area walking comfort, and amenable residential area traffic conditions, with a negative relationship to measured commercial street traffic volumes (Cao, Handy, and Mokhtarian, 2006).

Although the available quantitative data did not support separate examination of traffic and safety effects for streets with versus without sidewalks, focus group results from 1995 suggest that low traffic volumes and speeds are required for lack of sidewalks to be not perceived as a hindrance to walking. Conversely, heavy traffic was viewed as being detrimental even with sidewalks available (Handy, Clifton, and Fisher, 1998). Attitudinal intercept surveys in four neighborhoods found continuous sidewalks or trails and tree shade to be important to persons exercising or strolling but not to persons walking for utilitarian purposes (Shriver, 1997). The conflict between this finding and the frequency data for strollers in Table 16-3, which shows the pairs of neighborhoods with incomplete residential sidewalk systems (traditional and early modern) to have somewhat higher strolling frequencies (Cao, Handy, and Mokhtarian, 2006) suggests that other factors are at work as well. Though not a stated conclusion of the various Austin researchers, one possible interpretation of the results is that narrow and pleasant low-volume streets, when associated with lower traffic speeds, can tend to compensate—at least for able-bodied adults—for partial lack of residential area sidewalks. Behavior of child pedestrians and perceptions of their guardians were not studied.

A San Francisco Bay Area study of trip tours involving a pharmacy shopping stop among the tour's activity stops (2nd entry in Table 16-2) provides a finding similar to that of the Austin studies in that sidewalk coverage did not achieve statistical significance or contribute to any of the three mixed-logit mode choice models developed. Unlike the Austin research, however, tree canopy coverage was found significant and positive for shopping trip walk mode choice (Schneider, 2011). What is not clear, however, is whether the sidewalk insignificance outcome reflects nothing more than too little variability in sidewalk coverage (a very high 91.3 percent mean coverage within the sample) for sidewalk variable calibration or whether sidewalk presence truly was unimportant in the choice to walk or not walk when shopping.

A highly significant variable in the model for trips made internal to shopping districts was, however, the number of major driveways and alleys per mile that had to be crossed to walk along the main commercial roadway. Major driveways were defined as active commercial driveways or residential driveways serving more than 10 dwelling units. Survey respondents who would encounter more such crossings to walk between stores were less likely to do so and more likely to drive. The calibrated model parameters suggested that having 10 fewer major driveway and alley crossings per mile was worth walking an extra minute, and it also appeared that beyond 30 crossings per mile walk mode share dropped sharply (Schneider, 2011). These results are consonant with the Austin determination that perceived quality of commercial area pedestrian facility connections is important in the choice of walking for shopping trips. Driveway/alley crossings per mile may be in part a surrogate for auto orientation including presence of front-of-store parking facilities, but the policy implications are basically the same in any case.

The other six adult-focused cross-sectional walking studies in Table 16-2, the 3rd through 8th table entries, generally found presence of neighborhood sidewalks or major road sidewalks to be positively related to walking activity, although typically not the strongest indicator. Three of the study summaries identified some form of store proximity to be important, as in Austin. Two found positive significance in some friendly neighborhood measure and two found presence of open space to be a positive. The Netherlands study joined Austin in finding traffic impacts to be a negative, while the Australian study was unique in finding a positive relationship between walking and traffic, perhaps as a reflection of density or high activity.

The previously introduced King County research (the 3rd table entry) tested several objective traffic and road-size measures without finding any significant relationships, although attitudes and perceptions did contribute to explanation of walking activity. Major road sidewalk length was significant in one of two modeling approaches (Moudon et al., 2007). The closely related Seattle-only research (the 4th table entry) was, unlike the county-level analysis, able to use as a model variable total length of all sidewalks within a 1 km. buffer. It found that sidewalk extent was neither a consistent nor a significant variable for explaining choice to walk for transportation (utilitarian trips), but was significant as an explanatory variable for frequent recreational walking. Similarly, perceived architectural variety was associated with frequent recreational walking but not utilitarian walking. Traffic volume was not significant for either type of walking trip, and neither was presence of parks or trails (Lee and Moudon, 2006a). The county-level research found that trails attracted walk trips but did not appear to induce more (Moudon et al., 2007).

The one descriptive analysis included in Table 16-2, the 9th entry, supports the importance of sidewalk system completeness. The first-phase NMT Pilot Program statistics offer only circumstantial evidence, but the five-city comparison is striking, with double the walk mode share in the one city (Minneapolis) where all but a few residents agree that most streets have sidewalks. Also particularly telling are the Seattle neighborhood comparisons, covered below in the business districts discussion and tabulated in Table 16-4, which find three times the walking to and from the neigh-

Table 16-4 Summary of Descriptive Studies of Sidewalk Extent/ Enhancements and Traffic Calming Affecting Business Districts

Study (Date)	Process (Limitations)	Key Findings
1. Hess et al. (1998), Moudon et al. (1997), and SR 282 (see case study "Pedestrian Activity... Seattle")	Descriptive, comparative analysis of 12 Seattle area shopping districts and their surrounding neighborhoods, 6 urban and 6 suburban, controlled for density and mix, using 16-hour shopping area pedestrian cordon counts. (No statistical testing.)	The urban examples, with small blocks and averaging 38 miles of sidewalks, averaged 38 pedestrians/hour cross-cordon flows per 1,000 residents. Suburban examples, with large blocks and averaging 8 miles of discontinuous, incomplete sidewalks, had 12 pedestrians/hour/1,000 residents.
2. Harkey and Zegeer (2004)	Main Street in the mountain town of Hendersonville, NC, was 4 lanes plus parking on a 100-foot right-of-way. In late 1970s a 2-lane traffic-calmed design was installed with mid-block lateral shifts defined by bulb outs with crosswalks, framing 1/2-block angle plus parallel parking sections. (No before counts.)	Recalled as being virtually lifeless in the mid-1970s, with 17 closed stores, the pedestrian volume 25 years later on Main Street averaged 1,750/day. Designated a National Trust "Main Street City," 100 retail businesses were in place downtown with a waiting list for occupancy, despite after-condition regional shopping mall competition.
3. PBIC and APBP (2009)	As part of a post-1999 revitalization, East Main Street in downtown El Cajon, CA, was converted from 4 to 2 lanes, with angle parking and sidewalks widened for shared use activities. Pedestrian connections were bettered. (NMT impacts must be inferred from economic impacts.)	Starting with a downtown that was partially vacant in the 1980s, and aided by a denser mixed-use land use plan, circa 2008 property values have risen by 181% relative to 1996 (versus 75% citywide) and leasing rates have increased 56%. Shopping and dining customers are up 91% relative to 2002.

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column.

borhood commercial district in those cases where blocks are small and the sidewalk system is largely complete.

The last five studies summarized in Table 16-2, the 10th through 14th entries, are child-oriented active transportation studies. All three of the U.S. studies found walking to be positively related to sidewalk availability, while the two Australian studies found it to be negatively related to heavy or problematic traffic. Perceptions of safety were mentioned as a positive in one U.S. ("personal safety") and one Australian ("traffic safety") study summary. Good transit service was positively related to walking in one of the child-focused studies, as it was in one adult-focused study (see Table 16-2 for citations).

Sidewalk coverage is an NMT feature that has probably been studied as much for its health impacts as for its effects on travel demand. Active living research relating to sidewalk availability is covered within the "Public Health Issues and Relationships" subsection of the "Related Information and Impacts" section (see both "Health Benefits for Adults of Enhanced NMT Systems and Policies" and "Health Benefits for Children of Enhanced NMT Systems and Policies").

Residential and Mixed-Use Traffic Calming

Traffic calming in the United States has tended to focus narrowly on crash prevention, whereas in Europe this objective has been joined for some time by other objectives including enhancement of walking and bicycling (Ewing, 2008). Traffic safety benefits in residential neighborhoods are well established for vehicle crashes overall, although not specifically for pedestrians and bicyclists. A comprehensive study of Vancouver, BC, Canada, and international experience found 85 traffic calming projects throughout the developed world to have reduced crashes by 8 to 100 percent (8 to 95 percent where at least five crashes were recorded in the before period). In four Vancouver case study neighborhoods, the crash reduction was 18 to 60 percent, the average was 40 percent, and the annual claims cost reduction was 38 percent. Effects on pedestrian and bicycle crashes were reported only for the Vancouver neighborhoods, and it appears that the projects where such crashes decreased were counterbalanced by projects where they increased (Zein et. al., 1997). Compilations of effectiveness for various physical traffic calming measures, such as street narrowing and small traffic circles, indicate average speed reductions ranging from none (diagonal diverters) to 23 percent (speed humps), and volume reductions from 20 percent (choker) to 44 percent (full street closure) (Traffic Calming.org, 2011).

Among studies covered in the previous “Sidewalk Coverage and Traffic Conditions” discussion, roughly 1/4 identified some favorable effect on degree of walking of lesser, slower, and/or less problematic street traffic. This is suggestive that traffic calming is likely to have some positive impact on extent of walking. Also suggestive is the experience with bicycle boulevards (essentially traffic-calmed streets with bicycle preference) that shows these streets to be attractive for bicyclists (see both “Popularity, Preferences, and Route Choice” and “Bicycle Lane Variations, Bicycle Boulevards, and Other Signed Bicycle Routes” in the “Bicycle Lanes and Routes” subsection). In addition, one would expect the public perception that traffic calmed streets are safer would support walking and bicycling activity.

Two studies of pedestrian and bicycle street traffic volumes, before and after traffic calming, both support a supposition of favorable impact on walking and bicycling.[10] Analysis of street use before and after the 1990 traffic calming of Milvia Street in Berkeley, California, found afternoon peak hour vehicular traffic decreases from about 520 to 420 autos, approximately a 20 percent decrease. Pedestrian traffic increased from about 55 to 95 and bicycle traffic increased from 65 to 110, increases of roughly 70 percent. In Vinderup, Denmark, 7-1/2 hour daylight counts showed pedestrians increasing from about 850 to 1,150 and bicyclists increasing from 1,050 to 1,950 in response to a circa 1984 traffic calming project. The combined increase was thus over 60 percent, with a greater effect on bicycling (Ewing, 2008).

Sidewalks and Traffic Calming for Business Districts

The Austin neighborhoods research described above and entered in Table 16-2 highlights the importance of commercial area sidewalks, and good sidewalk connections to stores, in attracting more persons to the walk mode for shopping trips (Cao, Handy, and Mokhtarian, 2006). The San Francisco shopping-tour research, also entered in Table 16-2 and described above, found minimum driveway/alley crossings of commercial district sidewalks to be strongly associated with more

[10] These were the only pedestrian and bicycle impact studies encountered for traffic calming projects. The numerical values reported are approximate, having been scaled by the Handbook authors from charts in the source.

walking between stores (Schneider, 2011). This importance of customer-friendly commercial-area sidewalks is underscored by the already-mentioned comparative analysis in Seattle, which focused on volumes and characteristics of pedestrians walking between residences and the local commercial centers of 12 neighborhoods (Moudon et al., 1997). The 1st Table 16-4 entry pertains to this analysis, with further detailing in the case study "Pedestrian Activity Effects of Neighborhood Site Design—Seattle."

The Seattle area study sites were described in terms of a 1/2-mile pedestrian travel catchment area around each of the 12 neighborhoods' commercial centers. The six sites classified as "urban" had in their catchment areas almost 5 times as many miles of sidewalks as the six sites classified as "suburban." Their commercial parking was on-street or in small lots as contrasted to large expanses of parking. At these "urban" sites about 3 times as many pedestrians per 1,000 residents—38 per hour over a 16-hour period—were found to be walking between residences and the commercial centers. Evaluation of pedestrian makeup relative to neighborhood resident characteristics suggested that those who *did* walk in the sites classified as "suburban" were—including persons under 18 years of age—probably disproportionately among the transportation disadvantaged. It was thus more often those persons with limited mobility options who were left to navigate inadequate pedestrian infrastructure (Hess et al., 1998, Moudon et al., 1997).

The two other studies entered in Table 16-4 offer no or limited pedestrian flow information, but present an anecdotal picture bolstered by economic resurgence information of substantial sidewalk-oriented business activity increases. Both of these smaller cities, one in rural North Carolina and one in the San Diego metropolitan area, put their Main Street on a "road diet" while at the same time engaging in economic redevelopment activities. Traffic calming and sidewalk connectivity enhancements were part of overall programs that successfully engendered increased overall activity and business retail viability in old downtowns (Harkey and Zegeer, 2004, PBIC and APBP, 2009).

In the central business districts (CBDs) of large metropolitan regions, sidewalk systems are usually almost complete. Sidewalk improvements are typically along the line of "tweaking" the system, such as through selective sidewalk widenings, removal of sidewalk obstructions, introduction of ADA provisions, or enhancement of street furniture amenities. There are also "beyond-sidewalk" improvements for CBDs, such as pedestrian malls and skywalks. These types of actions and their effects on walking are covered in the "Pedestrian Zones, Malls, and Skywalks" subsection to follow, and a major example is provided by the case study, "50 Years of Downtown NMT Facility Provisions—Minneapolis."

Sidewalk Use by Bicyclists

Sidewalks are built primarily for pedestrian use, although some sidewalk facilities have been designed specifically to accommodate bikeways. There are issues of safety with sidewalk use for cycling, more for the cyclists themselves than for the pedestrians. Cyclist use of sidewalks is not insignificant. One U.S. national survey reported that about 14 percent of respondents who had cycled in the previous 30 days used mostly sidewalks for their trip (NHTSA and BTS, 2002). A separate U.S. national survey, taking all trip purposes into account, arrived at a figure of about 11 percent for bicyclists traveling mostly on sidewalks (Bureau of Transportation Statistics, 2002).

The significant usage level of sidewalks for cycling could be attributable to lack of acceptable alternatives or misperceptions of risk. Indeed, many non-cyclists and beginning cyclists think riding on sidewalks is safer than riding on the street (Zehnpfenning et al., 1993). This perception may actually be "close enough" for children: Sidewalk safety problems appear to apply primarily to adult cyclists, likely because they bicycle faster and thus surprise motorists at points of conflict (Wachtel and Lewiston, 1994, Turner et al., 2006). Even for adult cyclists, agreement on sidewalk-riding safety is not universal (Lusk et al., 2011). A brief examination of these safety issues is provided in the "Related Information and Impacts" section (see "Safety Information and Comparisons"—"Facility Type Safety Comparisons"—"Cycling Crashes on Sidewalks versus Other Facilities"). Obviously, sidewalk vehicle-conflict safety concerns do not apply to long stretches of sidewalks or side paths free of driveways, alley crossings, and intersections.

Reductions in bicycle use of sidewalks have been achieved by offering parallel on-street bicycle provisions. The only relevant study data encountered apply to instances where the parallel provisions have been bicycle lanes. The findings presented here are extracted from studies more fully covered in the "Bicycle Lanes and Routes" subsection under "Bicycle Lane Implementation" (see Table 16-11) and in the case study, "Anderson Road Bicycle Lanes—Davis, California."

Fell Street, in San Francisco, must have been a challenging environment for bicyclists before implementation of bicycle lanes. PM peak period 2-hour counts found 37 out of 71 cyclists (52 percent) to be using the sidewalks in the "before" condition. After bike lane installation, sidewalk use by cyclists dropped to 7 out of 94 cyclists (7 percent). Results were less striking in Fort Lauderdale, Florida, where narrow 3-foot bicycle lanes were installed along a beachfront state highway. Saturday afternoon counts totaling 1 hour found 29 out of 68 cyclists (43 percent) to be using the sidewalks in the "before" condition, along with 344 pedestrians. With bike lanes, off-season sidewalk use by cyclists was still 23 out of 51 cyclists (45 percent), along with 206 pedestrians (Chaney, 2005). As tentatively hypothesized in the "Bicycle Lanes and Routes" subsection, bicycle lanes may be less effective where there are large proportions of less skilled cyclists. This may be particularly so when the bike lanes are narrow.

Bicycle lane provision along Anderson Road in Davis, California, was accompanied by before and after counts and surveys that identified age and sex. This process involved observer estimation in the case of the counts. Bicyclists on sidewalks were not quantified directly, either before or after, and the absolute numbers of children counted bicycling on Anderson Road actually declined slightly. In the "after" bike-lanes-implementation *count,* out of 1,577 cyclists on Anderson Road during 3 peak period hours, seven were estimated to be of age 11 and under, and 41 were judged to be between 12 and 17 years old. Anderson Road cyclists picked up in the "after" *survey* included five in the youngest age category and six in the age 12-through-17 category. Among these, two in the 11-and-under group (both female) and three in the 12-through-17 group (all male) were children and adolescents who had switched from sidewalk bicycling to on-road cycling. No cyclists of age 18 and up were identified in the survey as having previously used the sidewalks (Lott, Tardiff, and Lott, 1979).

None of these three case studies involving bicycle lane provision suggests any significant adverse effect relative to the objective of having fewer bicyclists using sidewalks. The Fell Street example achieved a major reduction in on-sidewalk bicycling that probably involved predominantly adult activity, likely high-risk, although age group identification was not provided in the source and is only a guess. The Anderson Road example appears to have had a positive effect on child bicyclist behavior, vis-à-vis sidewalk use, but incomplete information prevents a firmer conclusion.

Street Crossings

Pedestrian crossing improvements are intended to make the crossing of roadways easier and safer for pedestrians, and bicyclists as well. Street crossings figure prominently in most pedestrian trips. A survey of Florida residents found, based on 175 "most recent" pedestrian trips reported, that

76 percent of trips required crossing streets and 53 percent involved crossing at intersections (NuStats International, 1998). Unfortunately, about 30 percent of all pedestrian fatalities are related to improper crossing of a roadway or intersection (Institute of Transportation Studies, 2003). Traffic control devices such as pavement markings, signs, and signals may be used to facilitate and channel pedestrian crossings. Alternatively, normally at high fixed cost, a pedestrian and/or bicycle underpass or overpass may be constructed to provide absolute separation from vehicular traffic. Both at-grade and grade-separated crossings are covered here.

The bulk of the studies encountered on crossing improvements have focused on safety and design issues rather than on travel demand response, the core subject of this "Traveler Response" Handbook. From a travel behavior standpoint, the primary underlying traveler response factors addressed by these improvements are travel time and perceived safety. Crossing improvements may also help maintain the continuity of the pedestrian network by mitigating barriers to pedestrian movement. Long crossing delays, indirect pedestrian routings, high vehicle speeds, or frequent vehicle-pedestrian conflicts can all contribute to a barrier effect. High-quality crossings can contribute to a sense of connectedness and enhance the overall value of pedestrian facilities in an area. Measures of street crossing ease have been found to be related to transportation mode choice (Replogle and Parcells, 1992).

An on-street survey covering seven U.S. marked-crosswalk sites in three southern-tier states found "that as the control at a pedestrian crossing increases through the addition of signs, flashing lights, and/or signals the pedestrians' perception of safety also increases." On a scale of 5 (unsafe) to 1 (very safe), perceptions shifted from an average score of greater than 4 in cases of simple marked crosswalks to better scores in the range of 3 to 2 or less for cases of signalized crosswalks (Fitzpatrick, Ullman, and Trout, 2004).

Table 16-5 provides a summary compilation of usable pedestrian and bicyclist travel behavior impact studies. It includes both quantitative research and less formal reporting, but the findings are consistent to the extent that—in their totality—they largely demonstrate provision of safe and attractive crossings is an essential and full-partner element of providing an overall NMT system that will attract and induce additional walking and bicycling. The table starts with studies involving crosswalks, associated traffic controls, and major street crossings in general, that address general-purpose (mostly adult) pedestrian and cyclist usage. These are followed by similar at-grade crossings studies focused on the school commute of children and adolescents. The last three entries of Table 16-5 involve grade-separated crossings. While traffic calming may properly be considered a tool for making street crossings less of a barrier to pedestrians and cyclists, that strategy is covered in the preceding "Sidewalks and Along-Street Walking" subsection under "Residential and Mixed-Use Traffic Calming" and also "Sidewalks and Traffic Calming for Business Districts."

Table 16-5 Summary of Before and After Studies and Research Findings on Relationships between Street Crossing Provisions and Walking/Biking Activity

Study (Date)	Process (Limitations)	Key Findings
1. Knoblauch, Nitzburg, and Seifert (2001) (see this section for more information)	A study was conducted at 11 intersections in 4 U.S. cities where painted crosswalks were installed or, in 1 case, upgraded. Before-and-after 8 AM - 7 PM observations covered the crossings and vicinity (All streets had the same 25 mph posted speed).	Percentage use of crosswalks increased <1% in Stillwater, MN (2 sites), 4% in Sacramento, CA (3 sites), 11% (significant) in Richmond, VA (3 sites), and 12% (significant) in Buffalo, NY (3 sites). No statistically significant change was observed in total observation-area crossings (up <1% overall).
2. Zegeer et al., (2005) (see this section for more, including safety information cross-reference)	Study of crashes, with exposure rate assessment, at 1,000 marked crosswalks and 1,000 matched unmarked mostly nearby crosswalks in 30 U.S. cities. (Cross-sectional analysis.)	Study could not examine changes in volumes, but compared to 66% total choosing marked crosswalks, 73% of children ≤12 and 73% of seniors age ≥65 chose marked crosswalks. (Volumes may exhibit legacy characteristics from before marking: See Footnote 11.)
3. PBIC and APBP (2009)	An intersection of 2 state roads in Edwards, CO, had a typical "rural" layout with free right turns separated from through traffic by "pork-chop" traffic islands containing the signal poles. It was rebuilt and upgraded in an "urban" configuration. (Limited NMT analysis.)	Removal of the right turn islands and substitution of sharper corner radii provided shorter total walking distance in the intersection, signal control of all movements, and ADA compliance. Pedestrian use of the intersection more than doubled and other traffic functions were improved as well.
4. Harkey and Zegeer (2004) (see "Pedestrian/ Bicycle Systems and Interconnections" for more)	As part of downtown Ft. Pierce, FL, revitalization, the pedestrian-unfriendly intersection at the gateway to the waterfront was rebuilt with a traffic circle, sidewalk extensions, and median refuge islands. (Analysis approach not reported.)	The intersection improvement was part of an overall program to slow traffic, widen sidewalks, and improve beach access. Intersection traffic remained at about 14,000 vehicles/day, but for pedestrians, increased from about 50 to approximately 1,000 pedestrians/day.
5. UK Department for Transport – 2004 as summarized in Booz Allen Hamilton (2006) (see this section for more information)	When one-way traffic flow was reversed in London's Shoreditch Triangle, the number of traffic-signal-controlled intersections was increased, with placement in accord with pedestrian desire lines, and sidewalks were selectively widened. (Evaluation approach, likely "before and after," not summarized.)	The evaluation consultant, Intelligent Space, found a 56% increase in pedestrian use of assigned crossing areas, a 61% decrease in jaywalking, and a 9% increase in overall pedestrian crossings. Parties to the scheme believe crash risk has been reduced and that "with the roads easier to cross, their severance impact has been reduced."
6. Troped et al. (2001) (see also "Shared Use, Off-Road Paths and Trails" — "Preferences... Walk/Bikesheds")	Conducted cross-sectional mail survey in Arlington, MA, with multivariate analysis including various neighborhood feature and rail-trail access variables. (GIS-identified busy crossings and *perceived* steep grades between home and trail not statistically significant for trail use.)	Minuteman Trail use was twice as likely, taking other factors into account, if survey respondent *perceived* they did not have to cross a busy street for trail access. Other access factors significantly deterring use were distance from trail entry point and GIS-measured presence of a steep grade.

Table 16-5 (Continued)

Study (Date)	Process (Limitations)	Key Findings
7. Gårder, Leden, and Pulkkinen (1998)	Cycle tracks on 5 streets involving over 30 intersections in Gothenburg, Sweden, were improved: primarily by replacing painted bike cross-walks with raised/red-colored speed tables. Before/after volumes obtained on 2 streets, with controls. (No details on volume analysis.)	Bicycle flows on the 2 streets with volume investigations increased 75% (one side) to 79% (other side) on one street and 100% on the other, compared to 20% at control intersections. (No information on diversion.) The raised/colored crossings were judged to have led to at least 30% greater safety.
8. Boarnet et al. (2005a and b) (for more see "NMT Policies and Programs" — "Schoolchild-Focused Programs" within this "Response by Type of NMT Strategy" section)	Of 10 CA schools surveyed to ascertain 2002-03 SRTS impacts, 2 had received full traffic signals and 3 had received crossing improvements. Parents were asked retrospective questions about changes in walking and cycling to school. Counts were made 2 days running of child pedestrians at project sites, before and after improvement. (Survey obtained parent perceptions, not expressed in numbers. Seasonality of counts not reported.)	Walk/bike increases were more likely to be reported for children passing via new traffic signals (16%) than for study control subjects (4%). Similarly, increases for other crossing improvements were 12% (vs. 6% for controls). These crossing improvement results compare to 17% (vs. 2% for controls) for sidewalk projects. After-signalization counts showed a weighted average 2-site 24% increase. Overall, crossing improvement counts were inconclusive. Traffic yielding improved, significantly so, at 3 of 5 sites.
9. Timperio et al. – 2004, Timperio et al. – 2006, both as summarized by Davison and Lawson (2006)	Conducted cross-sectional analysis of parental or adolescent perceptions (2004) and objective measures (2006) of various area or school access conditions in Australia. (Parental reporting of walking and cycling in both studies.)	Lesser walking/cycling among 10 to 12 year olds was associated with multiple roads to cross, lack of signals and crossings, and other factors. Lesser walking/cycling to school by both 5 to 6 and 10 to 12 year olds was associated with busy road barriers and a commute over 800 m. (1/2 mile).
10. Two additional studies of school access examined by Moudon, Stewart, and Lin (2010)	Cross-sectional evaluations of the effect on active commuting to school of need to cross a major street en route. (No methodological or background details reported.)	A model variable representing a major street crossing was found, in Switzerland, to be associated with less NMT school commuting, but no association was identified in an Oregon study.
11. Harkey and Zegeer (2004)	In Phoenix a 7-lane arterial was built across a field previously crossed by elementary students. Later a bridge was installed with ramp and spiral staircase access. (Limited NMT impact information.)	Before pedestrian bridge installation, 2 crossing guards proved no match for the 50 mph Greenway Parkway traffic. Over 60 students now use the bridge. One school crossing guard enforces bridge use.
12. Moore and Older (1965) (see this section for more information)	Investigated some 30 or so origin-destination pairs with at-grade versus grade-separated pedestrian route options, counting use and timing trips. (Hand-fitted curve.)	Pedestrians showed a very small route choice tolerance for added travel time (Fig. 16-1) in U.K. context examined, with some tolerance for undercrossing use and none for overcrossings.
13. Pedestrian and Bicycle Information Center (2010)	A pedestrian and bicycle overpass was built in Clark County, WA, to connect growing residential/commercial communities on opposite sides of a 4-lane parkway with limited crossing opportunities. (No analysis beyond counting.)	February/March 2004 2-hour counts (no rain) were 8 pedestrians and 5 bikes in a Wednesday AM peak period, 29 pedestrians and 7 bikes in a Friday PM peak period, and 9 pedestrians and 10 bikes on a Saturday midday. NMT travel distance saved not reported.

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column.

Crosswalks and Traffic Controls

Pedestrian Crossings. The first-listed research in Table 16-5 is a before-and-after study, covering four U.S. cities, of 11 intersections where painted crosswalks were implemented—or in one case upgraded. (As indicated earlier in Footnote 2, intersection crosswalks legally exist whether they are marked or not.) The study featured a comprehensive quasi-experimental design. Traffic speeds at all 11 locations were signed for 25 miles-per-hour. As indicated, the proportions of pedestrians crossing within the one-block stretch extending 1/2-block to each side who chose to use the crosswalk increased by less than 1 percent up to 12 percent (city averages). The percentage increases were statistically significant in Buffalo and Richmond. There was also an increase of somewhat less than 1 percent in pedestrians overall, not statistically significant, in the crosswalks and the 1/2-blocks to either side (Knoblauch, Nitzburg, and Seifert, 2001).

A brief look at crosswalk safety issues is provided in the "Related Information and Impacts" section under "Safety Information and Comparisons"—"Other Traffic Safety Issues and Findings"—"Street Crossing Safety." There it will be seen that, out of 11 studies from 1965 to 2005, only two did not find *lesser* safety in the presence of plain marked crosswalks as compared to unmarked crosswalks (Chu, Guttenplan, and Kourtellis, 2007). The four-city study of 11 intersections described above is one of the two studies not identifying lesser safety where crosswalks without traffic controls were marked.

The four-city study results do mesh, however, with findings of a 2005 study that looked separately at uncontrolled crossings of two-lane streets and uncontrolled crossings of multi-lane arterials. (An uncontrolled crossing in this context is one with no stop sign or signal on the crosswalk approaches.) That study found no significant difference in vehicle-pedestrian crash rates with or without crosswalk markings where two-lane or low-traffic volume streets were involved, but several times higher crash rates with marked crosswalks than without where multi-lane roads with higher volumes were involved (Zegeer et al., 2005).

The 2005 study is included as the 2nd entry in Table 16-5 because of its finding that marked crosswalks seem to be especially attractive to the young and the elderly. Whereas 66 percent overall of all pedestrians observed at all 1,000 pairs of crossings studied used the marked crosswalks in the marked/unmarked pairings, the proportion for persons age 65 and older having to cross four-or-more lanes was 81 percent. The proportion for children up through age 12 under comparable conditions was 76 percent.[11] The four-or-more lane facilities (with more than 12,000 or so vehicles per day) involved precisely the types of roadways found to have the higher crash rates within marked as compared to unmarked crosswalks. Marked crosswalks in this study excluded any with active warning devices (Zegeer et al., 2005).

The 3rd and 4th entries in Table 16-5 are case examples that do not appear to have extensive travel demand research behind them. Nevertheless, they illustrate that conventional urban signalized intersection design is much more attractive to pedestrians than typical rural design, even when the latter is signalized, and that a well designed traffic circle installation with pedestrian safety and traffic calming features is more attractive to walkers than an unfriendly intersection (PBIC and APBP, 2009, Harkey and Zegeer, 2004).

[11] Caution should be used in deducing crossing choice behavior from these percentages. The original selections of which crosswalks to mark may have reflected already-established crossing-volume characteristics (Zegeer, 2011).

The 5th table entry is of special interest because it covers, apparently with "before and after" evaluation, a sector approach to crossing improvements. When one-way circulation was reversed in the Shoreditch Triangle, an East London arts and entertainment destination adjoining the financial district, pedestrian needs were examined in terms of desire lines and pedestrian concentrations. The number of signalized crossings was increased, their locations were aligned with the pedestrian desire lines, and road space was reallocated to widened sidewalks where need was indicated. Among quantitative findings listed in Table 16-5, it is notable that a 9 percent increase in total pedestrian crossings was identified in the evaluation (Booz Allen Hamilton, 2006). Given the system approach, it may reasonably be presumed that this overall increase does not reflect walking route shifts, but rather changes in travel mode, choice of destination, and/or amount of walking activity.

Bicycle or Mixed NMT Mode Crossings. The more extensive investigation encountered of effects on bicycling of crossing conditions is from Portland, Oregon. It is more fully described in the "Bicycle Lanes and Routes" subsection under "Popularity, Preferences, and Route Choice"—"GPS-and-Network-Based Revealed Preference Research," and is not included in Table 16-5. In this research, an explanatory model was developed based on the routes a cross-section of cyclists were observed to use, compared to the minimum-path routes available to them. The study approach was a form of cross-sectional analysis, not a before-and-after study, and focused on route choice rather than mode choice or propensity to cycle.

The explanatory-model results provide elasticities to quantify the negative route choice effects of various intersection conditions in terms of presence or lack of traffic controls. Effects for bicyclists making a right turn were found to be minimal, and the results summarized here pertain to cyclists not turning right. It was found that even having to pass through stop signs and signals was a measurable deterrent to use of a route, reflected in negative route choice elasticities of –0.24 for number of stop signs encountered per *kilometer* and –0.28 for number of traffic signals per km. The negative effect was only slightly stronger for encountering one unsignalized crossing per km. of a street with daily vehicular volumes in the 10,000–20,000 range (elasticity of –0.33). On the other hand, the negative effect was 3 to 4 times as substantial for one unsignalized crossing per km. of streets with vehicular volumes over 20,000, producing an "elastic" value for elasticity of –1.08 (Broach, Gliebe, and Dill, 2009a).[12, 13]

More immediately graspable statistics have also been produced through further application of the Portland route choice model. It is estimated, for example, that the typical cyclist will go 1.5 percent

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[12] An elasticity for route choice response to traffic control conditions of –0.3, for example, indicates an 0.3 percent decrease (increase) in route choice probability in response to each 1 percent increase (decrease) in the crossing condition examined, calculated in infinitesimally small increments. The negative sign indicates that the effect operates in the opposite direction from the cause. An *elastic* value is 1.0 or greater (negative or positive), and indicates a demand response that is more than proportionate to the change in the impetus. Elasticities reported in this chapter are thought to be point elasticities or closely comparable values, although none were explicitly defined in the source documents. (For additional background, including application procedures, see "Concept of Elasticity" in Chapter 1, "Introduction," and Appendix A, "Elasticity Discussion and Formulae.")

[13] All numerical values presented here that are based on the Portland bicyclist route choice modeling derive from the initial research model of 2009, which encompasses all utilitarian trip purposes in a single model. For information about subsequent modeling, see Footnote 16 in the cross-referenced "GPS-and-Network-Based Revealed Preference Research" discussion.

out of their way to avoid one more stop sign per *mile,* and 2.5 percent to avoid one more traffic signal per mile. (Cyclists apparently do not like turns in their route, either: it is estimated that they will go 6.5 percent out of the way to avoid one more turn per mile.) With respect to avoidance of unsignalized traffic conflicts, *in the context of a 3.5 mile trip,* it is estimated that cyclists will deviate by 16.5 percent to avoid *each* unsignalized major arterial crossing. Comparable values for other conflict/delay situations include 2.5 percent per minor unsignalized arterial crossing, 11.5 percent for each unsignalized left turn from a major arterial, and 4.5 percent for each unsignalized left turn from a minor arterial (Broach, Gliebe, and Dill, 2009b).

The 6th entry in Table 16-5 touches on barriers to trail use by neighborhood pedestrians and cyclists. Although it fails to find significant impact of actual GIS-determined need to cross a busy arterial, to access a shared use trail, it estimates that the perception of such need can cut trail use in half (Troped et al., 2001). The 7th entry provides evidence of major bicyclist volume increases on urban cycle tracks (bike lanes with physical separation from traffic) in response to carrying the cycle tracks through intersections in the form of raised speed tables (raised crossings intended to alert and slow vehicular traffic) (Gårder, Leden, and Pulkkinen, 1998).

School Access Street Crossings. The 8th through 10th entries in Table 16-5 pertain to situations where students must cross streets on the way to school. The 8th entry provides an extraction of street crossing improvement response information from the early California Safe Routes to School (SRTS) program. The study itself is further described within this "Response by Type of NMT Strategy" section under "NMT Policies and Programs"—"Schoolchild-Focused Programs." Assessments based on child route-to-school choices obtained in surveys of parents indicated that the effectiveness of intersection improvements was only moderately less than the impact of paved sidewalk projects such as sidewalk gap closures. Before-and-after 2-day child pedestrian counts showed a 24 percent increase in schoolchild usage of the two intersections that had been newly signalized. Counts at the three intersections receiving crossing improvements without traffic signal installation were inconclusive, especially where only a marked crosswalk was provided, in contrast to the in-pavement crosswalk lights deployed at the other 2 locations (Boarnet et al., 2005a and b).

The 9th and 10th Table 16-5 entries cover four research efforts in Australia (two studies), Switzerland, and Oregon that used cross-sectional analysis to examine the effect on walking and bicycling to school of necessity to cross multiple, busy, or major roads. A negative impact was identified in three out of the four studies. In addition, the first of the two Australian studies isolated a negative impact for lack of traffic signals and crossings (Davison and Lawson, 2006, Moudon, Stewart, and Lin, 2010).

Pedestrian and Bicycle Grade Separations

Constructing pedestrian and/or bicycle grade separations—overpasses (or bridges) and underpasses (or "subways")—entails major capital investment to achieve traffic safety through total segregation of motor vehicle and crossing NMT traffic. Pedestrian and bicycle grade separations are used where roadway volumes, conditions, NMT volumes, user group characteristics, or facility type cannot reasonably accommodate at-grade pedestrian crossings. However, if not carefully placed and designed, there may be drawbacks in addition to the investment cost. Walkers and cyclists have a basic resistance to changes in elevation and often avoid using special grade-separated facilities to cross roadways. In addition, such facilities may isolate or obscure pedestrian activity and thereby generate personal safety concerns (AASHTO, 2001, Zegeer, 1998). The grade and safety concerns may not apply in greenway and other applications where topography is favorable and visually open construction is possible. Boulder, Colorado, offers many examples.

As with other pedestrian and bicycle facilities, travel time is an important determinant of use. Those facilities where land uses or topography permit direct connections without large up or down grade changes may be the most successful (Zehnpfenning et al., 1993, Moore and Older, 1965). Where pedestrian bridges are integrated with second-storey land development and connected with one another, they become skywalk systems as covered in the upcoming "Pedestrian Zones, Malls, and Skywalks" subsection. Bridges over major barriers are examined further on in this chapter under "Pedestrian/Bicycle Systems and Interconnections"—"River Bridges and Other Linkages."

Many pedestrian bridges and "subways" were built in the middle decades of the 20th Century to provide safe school crossings of major arterials, and this type of application remains relevant in special applications. The 11th entry in Table 16-5 provides an example from Phoenix. Note that a crossing guard has to be employed to enforce bridge use by students (Harkey and Zegeer, 2004). Omaha, Nebraska, is an example of a city with a history of using pedestrian overpasses as a strategy to provide safe routes to school for children. In 2000, Omaha had 23 pedestrian overpasses, many built in the 1970s. The city traffic engineer found that children over age 11 or so tended not to use the bridges, but instead to cross at-grade, engendering proposals to meet future crossing needs with traffic signals or crossing guards (Urban Transportation Monitor, 2000). This is not always feasible, of course, with higher-type highway facilities.

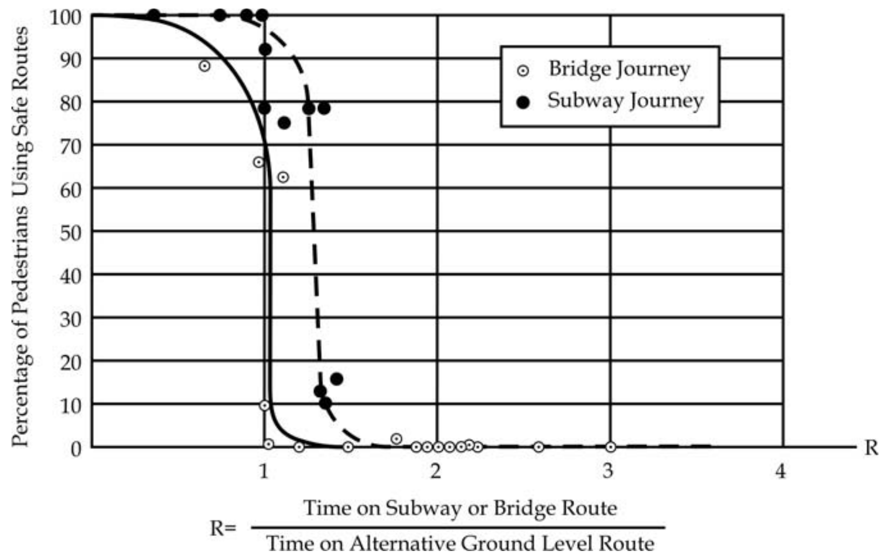
The inclination of pedestrians to choose the shortest path is made note of, in connection with interpreting observed phenomena, at a number of points in this chapter. Perhaps nowhere is this tendency so vividly illustrated than in the case of pedestrian grade separations. Grade separations are costly investments, yet if adolescent and adult pedestrians can save time and effort by avoiding them, many (or most) will do so.

This phenomenon began to attract attention early on, and in the 1960s, an extensive study was made in Great Britain of the travel route choice outcomes of pedestrian decisions to use or avoid pedestrian grade separations (12th entry in Table 16-5). Figure 16-1 illustrates the striking results. With percentages of pedestrians choosing to use a bridge or "subway" crossing plotted against a value "R," which is the ratio of time via the grade-separated route to time via an at-grade route (and which may be interpreted as a convenience measure), a highly sensitive response to travel time is shown. In the study, virtually no one used an overcrossing requiring 25 to 50 percent more crossing time (R = 1.25 to 1.5) than the at-grade route. Undercrossings were shown to be slightly more attractive, perhaps because they typically involve lesser grade changes to access. With equal travel time via either the grade separation or an at-grade route, the study results suggest (at least under 1960s urban English conditions) that an underpass will be chosen by 95 percent of pedestrians and an overpass will be chosen by 20 to 70 percent (Moore and Older, 1965, Zegeer, 1998).

The 13th and final entry in Table 16-5 gives an example of a suburban pedestrian/bicycle overcrossing with peak-period and Saturday midday 2-hour NMT volumes in the 13 to 35 users range (Pedestrian and Bicycle Information Center, 2010). Such volumes would not meet quantitative grade-separation justification warrants such as those in the 1984 Federal Highways Administration Report No. FHWA/RD-84-082, "Warrants for Pedestrian Over and Underpasses," but they could well pass muster under more qualitative benefit analyses that include such NMT system connectivity considerations as maintenance of neighborhood continuity and support of existing and future land uses (Zegeer, 1998).

Guidebooks such as *NCHRP Report 240: A Manual to Determine Benefits of Separating Pedestrians and Vehicles,* offer procedures for structuring grade separation benefit analyses involving multiple considerations, many not readily quantifiable (Roddin, 1981). The struggle to address unknowns such

Figure 16-1 Street crossing route choice in response to pedestrian grade separation



Source: Moore and Older (1965).

as potential pedestrian and bicyclist use of grade separations bridging barriers of long standing can be clearly seen in innovative approaches such as New Jersey's efforts to prioritize pedestrian and bicycle crossings using such tools as pedestrian potential indices, bicycle demand models, and GIS systems (Swords et al., 2004).

Pedestrian Zones, Malls, and Skywalks

Pedestrian zones, malls, and skywalks all serve to more extensively separate walkers from motorists, and to provide more walking space, thus facilitating pedestrian travel. Historically, however, the impetus for establishing the pedestrian treatment has often been less about transportation than about efforts to secure the economic health of a business district, normally a central business district (CBD). Installations of pedestrian zones, malls, and skywalks are often intended as strategies for stabilizing or enhancing the viability of CBD retail and office space (Robertson, 1992 and 1994).

Economic perspectives, although introduced here, are quantified primarily under "Economic and Equity Impacts," in the "Related Information and Impacts" section. Although the same general themes run through all three project types, in this subsection experiences with skywalks are looked at separately from pedestrian zones and malls. Skywalks, and their underground concourse counterparts, are unique in providing total separation from street traffic. They also have had a significantly lower failure rate in terms of overall success.

Pedestrian Zones and Malls

The distinction between pedestrian zones and pedestrian malls is not clear-cut. Pedestrian zones are areas in which vehicle traffic is restricted and pedestrian travel is encouraged, typically composing a small-area network of pedestrian streets in an urban commercial core. In most countries, enhancing central area commerce has been the main impetus, although Sweden is reported to have placed priority on enhancing pedestrian and traffic flow and safety. Many cities outside North America now have such areas in their core, with some in Europe dating back to post-World-War-II reconstruction. There has been steady growth, until today there are over 1,000 cities with such treatments in Germany alone.

There are only very few strictly comparable examples in the United States. More common in the United States are pedestrian malls, created by closing and beautifying a single street, albeit often for several blocks or sometimes involving sections of two intersecting streets. The vast majority—at one time found in some 200 cities across the United States—were implemented in the 1960s and 1970s in a wave of interest in city center revitalization. The pedestrian mall was envisioned as an enticing alternative to the suburban shopping center (Robertson, 1994 and 1995).

Physical and Economic Context. To understand the travel impacts of downtown pedestrian malls in the United States, it is necessary to appreciate both what physical forms they can take and how they have been affected by secular (long-term) trends. "Traditional Pedestrian Streets," including the vast majority constructed in the 1960s/70s, are designed for pedestrian use only, and a number have even given pedestrians the right-of-way at cross streets. "Shared Malls" are predominantly pedestrian but accommodate a narrow traffic-calmed passage for vehicles, typically a single lane with or without parking. "Transit Malls" are likewise pedestrian oriented but with exclusive transit vehicle lanes and amenities for waiting passengers.

These three basic facility types generally apply to both foreign and domestic pedestrian zones and malls, except the European pedestrian streets are typically minimalist in landscaping (if any) and street furniture. They are more dedicated to accommodating substantial pedestrian volumes on narrow street cross-sections (Robertson, 1994). In addition, recent systems approaches to pedestrianization have used combinations of facility types to match specific needs. New York City (Broadway) and Oxford, England, examples are covered here under a "Combination Projects" classification (New York City Department of Transportation, 2010, Booz Allen Hamilton, 2006).

With regard to secular trends, many traditional pedestrian streets (malls) were superimposed in the 1960s/70s on U.S. downtowns in decline. Many were unable to stem the tide toward suburban shopping in the years to follow. In a dying downtown with low pedestrian volumes, even a thoughtfully designed and promoted pedestrian mall can feel empty and actually discourage further use. Since 1980, few new traditional pedestrian streets have been implemented and many existing malls have either been totally "re-streeted" or altered into shared-mall constructs. Norfolk, Virginia, and New London, Connecticut, for example, have converted pedestrian malls back to streets. For some downtowns, this has recreated a sense of street life by concentrating pedestrians on smaller walking spaces and reintroducing the bustle of motor vehicle traffic (Levinson, 1986, Project for Public Spaces, 1993, Robertson, 1993 and 1995). In other cases, pedestrian streets have been and are highly successful. Given the circumstances, the limited amount of pedestrian activity response data there is on pedestrian zones and malls must be viewed through the lens of short-term impact, recognizing that short-term gains may have become permanent in a stable or thriving economic environment, or may have been negated in an environment of overall area decline.

Pedestrian Zones. Perhaps the only U.S. location where an area-wide vehicle traffic restriction has been introduced is the 12-block Downtown Crossing in Boston, Massachusetts. Within and around the zone are about 125,000 employees and numerous retail establishments. Boston's pedestrian zone is actually characterized by the narrowness of streets so common in European applications. At critical points in the core retail district, original sidewalk widths averaging 9 to 10 feet had effective widths of only 5–6 feet because of obstructions. Pedestrian levels of service on four contiguous blocks of Washington Street in the zone were E, C, D, and E, on a scale of A to E (collisions probable), with worse conditions at intersections.

The Downtown Crossing project was created in 1978 by closing 2/3 of the street segments in the zone to general traffic while improving the transit service and parking management. Some of the street segments were made pedestrian-only while others continued to allow transit service and taxis. Several local bus routes were extended into the zone. Street furniture, brick pavement, new lighting, and information kiosks were introduced in 1979. The changes eliminated sidewalk congestion on the affected streets along with conflicts at the affected intersections along Washington Street. When surveyed, both businesses and pedestrians responded positively about the project (Weisbrod and Loudon, 1982, Replogle, 1995).

Pedestrian activity and store purchases increased overall following closing of the streets, despite increasing competition from other areas. Much of the increase was attributed to midday activity by nearby office workers. The volume of 10:00 AM to 4:00 PM weekday visitors to the area was up 11 percent in 1980 compared to 1978, from 74,200 to 82,400, based on pedestrian counts. Weeknight visitors from 6:00 PM to 8:00 PM were up 8 percent, from 11,300 to 12,200, and 10:00 AM to 4:00 PM Saturday visitors were up almost 10 percent, from 57,800 to 63,400. Pedestrian volumes between noon and 2:00 PM, as a percentage of total weekday pedestrian volumes, went from 45.8 to 48.4 percent.

Sidewalk volume changes varied throughout the pedestrian zone. The northern blocks, closest to the government and financial office districts, saw pedestrian traffic increase by more than 15 percent. Southern blocks experienced pedestrian traffic decreases that were similar percentage wise, but smaller in the absolute. The largest volume increase occurred on a northerly block of Washington Street that had sidewalk widening rather than total pedestrianization, leading the researchers to conclude that proximity to activity generators can be more of an influence than the form of auto restriction. Weekday pedestrian volumes on the block in question were 38,000 in 1980 during a 6-hour period, including 8,000 pedestrians/hour volumes during the midday peak.

Over the 2-year 1978 to 1980 period, the weekday mode shares for worker and shopper trips into and in the pedestrian zone shifted from 48 to 54 percent walk, 37 to 39 percent transit, and 11 to 6 percent auto. As shown in Table 16-6, weeknight and Saturday walk shares also increased, with auto shares decreasing, but transit usage shifts varied in direction. The increased weekday transit usage was a result of the extension of the bus routes, but given the no-free-transfers fare structure of the time, it came at the expense of subway transfer revenue. The net increase in fare box revenue overall covered only 5 percent of the cost of the extended service in the first year.

The project evaluation also examined effects on Downtown Crossing worker's and shopper's mode choice for the trip from home to downtown Boston, as contrasted to the trip into the pedestrian zone, which often started from elsewhere in the downtown. These home-based walk and transit shares either held essentially constant or increased, as illustrated in the shaded portion of Table 16-6, and the corresponding auto travel to downtown was down for all time periods (Weisbrod and Loudon, 1982).

Table 16-6 Mode Shifts Accompanying Implementation of the Downtown Crossing Pedestrian Zone in Boston

Time Period	Year	Mode Shares to Pedestrian Zone				Mode Shares to Downtown Boston			
		Walk	Transit	Auto	Other	Walk	Transit	Auto	Other
Week-days	1978	48%	37%	11%	4%	10%	62%	23%	5%
	1980	54%	39%	6%	2%	9%	75%	13%	3%
Week-nights	1978	48%	38%	13%	1%	11%	71%	17%	1%
	1980	60%	36%	3%	0%	12%	80%	7%	1%
Satur-days	1978	21%	54%	20%	4%	13%	59%	23%	5%
	1980	32%	49%	14%	4%	19%	59%	18%	5%

Note: Includes all interviewed visitors to the pedestrian zone study area irrespective of trip purpose.

Source: Weisbrod and Loudon (1982).

Limited information is also available on effects of overseas pedestrian zone implementations, but must be inferred from available retail sales statistics. Sales increased by 30 percent on Copenhagen's Stroget, actually three contiguous streets in the main shopping district, after it was closed to motor vehicles in 1962. Technical studies of 1968 conditions showed the facility to be filled to near capacity with people walking, sitting, standing, and lingering. London Street in East Anglia, England, saw sales increases of 5 to 20 percent (Robertson, 1994).

An alternative that has been tried in New York City, and also is used in Japan, is to close streets to vehicle traffic temporarily during certain hours of the day. Midday closure of Fulton Street in lower Manhattan increased pedestrian activity by 11 percent, with nearby workers flooding the street from 11:00 AM to 2:00 PM. An average of 4,132 pedestrians *per hour* was observed before the closure. After the closure, usage grew to an average of 4,594 pedestrians per hour (University of North Carolina, 1994, Replogle, 1993).

Traditional Pedestrian Streets. The first U.S. pedestrian mall opened in downtown Kalamazoo, Michigan, in 1959. By 1978 the documented number of such malls was approaching 100. Non-transportation factors found to be associated with success—generally defined in terms of usage, popularity, and perceived effect on sales—have included development of a sound organizational structure for mall management and preexisting sound economic health of the downtown. A key transportation factor linked to success is presence of a major nearby pedestrian traffic generator such as a college campus, government center, or medical complex (Robertson, 1994).

A survey of 36 downtown pedestrian malls taken in 1989 by the City of Eugene, Oregon, found seven malls that "were doing well or great." Some 25 had either been or were to be removed, or were reported to be doing poorly (Rathbone, 2006). In a number of cases, particularly those without supplemental pedestrian traffic generators, success or failure has had more to do with retail economics than transportation issues.

A not uncommon example of a mall deemed to be hobbling along when examined in 1988 was the nicely maintained three-block Mall Germain in St. Cloud, Minnesota. Retail included one blank-walled department store and a small-business retail mix observed to be outdated vis-à-vis student and office worker populations nearby. It lacked a 1-block extension that would bring it to the river and a conference center, and was "empty of pedestrians most of the time."

Another pedestrian street examined in 1988 and found not to be doing well was Westminster Mall in Providence, Rhode Island. Highly active between 11:00 AM and 3:00 PM thanks to workers from the nearby financial district, the mall was relatively deserted otherwise, and devoid of use after 5:00 PM. Negative factors included retail that was declining in the face of intense competition from 12 suburban shopping centers, exacerbated by low levels of mall maintenance and an undoubtedly related perception of crime (Robertson, 1994).

Both the Mall Germain in St. Cloud and the Westminster Mall in Providence are among those changed back to a conventional street and sidewalk cross-section. The Westminster Mall decline is an example of the strong role of retail economics in pedestrian mall success or failure. This mall was quite successful for a number of years. The final straw was a business decision by the key retailers to build a conventional modern enclosed mall nearby and relocate.

In places that are thriving, and have high pedestrian volumes, traditional pedestrian streets have done well. Examples include Seattle (Occidental Street), San Francisco (Maiden Lane), Las Vegas (Freemont Street), and Santa Monica, California (Third Street Promenade). Other malls perceived to be faring well include those in the college towns of Charlottesville, Virginia; Boulder, Colorado; and Burlington, Vermont. A standout example in Madison, Wisconsin, is actually 3/4 transit mall and 1/4 conventional pedestrian street. Known as the State Street Mall (see "Transit Malls," below), it links the University of Wisconsin and the state government complex (Harkey and Zegeer, 2004, Robertson, 1994).

Shared Malls. A broad-scale overseas application of the shared mall approach is the Japanese "community street" concept. More than 140 were introduced in the 1980s in Japan after a successful demonstration project in Osaka. There, a 10-meter wide street was converted into a 3-meter (9.8-foot) wide zigzag space for vehicles. Motor vehicle traffic dropped by 40 percent and pedestrian and bicycle traffic increased by 5 and 54 percent, respectively (Replogle, 1993).

Such applications blur the distinction between shared malls and traffic calming. In the United States, the Santa Cruz, California, Pacific Garden Mall is an example of a shared mall cited as successful in the previously noted 1988 review. Pedestrian information is lacking, but of the six malls examined, this mall was second highest in number of mall businesses (106 establishments) and in percentage selling retail goods (67 percent), and lowest in ground-floor vacancies at less than 1 percent (Robertson, 1994).[14] The Portland Mall, covered below under "Transit Malls," actually has a significant shared mall component. Close cousins to shared malls are downtown streets that have been put on a "road diet," decreasing the number of traffic lanes, introducing traffic calming, and allowing angle parking, mid-block crosswalks, and/or widened sidewalks. Two successful examples, Hendersonville, North Carolina, and El Cajon, California, were included in Table 16-4 of the earlier "Sidewalks and Along-Street Walking" subsection.

Transit Malls. A shared-use approach that creates more activity without necessarily allowing private vehicles is creation of a "transit mall." Such malls dedicate a portion of the street right-of-way to use by public transit vehicles, potentially enhancing transit operations and maintaining or adding transit patrons in the pedestrian mix (Levinson, 1986, Robertson, 1993).

Different reviews of transit malls have arrived at disparate conclusions about their success. One examination of six U.S. pedestrian malls in 1988 concluded that, as viewed from the perspective of

[14] These 1988 data were collected 1 year before the Loma Prieta earthquake, which in 1989 disrupted the Pacific Garden Mall by destroying more than 1/3 of the buildings along it (Robertson, 1994).

economics and mall vitality, "the most successful malls . . . [were] the three transit malls and the shared mall" (Robertson, 1994). Certain transit malls have arguably not had success. Commercial activity on Howard Street in Baltimore suffered from the construction activity of building street-level Light Rail Transit (LRT) and never rebounded (Calvert, 2001). The State Street transit mall in Chicago was disliked for its concentration of large buses and the thinned crowds spread across too much walking space. It was restored to a conventional streetscape with 22-foot sidewalks, a better match for the pedestrian volumes (Engelen, 2004, Kamin, 2009). A factor in its removal was a reduced bus transportation role once Orange Line rail rapid transit service opened in Chicago's southwest corridor. An elaborate glass-enclosed transit mall in Canada's capital city of Ottawa, the Rideau Mall, created a confining space, blocked views of storefronts, and sheltered "undesirables." Financial difficulties faced by merchants and property owners precipitated a decision to revert back to a traditional street. The negative view is summed up in the contention that, "in nearly every city where they have been built, transit malls are being rethought or have been altered from their original concept" (Project for Public Spaces, 1993).

Despite individual failures, U.S. transit mall development has produced solid and enduring success stories. Lacking a broader quantitative success and failure tabulation, it is instructive to look at the five transit malls and mall proposals selected in the 1970s for an Urban Mass Transportation Administration (UMTA) Service and Methods Demonstration Program (SMD) review (Koffman and Edminster, 1977) and actually implemented. Of the five implemented transit malls, four remain in full use. The Minneapolis, Minnesota, transit mall was given a 1990–1991 upgrade, following the original design outlines, to restore it after a quarter century of hard use. The Madison, Wisconsin, and Denver, Colorado, installations apparently remain essentially as built. The Portland, Oregon, bus mall was reconstructed in 2007–09, after 3 decades, primarily to add LRT. Only in Philadelphia has the transit mall examined in the UMTA/SMD review been dismantled. Opinions diverge on whether Philadelphia's Chestnut Street Mall hastened retail decline or whether retail decline occurred as a result of competition once the nearby Market Street East commercial area was developed.

The Minneapolis, Madison, Denver, and Portland transit malls are examined in the following paragraphs. It should also be noted that elements of Boston's Downtown Crossing pedestrian zone, discussed above, operate—in effect—as transit malls.

The Nicollet Mall in Minneapolis was apparently the first U.S. transit mall when built in 1967. It features a 24-foot serpentine travelway for buses, heated sidewalks ranging from 20 to 36 feet wide, and numerous amenities. Originally eight blocks in length, it was extended to 12 blocks in 1982. Circa 1988 ridership on six bus routes serving the mall was 30,000 riders (Robertson, 1994, Project for Public Spaces, 1993). Average 11- to 12-hour pedestrian counts *per side* for the six blocks central to retail activity were 12,400 to 12,800 in 1958 well before introduction of the transit mall, 13,600 in 1973 after transit mall development (Koffman and Edminster, 1977), 7,400 in 1976 after Skyway interconnection of major retail centers (Edminster and Koffman, 1979), and 7,200 in 2002 in the context of an 8-mile Skyway system. Recent pedestrian count data show that Skyway usage now does tend to dominate, but that the mall holds its own (Bruce, 2002a and 2002c), with 38 to 46 percent of the immediately parallel pedestrian flow on a September day in 2002.

Additional detail is provided in the case study "50 Years of Downtown NMT Facility Provisions—Minneapolis," which concludes that the Nicollet Mall has played a supporting role in the city's success in stabilizing and enhancing its downtown area and its NMT attractiveness. As covered in the case study, the block-wide corridor centered on the Nicollet Mall is estimated (as of 2002) to be attracting an 11-hour pedestrian flow averaging 15,600 to 18,700 per side (Skyway traffic included), contrasted to the 12,400 average per side in 1958—an increase of some 25 to 50 percent. (In the case study, under "More . . . ," see Table 16-131 for a full presentation of Nicollet corridor pedestrian flows over time.)

The State Street Mall in Madison, Wisconsin, opened in stages between 1977 and 1982, draws much of its layout from the Minneapolis example. Despite being introduced into a downtown suffering from 1960s Vietnam-era turmoil, it is an economic success (see "Related Information and Impacts"—"Economic and Equity Impacts"—"Land Value and Commerce Impacts"—"Downtown Pedestrianization Effects" for quantitative measures). The six-block transit mall is anchored at one end by the state Capitol, with nearly 25,000 government workers, and at the other end by a two-block section of traditional pedestrian street and the University of Wisconsin, which represents 13,000 employees and 44,000 students (circa 1988). The mall is served by 700 buses running on 16 routes. It features a retail mix representative of college towns and has an active night life. Bicycle traffic is a major component of the pedestrian-bicycle-bus mix (Robertson, 1994). A refurbishing plan in 2002 featured a "cleaner look" but retained the original basic layout (Harkey and Zegeer, 2004). Quantitative NMT volume data are not available.

The 16th Street Mall in Denver opened in 1982 over a 13-block, 1-mile distance between two concurrently planned urban bus terminals. Along the mall runs a very frequent fare-free low/no-emissions-vehicle shuttle-bus service, distributing passengers from and to the bus terminals and more recently constructed LRT. Interesting design features and ability to hop on a free bus mitigate the spread-out character of the mall. Bus shuttle operating parameters and results circa 1997 are described in Chapter 10, "Bus Routing and Coverage," under "Response by Type of Service and Strategy"—"Circulator/Distributor Routes"—"Transit Terminal and Parking Distributors." Chapter 17, "Transit Oriented Development," describes changes in downtown Denver's development regulations and land use mix in that chapter's "Response by TOD Dimension and Strategy" section, under "Response to TOD by Regional Context"—"City Center TODs." As reported in Chapters 10 and 17, average weekday free bus shuttle ridership was 47,000 in 1997, and 60,000 in 2004, the latter after extension to serve residents of an adjacent rail-yard redevelopment. Pedestrian usage of the 16th Street Mall was estimated in the late 1980s at 90,000 walkers daily (Robertson, 1994).

The Portland Mall, opened in Portland, Oregon, in December 1977, is actually a combined pedestrian/transit/shared mall through the primary office district and into the downtown retail area. It first served successfully as a bus transit mall, for three decades, followed by reconstruction and addition of LRT in 2007–2009. The twin mall occupies a one-way street pair, 5th and 6th Avenues. As constructed and operated initially, it was 11 blocks in length, with two exclusive bus lanes on each street, plus a lane for general traffic access, 26-foot wide sidewalks along the right sides where buses load, and mostly 18-foot sidewalks on the left. Originally the general traffic lane was interrupted every 4th block by a block of 30-foot left-side sidewalk, but the general traffic lane has been made continuous in the 2007–2009 reconstruction. Traffic signal timing is currently set for 12 mph, appropriate for exclusive-lanes transit service with heavy passenger loading and unloading at multiple stops, and allowing bicycles and autos to move together on the general traffic access lane. Originally bicycles were prohibited. Portland bicycle mode shares have increased in recent years (see Figure 16-7 under "NMT Policies and Programs"). One feature of the mall rehabilitation is addition of more bicycle parking, including covered "bike oases" (Edminster and Koffman, 1979, Dueker, Pendleton, and Luder, 1982, TriMet, 2009).

Simulation-aided pedestrian estimates circa 1980 indicated that the Portland mall had focused pedestrian activity on the mall area and nearby sections of cross-streets, as compared to a more even distribution of pedestrians (without the mall) on streets in the downtown. Of all downtown bus runs, 88 percent had been concentrated on the two mall streets. An average of 13 passengers boarded or alighted at each bus at each stop along the mall in the PM rush hour. Total mall pedestrian volumes were estimated to be 75 percent bus patrons. (This is a much higher percentage than in Minneapolis, where as detailed in the downtown Minneapolis case study, 16 percent of surveyed Nicollet mall pedestrians were headed to or from a bus stop.) Together, these statistics led to an estimate that 800 persons per hour were passing along the average block of the transit mall during the peak hour. The midday estimate was 600 persons per hour. The only pedestrian volume data for the before condition are 1975 counts indicative of a 565 persons per hour average flow on 5th and 6th Avenues through the retail district, mid-morning and mid-afternoon.

Portland Mall employees, bus riders, and pedestrians were separately surveyed about their satisfaction, using a 5-point scale ranging from “1” for strongly disagree to “5” for strongly agree with various statements. “The Transit Mall is attractive” engendered a 4.2 to 4.6 mean response (between agree and strongly agree) across the three surveys. The means for “The Mall is a good place to shop” ranged from 3.8 to 4.1; “The Mall is a good place for entertainment,” from 2.8 to 3.3 (basically neutral); “The Mall is a good place to relax,” from 2.5 to 3.2; “The Mall is safe,” 2.9 to 3.7; and “The Mall is a good place to walk,” 3.8 to 4.5. In each of these instances, employees were the least affirmative, bus riders were more so, and pedestrians tended to be the most positive by a small margin. Both the intent and results were unique for the survey statement “The Mall sidewalks are crowded.” Here the means were 3.5 for both employees and bus riders (between neutral and agree), while the mean for pedestrians was 2.8 (fairly neutral but tilted toward disagreement). The researchers felt these mid-range responses were close to ideal, reflecting enough crowding for comfortable social interaction, but not too crowded. This interpretation meshed with the generally positive responses to the perceived safety and “good place to walk” questions, which were offered despite actual crime statistics suggestive of more off-street crime on the mall-frontage blocks than further away (on-street crime distributions could not be assessed) (Dueker, Pendleton, and Luder, 1982).

Combination Malls. Two major pedestrian mall systems employing combinations of mall facility types offer roughly comparative data. Each reports overall project area pedestrian volume increases on the order of 8 percent. Table 16-7 provides a summary.

Table 16-7 Summary of System-Scale, Combination Pedestrian-Mall-Type Application Effects in New York City and Oxford, England

Study (Date)	Process (Limitations)	Key Findings
1. New York City Department of Transportation (2010), Grynbaum (2010), Philip Habib & Associates (2011)	Pilot project partial-mall-with-bike-lane and full-pedestrian-mall combinations for all of Broadway within Manhattan's Midtown, implemented in May, 2009. (No means for separating pedestrian attractiveness effects from strong secular trends.)	Times Sq. pedestrian volumes along Broadway and 7th Ave. up 11% overall, Herald Sq. pedestrian volumes up 6%, but 80% fewer walking in road at Times Sq., injuries down 35% for pedestrians, 63% for vehicles, net bus and car traffic effects neutral to positive.
2. UK Department for Transport – 2004 as summarized in Booz Allen Hamilton (2006)	Oxford, England, June 1999 central-area closure of Cornmarket St. to all traffic, daytime closure of High St. to all but cyclists, buses, and taxis, Broad St. closure to through traffic, bicycle network improvements, 300 more bicycle parking spaces. (Analysis approach not reported.)	Central area pedestrian flows up 8.5% (6,000/day) 1998-2000, 11% bicycle mode share maintained, local bus and park-and-ride use up 50% 1991-2000 (2,000/day) , parking at 3 central facilities down 14% (700 cars/day) relative to 3 previous years, total attraction of people to central area up.

Note: See this section for more information.

Sources: As indicated in the first column.

"Green Light for Midtown," the name given to New York City's pilot project for Broadway in Midtown Manhattan, may seem an odd name for a project involving extensive areas of pedestrian mall (labeled "plazas"). The reference is to the greater traffic signal green time afforded to the Manhattan streets and avenues with removal of Broadway's diagonal-to-the-grid traffic flows.[15] The selection of physical layouts for the different components of the pilot project, from Columbus Circle (59th Street) south to 23rd Street (with progressive extension further south), had much to do with traffic lane layouts and conflict-elimination intersection geometrics designed specifically to improve Midtown vehicular traffic and pedestrian crossing conditions.

From 47th Street to 42nd Street, inclusive of Times Square, and again from 35th Street to 33rd Street inclusive of Herald Square, all roadway space exclusive to Broadway has been converted to pedestrian plazas with tables, chairs, and awnings. Street space on the alignments of 7th Avenue (at Times Square) and 6th Avenue (at Herald Square) remain dedicated to vehicular traffic flow. From 59th Street south to 47th Street, and 42nd Street to 35th Street, plus 33rd Street to 23rd Street (and on south in project extensions), a partial-mall cross-section has been employed. Most partial-mall blocks from Columbus Circle to Herald Square have two southbound traffic lanes, two lanes of parking, a southbound buffered bike lane, and a minimum of one traffic lane's worth of added pedestrian space with seating. South of Herald Square, Broadway is narrower, there is only one southbound traffic lane in many blocks, and the narrow reserved space has no mall furniture in the pilot project arrangement.

[15] Broadway angles across 10th to 4th Avenues and roughly 77th to 17th Streets, creating numerous awkward intersections and problematic traffic conflicts as it follows the pre-street-grid trace of the original road from Albany (Grynbaum, 2010, New York City Department of Transportation, 2010).

The term "shared mall" has not been applied here to the partial-mall blocks given the lack of overt traffic calming, although the remaining traffic lane(s) do generally have parking on both sides. With a bike lane in all partial-mall blocks, the design clearly draws from "complete streets" principles. Bike lanes are provided in all blocks except those with a full-mall cross-section. In some blocks, left turn lanes are included (Grynbaum, 2010, New York City Department of Transportation, 2010). It was announced in early 2010 that the pedestrian plazas would be made permanent even though not all traffic congestion relief goals had been met (Urban Transportation Monitor, 2010).

The project substantially increased sidewalk and other pedestrian space. It needs to be understood that the term "square" is a misnomer as it applies to Times and Herald Squares. There is essentially no outdoor public space not in the street-right-of-way except for narrow triangles at each square. Times Square reputedly has the highest concentration of pedestrians in the world. With the new pedestrian plazas in place, sidewalk flow is vastly improved, in part because "stopping" activities such as reading a map, taking a picture, or looking at billboard displays now tend to take place in the plazas instead of on sidewalks as before.

Pedestrian flows have increased in part from growth in pedestrian visits and in part because higher pedestrian capacity has allowed choice of more direct routes by those who formerly deviated out of the way to avoid the pedestrian congestion. Pedestrian volumes at Times Square increased by 17 percent on the most historically crowded sidewalk sections and by up to 112 percent on popular crosswalks, which are now afforded more crossing time. As noted previously, overall weekday volumes are reported (apparently on the basis of peak hours averages) to have increased by 11 percent in the Times Square area and by 6 percent in the vicinity of Herald Square (New York City Department of Transportation, 2010).

These impacts have occurred in a context of pedestrian traffic that has been increasing over the course of a decade, likely in response to area revitalization. In 2010, cumulative growth in pedestrians on summer Wednesdays for an aggregation of 14 Times Square area traffic counts reached 50 percent for the 11 years since 1999. Saturday summer counts grew 89 percent over the same period, including a sharp increase between 2009 and 2010. The busiest section of 7th Avenue in the Times Square area, between 43rd and 42nd Streets, handled 109,793 pedestrians between 8:30 AM and midnight during Wednesday, August 11, 2010, counts. During the same hours, the highest count on Broadway, between 46th and 45th, was 52,897 on the sidewalk plus 43,419 in the plaza (Philip Habib & Associates, 2011). Herald Square pedestrian capacity improvements have allowed peak hour pedestrian flow increases in the range of some 30 to 60 percent (New York City Department of Transportation, 2010).

Satisfaction with the "Times Square experience," before and after pilot project implementation, grew from 80 to 91 percent for Tri-state residents, 78 to 89 percent for New York City residents, and 43 to 74 percent for Times Square area employees. The percentage of Broadway pedestrians agreeing that "I would avoid walking on this part of Broadway if I could" dropped from 28 to 16 percent, "It is too crowded here" dropped from 62 to 45 percent, and "I feel safe crossing the street here" increased from 80 to 90 percent. Pedestrian signal compliance shifts ranged from slight improvement at several Times Square locations to a 36 to 82 percent compliance increase at 7th Avenue and 47th Street. Herald Square compliance changes, although generally starting from lower levels, were comparable. Pedestrian and traffic injury reductions of 35 and 63 percent, respectively, attributed to simplified intersections and shortened crosswalks, are noted in Table 16-7 along with a summary bus service and traffic flow assessment (New York City Department of Transportation, 2010).

The central area pedestrianization project in Oxford, England, employed separate approaches on three different streets, as delineated in Table 16-7. The street closed to all traffic, Cornmarket Street, is a major shopping street. A central area pedestrian flow increase of 8.5 percent was measured between the 1998 "before" year and the 2000 "after" year, reversing a declining trend. The 11 percent bicycle mode share, which held steady, includes a journey-to-work bicycle share of 17 percent. These are among the highest bicycle shares in the United Kingdom. The project involved a bus priority route, around the central area, with general traffic pushed outward. Nevertheless, surrounding streets did not experience traffic volume changes. Opinion surveys, starting in 1993, "show overwhelming public support for the Strategy" (Booz Allen Hamilton, 2006).

Pedestrian Skywalks

Pedestrian skywalks offer direct connections among buildings, parking facilities, and transit terminals, including peripheral facilities. Most U.S. skywalk networks are above grade (hence the name) and, between street over-crossings, link through buildings or above alleys at the second story. At least 16 cities in the United States and Canada have downtown skywalk networks that interconnect 12 or more city blocks. Cities with skywalk systems include Calgary, Cincinnati, Des Moines, Duluth, Minneapolis, St. Paul, and Sioux City. Several systems have underground segments as well. A notable underground equivalent to skywalks is the Houston Downtown Tunnel System, while the largest underground system may be in Montreal, connecting some 300 retail and business establishments plus the area's subway system. Toronto's "PATH" underground network is nearly as large. There are also systems of underground concourses in additional North American cities, large and small, including Rochester, Minnesota, and the "Oklahoma City Underground."

Skywalks designed for general public use form a network of walkways that allow pedestrians to travel from one location to another—typically within a downtown—without having to deal with motor vehicle conflicts or weather. In addition to providing safe traffic crossings and weather protection, they usually offer a climate controlled environment with retail opportunities. Some in-building components resemble a shopping mall interior. Skywalks save travel time for many downtown trips, because of avoiding street crossings, and offer time-saving access to quick-stop retail services along their corridors. The first skywalks were built in the 1960s in cold weather cities, where they have continued to be expanded. Later, air conditioned skywalks were developed in warm weather cities such as Charlotte, Dallas, and Fort Worth (Corbett, Xie, and Levinson, 2008, Robertson, 1993, 1994, and 1995, Wikipedia, 2009, Bandara et al., 1994, Podolski and Heglund, 1976, Heglund, 1980).

Skywalk Impacts on Walking. No studies have been encountered that explicitly examine the relationship between presence or extent of skywalks and prevalence of walking, although a rough estimate of induced walking is provided below following Table 16-8. However, historic counts of pedestrian and transit passenger volumes and mode shares at the Minneapolis CBD cordon along with corresponding data on the extent of the Minneapolis Skyway system help to assess the role of that city's extensive system in downtown travel choices. The cordon and Skyway data are presented and examined in "50 years of Downtown NMT Facility Provisions—Minneapolis," in the "Case Studies" section. The case study finds that NMT cordon volumes have been heavily influenced by economic conditions, but that overall an NMT growth of roughly 1/2 of 1 percent per year since the mid-1960s can be discerned. Circumstantial evidence suggests a correlation with the development of the Skyway system and more recent introduction of bicycle facilities, while the Nicollet transit mall appears to play a positive supporting role.

An analysis covering 6 individual years from 1969 through 1974 indicated that opening of new Skyway bridges in Minneapolis was accompanied by at least a proportional increase in total

Table 16-8 Noon Hour Pedestrian Usage by Month in 1974 of Six Twin Cities Skyways in Comparison to Competing Crosswalks

	Weekday Noon Hour Volumes			Percent Using Skyway		
Month	**6 Skyways**	**Crosswalks**	**Totals**	**Highest**	**Lowest**	**Average**
January	16,400	5,400	21,800	90%	62%	76%
February	18,600	6,600	25,200	86%	48%	72%
March	19,400	6,400	25,800	85%	50%	71%
April	15,000	9,000	24,000	78%	62%	66%
May	10,800	11,400	22,200	75%	36%	56%
June	10,400	13,000	23,400	76%	25%	46%
July	10,200	11,800	22,000	79%	26%	47%
August	10,000	12,000	22,000	66%	30%	47%
September	11,600	11,800	23,400	76%	36%	52%
October	13,000	11,000	24,000	76%	32%	60%
November	15,800	8,400	24,200	95%	24%	68%
December	17,200	5,600	22,800	82%	51%	67%

Notes: Noon hour pedestrian counts made on three Minneapolis and three St. Paul Skyways in 1975, when the extent of each system was 4 blocks north-south and three to four blocks east-west.

The first two columns of volumes are weekday noon hour subtotals for the six Skyways and for the competing crosswalks. Both are scaled from hand-graphed Figure 5 in the source document. Discrepancies in totals, and vis-à-vis the average Skyway usage percentages (from Table 3 of the source document), have not been fully resolved. Newly computed totals are substituted for the graphed totals, reducing monthly aggregate noise in the surviving record of this unique data set to an equivalent of roughly plus or minus 800 to 2,800 pedestrians per volume observation total (equivalent to 4 to 12 percent of the individual monthly observation totals).

Two competing crosswalks were counted for each Skyway crossing to give total inter-block pedestrian flows. For example, in the case of the east-west Skyway crossing of Minnesota St. between 5th and 6th Sts. in St. Paul, the east-west Minnesota St. crosswalk at the north end of the block (6th St.) and the corresponding crosswalk at the south end of the block (5th St.) were counted (Podolski and Heglund, 1976).

Source: Adapted from Heglund (1980), with substitute totals by the Handbook authors.

Skyway system bridge crossings. Average December/July daily Skyway crossings were 10,100 in 1969 with two bridges and 11,600 in 1974 on nine of 10 bridges, with the excluded bridge functioning primarily as an intra-hotel facility. In between, with five bridges not forming a cohesive system, the average sagged to 8,600 daily pedestrian Skyway crossings per bridge. Downtown redevelopment was a factor, including opening in 1973 of the multi-level interior Crystal Court, which linked separated parts of the system (Podolski and Heglund, 1976).

As of 2002, with the Skyway system having grown to 82 bridges, it appeared that traffic *per bridge* in the core area had held steady (if one adjusts for the post-9/11 economic downturn), while average volumes on the outer reaches of the now-vast system were less. In September 2002 counts, the volume average for the nine core area bridges counted (out of 15 internal to the three by four block area originally connected as of 1974) stood at 10,050. The range for this area was 17,100 to 4,700 per bridge (Bruce, 2002a). Retail and office center Skyway volumes grew/rebounded by almost 1/4 between 2002 and 2007. Thus the proportional growth assumption may still hold for the core area, and then some. However, the 24 less-central Skyway bridges counted (out of 67 lying outside of the core area) averaged 3,700 in 2002. These lower counts suggest that overall system bridge volume averages will drop as a skywalk system is extended beyond a certain point to serve additional businesses, garages, transit terminals, public buildings, and the like. The range for these "outer" downtown Minneapolis bridges was 14,400 pedestrians (actually within the core area if one assumes it has shifted one block south over time) to 400 pedestrians (Bruce, 2002a, 2009, and 2002b; Case Study, "50 years of Downtown NMT Facility Provisions—Minneapolis").

Analyses covering specific aspects of walking choices as affected by skywalks, mostly based on Twin Cities Skyway data, also exist. Spring of 1975 all-day counts found roughly 1/4 of weekday Skyway crossings to occur during the noon hour (23 percent in Minneapolis and 28 percent in St. Paul). Nearly 1/2 occurred during the 3 hours from 11:00 AM to 1:00 PM. All-day counts on a selected Twin Cities Skyway bridge and its competing crosswalks showed the percent of pedestrians using the Skyway to be relatively constant throughout the day, ranging for the Skyway in question between 40 and 65 percent choosing the Skyway. The midday Skyway choice averaged close to 50 percent, while the lowest percentages occurred at the beginning and end of the business day, when many pedestrian trips start or end at street-level bus stops. These statistics pertain to relatively small systems—four blocks each way in extent—as compared to today's Twin Cities Skyway systems with their extensions to serve peripheral parking and (in the case of Minneapolis) transit terminals.

The 1974 counting program in Minneapolis and St. Paul included monthly noon-hour counts during a 12-month period that saw no system expansion. Table 16-8 shows the results in terms of volumes on six representative Skyways and their competing crosswalks, and reported ranges and averages of the percentage of pedestrians choosing Skyway use in preference to street-level crosswalks. A notable finding is that total volumes throughout the year of Skyways plus competing crosswalks varied relatively little, no more than 10 percent from the average. The lowest and highest totals both occurred in freezing-temperature months (January and March), suggesting little relationship between total volumes and season. The downtown pedestrians simply shift more to the Skyway systems in cold-weather months (Heglund, 1980).

The data in Table 16-8 lends itself to a parametric exploration of how much downtown pedestrian travel may be induced by the presence of skywalks in a cold-climate city like Minneapolis or St. Paul. The 1975 counts found 71 percent of pedestrians traversing Skyway-served blocks to be using the Twin Cities Skyways in the 6 months of November through April, compared to 48 percent in summer months. Thus roughly 1/3 of the November-April users were cold-weather users only. If 1/4 of the observed bridge crossings during those months are assumed to represent walking that would not occur without the weather protection of the Skyway systems, then the induced pedestrian blocks of travel represent 9 percent of the total annual observed walking and 15 percent of the Skyway traffic. Other parametric trials deemed reasonable by the Handbook authors give an induced-walking range of 6 to 12 percent of total annual observed walking and 9 to 20 percent of Skyway traffic. Whatever induced walking there actually is would represent some combination of new walk trips and walk trips that are longer than they otherwise would be.

Evidence exists that skywalk systems do encourage longer walk trips, though all that can be stated with certainty is that Skyway trips have been observed to be longer than sidewalk trips in one late 1970s study in St. Paul. There the median CBD walk journey via sidewalks was found to be approximately 2-2/3 blocks, while the median for trips making use of the Skyway system was some 3-1/3 blocks. The proportion of sidewalk trips in any given trip distance increment dropped off fairly steadily from 1-1/2 blocks on, while the proportion of Skyway trips across distance increments held relatively steady up to 4-1/2 blocks in length (Barton-Aschman, 1978). Indeed, the sharp drop-off in Skyway trips after 4-1/2 blocks may possibly have been a product of the limited extent of the St. Paul Skyway system at the time.

Responses to a five-city skywalker preference survey, conducted in 1985 and summarized in Table 16-9, articulate for a broader range of cities both the year-round appeal of skywalks to pedestrians and the variations which do occur in response to outside temperature. Preference for skywalk over sidewalk was reported by 72 to 100 percent of survey respondents except in Duluth, the northernmost city surveyed, where a warm day was cause for preferring the outdoors (Robertson, 1993 and 1994). It is not clear why the Minneapolis and St. Paul Skyway preference percentages obtained in this survey substantially exceed the Skyway usage percentages measured on the basis of actual counts in 1975. The differences may relate to growth of those cities' systems over the intervening decade, to biases inherent in preference surveys, to the fact that only summertime pedestrians on skywalks and not users of sidewalks were interviewed in the preference survey, or some combination of these factors.

Not all pedestrians prefer to use skywalks. Street-level entrances may be far inside buildings and thus inconvenient for short travel segments. Also, and not just in tunnel systems, there may be a disorienting lack of visual cues as to the user's location. Landmarks are not as visible as they might be at street level and the twists and turns of interior corridors can lead to wrong turns. In addition, some skywalk segments may close or become deserted at night and on weekends (Robertson, 1993). Despite their popularity in most applications, there is one known instance where skywalks have been dismantled—the Rosslyn district of Arlington County, Virginia (Fisher, 2005). The Rosslyn system had been built piecemeal by developers as a building approval requirement. It was characterized by relatively narrow walkways open to the weather, and never quite achieved full "system" status.

Table 16-9 Percentages of Skywalk Users Preferring Skywalk Over Sidewalk by Outdoor Temperature

Temperature (Fahrenheit)	Cincinnati, Ohio	Des Moines, Ohio	Duluth, Minnesota	Minneapolis, Minnesota	St. Paul, Minnesota	5 Cities Overall
Cold day (20 degrees)	100.0	97.1	99.0	96.0	99.0	98.2
Average day (50 degrees)	90.1	84.5	69.0	71.7	90.9	81.3
Warm day (80 degrees)	84.2	83.5	31.0	71.7	86.9	71.5

Notes: Survey conducted in summer of 1985, of skywalk users only, with 502 samples total (99 – 102 respondents per city). See discussion in text above of possible survey biases.

Source: Robertson (1993).

Urban Planning Considerations. Skywalks are not universally liked among city planners and observers of the cityscape, although 97 percent of skywalkers themselves interviewed in the 1985 five-city skywalk survey agreed that they "thought skywalks added to the visual attractiveness of the downtown." The concern is not just architectural effect on sightlines and building facades, or the potential to segregate people by social class, discussed further in the "Related Information and Impacts" section under "Economic and Equity Impacts"—"Equity Issues"—"Equity of Access." The most fundamental issue is whether skywalks draw pedestrians (or too many pedestrians) off of the sidewalks and away from the ground level, leaving lightly populated streetscapes not attractive to retailers and dominated by the automobile (Robertson, 1988 and 1995, Bandara et al., 1994, Peale, 1999).

The case of St. Paul garners the most attention in this regard. Disparities in ground floor versus Skyway-level rents and retail activity in downtown St. Paul are covered under "Land Value and Commerce Impacts"—"Downtown Skywalk Impacts" in the aforementioned "Economic and Equity Impacts" subsection. A factor not always considered in using St. Paul as a case example is that many of their

Skyways were installed in conjunction with urban redevelopment, inclusive of the new retail core, and that it was this urban redevelopment that moved much of the retail up to the second level (Heglund, 2004). With reference to the street level of key urban redevelopment components, St. Paul has even been criticized as "the blank-wall capitol (sic) of the United States" (Roberts, 2001). It appears that a substantial portion of the activity transfer that has caused 3/4 of the downtown retail to be on the second level in St. Paul is not directly attributable to any inherent characteristic of skywalk outcomes but rather to deliberate 1960s/70s city-planning and redevelopment-project-design decisions.

Bicycle Lanes and Routes

Bicycle lanes provide designated travel ways on roads for preferential or exclusive use by bicycles. They are created through the use of pavement markings and traffic signs and, in the case of cycle tracks, physical delineations (AASHTO, 1999, NACTO, 2011). Many researchers have concluded that bicycle lanes are advantageous, compared to streets with no bicycle space delineation, in that they make bicyclists and motorists more predictable and comfortable with each other's presence (RTC and APBP, 1998). However, there have been some bicycle advocates who have not supported bicycle lane development, particularly where bike lane use is mandatory when present (MacLachlan and Badgett, 1995). There are a number of subcategories of bicycle lanes, as described in the "Overview and Summary" under "Types of Pedestrian and Bicycle Improvements/Programs," but travel demand response of trip makers to bicycle lanes tends not to be differentiated at that level of detail.

Shared-roadway bicycle provisions other than bicycle lanes and tracks do not incorporate lane-line or separator designation of road space for bicyclists but do generally feature signage and other considerations. Included are wide curb lanes, bicycle boulevards, and other signed bike routes.

This subsection first provides a review of findings concerning bicyclist preferences and travel behavior with regard to on-street bicycle facilities, set in a context of comparisons to undifferentiated streets and also multi-use, off-road paths. This is followed by examination of actual changes in volumes and travel choices of bicyclists in direct response to bicycle lane implementation, both individually and as systems of bicycle lanes. Such information, being limited, is supplemented with research on the effects of bicycle facility system extent on overall cycling levels. The comparative and systems studies overlap substantially with research on impacts of off-road bicycle paths, a subject covered further in the subsection to follow on "Shared Use, Off-Road Paths and Trails." Finally, information specific to cycle tracks is offered along with findings about shared-roadway bicycle route applications including wide curb lanes, bicycle boulevards, and ordinary signed bike routes.

Popularity, Preferences, and Route Choice

Research on preferences and route choices offers a sound basis for concluding that most adult bicyclists prefer bicycle lanes relative to use of undifferentiated streets if vehicular traffic volumes are moderate to high. The picture is less clear when it comes to understanding preferences for bicycle lane use as compared to the alternatives of off-road paths or bicycle routes with or without special provisions. Seemingly conflicting findings are common. Revealed preference research from Portland, Oregon, utilizing global positioning system (GPS) and computer network analysis technologies, is providing added evidence of preference for off-road facilities and even bicycle boulevards over bicycle lanes where there is a reasonably direct option for any given bicycle trip.

Contradictory findings for lanes versus paths arise in part from different reactions and needs of differing bicycling populations. Bicyclists run the gamut from highly experienced bicycle commuters on the one hand to inexperienced recreational cyclists on the other. There is also the complexity introduced by need to get between specific points when bicycling for utilitarian purposes. Among facilities that are physically and operationally attractive, whichever type provides the most direct routing in any given circumstance is the most likely to be used for utilitarian travel. Bicycle lanes are often more direct because they can and do make use of the street system, while path facilities often follow natural features or former railway roadbeds and canals. Such path alignments may or may not offer linkages useful for commuting or other travel aligned to specific destinations.

Bicycle boulevards are only beginning to be addressed in quantitative preference or route choice analysis, and little has been encountered that covers other special provisions or signing of bicycle routes. Similarly, information on the bicycling preferences of children and their guardians is very thin.

Opinion Surveys and Observational Studies. Among opinion surveys is a case where respondents expressing interest in cycling were asked to allocate 100 points among different facility improvements to indicate their effectiveness in encouraging bicycle commuting. The importance assigned to safe bike lanes was (on average) more than three times higher than any other type of improvement among the choices offered (MacLachlan and Badgett, 1995). A 1991 Bicycling Magazine poll found 49 percent of active bicycle riders and 20 percent of all adults felt that "safe bike lanes" would encourage them to ride a bicycle to work (Goldsmith, 1992). Such surveys are influenced by question structure and wording, and only indicate what respondents might do, not what they actually will do (Dill and Carr, 2003).

The popularity of bike lanes encountered in preference surveys could possibly be attributed as much to respondents' experience as motorists as to their experience as cyclists. Some motorists like it that bicycle lanes take cyclists "out of the way" of the motor vehicle and vice versa.

A Florida study confirms this function of bike lanes. The study relied on more than 1,500 observations of passing-vehicle interactions between cyclists and motorists, between intersections only, on both bike lanes and wide curb lanes. The lateral separation between motorists and bicyclists, lateral position of bicyclists, and motor vehicle encroachments when passing bicyclists were all examined. There were not huge variations between the two facility types, but bike lanes resulted in the smallest movements on the part of motorists and the least spatial separation between bicyclists and motorists.

Bike lanes seemed to give motorists greater confidence about the likely movements of cyclists, encouraging them to accept smaller separations, while cyclists seemed to be less timid about road position. On average, the separation of motorists from bicyclists was 5.9 feet for bicycle lanes versus 6.4 feet for wide curb lanes. Motorists moved to the left an average of 1.0 feet for facilities with bike lanes versus 2.4 feet for passing bicyclists on facilities with wide curb lanes. Cyclists did not feel the need to ride as close to the edge of the road on facilities with bike lanes (riding 2.6 feet from the edge) as on wide curb lane facilities (1.4 feet from the edge). Only 8.9 percent of motorists passing cyclists shifted into the left lane on facilities with bike lanes as compared to 22.3 percent with wide curb lanes. The study did not report on crash rate differentials (Harkey, Stewart, and Rodgman, 1996).

Stated Preference Experiments. While stated preference surveys have tended to indicate cyclists have an increased comfort level on bicycle lane facilities (Hunter et al., 1999), they have not resolved discussions of which is the better solution—bicycle lanes or off-road facilities. A more recent published review of both stated and revealed preference research found "results [that] seem somewhat mixed" on the subject of bike lane versus off-road facility preference. Among five stated preference experiments examined as part of the review, two specifically identified travel time as being of utmost importance. One-third found safety to be of top priority, and posited that safety improvements were more important than travel time reductions for encouraging bicycling. Among the four studies with reported results for facility type preferences, one found a preference for bicycling on residential streets and an aversion to cycling alongside parked cars. It also estimated that either bicycle lanes or off-road facilities added value, with the greater added value for bicycle lanes. Another identified a trip routing preference for off-road facilities, along with low-traffic residential streets. One of the studies found surface quality to be of more importance than type of facility or traffic volumes. A study that looked only at bicycle lanes versus wide shoulders, in the context of transit access, found bicycle lanes to have the greater positive influence on access mode choice—more strongly so in the case of inexperienced cyclists (Tilahun, Levinson, and Krizek, 2007).

The same researchers conducted their own stated preference experiment with employees (faculty and students excluded) at the University of Minnesota. Summer and winter facility conditions at selected St. Paul locations, shown in video clips, were presented in separate summer/winter sessions. Paired comparisons were employed, and a travel time was associated with each option. Participants were asked to choose their preferred route in the context of commuting to work. In an iterative process, the maximum added travel time each participant would tolerate to use his or her preferred facility type, within paired comparisons, was determined.

Using combined summer and winter results, the estimated marginal utility of an off-road bicycle facility relative to having a bicycle lane with no parking alongside was small, while the marginal utility of a bicycle lane relative to having no lane was large. The estimated marginal utility of not having parking alongside (on either a bicycle lane or on a street with no bicycle lane) was intermediate in value. That said, the estimated order of participants' facility preference was: (1) off-road bicycle facility (most preferable); (2) bicycle lane with no parking; (3) bicycle lane with parking; (4) street without bicycle lane, no parking; and (5) street without bicycle lane, with parking (Tilahun, Levinson, and Krizek, 2005 and 2007). Findings were found to be independent of regularity of actual bicycling to work. A greater willingness to accept longer travel times to travel on preferred facility types was exhibited, however, by female and older participants (Tilahun, Levinson, and Krizek, 2005). Retired persons and children were, obviously, not included in this work-trip-based experiment.

GPS- and Network-Based Revealed Preference Research. The previously alluded to GPS- and network-based research in Portland, Oregon, provides revealed preference information in the form of actual routes taken in comparison to minimum time paths through a bicycle network. GPS technology was employed to track bicycle trips made during one week by a sample of 164 adults in the region, primarily within the city limits. Volunteers were obtained, not working through groups of avid cyclists, but instead using more general appeals. An extra effort, somewhat but not entirely successful, was made to include infrequent cyclists—deemed to be a surrogate for less skilled cyclists. Quota sampling was used to obtain roughly equal representation for men and women. Data collection took place from March through November, 2007.

After processing the bicycle trip data, and determining trip origins and destinations, minimum-distance-path traces were determined for the same origin-destination pairs utilizing standard transportation-planning network algorithms. This, together with further network processing, allowed analysis of deviations from minimum-distance paths in terms of bicycle facility types utilized. Recreational and exercise bicycle trips were omitted from the minimum-path tracing and comparative analyses, as were transit access trips, but all types of bicycle-mode-only utilitarian trips—not just commute trips—were included (Dill and Gliebe, 2008). Cycle tracks were not included in the research, for lack of such facilities in Portland at the time of data gathering.

The route choice implications of this research are explored in the "Underlying Traveler Response Factors" section under "Trip Factors"—"Bicycle Trip Distance, Time, and Route Characteristics"—"Bicycle Route Choice." (See Table 16-67 and subsequent discussion. Table 16-67 compares the bicycle mileage actually accumulated on different types of facilities compared to the mileage that would be accumulated if all cyclists making utilitarian trips followed a minimum distance path. It shows the surveyed adult bicyclists overall rode 4 percentage points more miles on bike lanes than minimum-distance routings would suggest, 6 percentage points more miles on bicycle boulevards, and 8 percentage points more miles on off-road trails. It also shows 17 percentage points fewer miles were ridden on busy and moderate traffic streets without bike lanes than minimum-distance routings would predict.)

Subject to the limitation that only the Portland, Oregon, urban area was included in the research, this indicates a hierarchy wherein bicycle lanes are preferred over all categories of undifferentiated streets except maybe quiet streets, bicycle boulevards are preferred over bike lanes, and off-road trails are preferred over bicycle boulevards. (A hierarchy derived such as this one assumes ideal comparability, in other words, equivalent connectivity and directness between origin and destination for each alternative facility type.) Although the strength of these relationships varied among subgroups of adult bicyclists, only infrequent cyclists showed a negative response to any type of bicycle facility. Bike lanes held a slight negative attraction for the infrequent cyclists, though not nearly as negative as riding on non-quiet streets without bike lanes (Dill and Gliebe, 2008).

The minimum-distance and actual route data for bicyclists from this study were subsequently used to develop an explanatory model to mathematically describe cyclist preferences (Broach, Gliebe, and Dill, 2009a). Using this model, the analysts predicted how far out of his or her way an average adult cyclist would go in order to make use of various types of bicycle facilities for the full trip, or in the case of major bridges, a full bridge crossing. It was estimated, for example, that the average cyclist will be willing to bicycle 31 percent farther to avoid a moderate traffic street without a bike lane and be able to use a bike lane instead. This result and other estimates using the explanatory model are shown in Table 16-10 (Broach, Gliebe, and Dill, 2009b). The same basic hierarchy of preferences can be seen here as discussed above and illustrated later (see Table 16-67).[16]

Table 16-10 Estimated Percent Out-of-the-way a Cyclist Would Go to Avoid a Street or Bridge Without a Bicycle Lane

To Avoid A...	And Use, for the Entire Trip or Bridge Crossing,...		
(Without Bike Lane)	A Bicycle Lane	A Bicycle Boulevard	An Off-road Trail
Quiet Street	0%	14%	26%
Moderate Traffic Street	31%	45%	57%
Highway Bridge	19.5%	n/a	34%

Source: Broach, Gliebe, and Dill (2009b).

[16] All numerical values based on the Portland bicyclist route choice modeling that are presented here in Chapter 16 derive from the initial research model of 2009, which encompasses all utilitarian trip purposes in a single model. Subsequently, the model has been refined for use in regional forecasting, including stratification into work and non-work trip purpose components. The purpose-stratified models continue to exhibit the same on-street hierarchy with off-road trails ranking highest in preference, bicycle boulevards next, followed by quiet streets along with bicycle lanes on streets of any volume, and lastly by busy streets without lanes (Annual Average Daily Traffic {AADT} of 10,000 vehicles or greater), which rank progressively lower with higher traffic volumes. The on-street hierarchy holds for both commute and non-commute travel purposes, with the higher sensitivity to facility type found with non-commute trips, as might be expected. Bridge bicycle facility types have been subdivided into bike lane and separate bike facility categories, both exhibiting substantial preference, especially the one bridge with a separate bike facility (Broach, Gliebe, and Dill, 2011).

Bicycle Lane and Route User Makeup. The user makeup of bicycle lanes, as compared to other types of facilities, may possibly be tilted toward use by adults commuting to work. A weekday 7 to 9 AM survey of bicycle lane users in the Seattle CBD found 97 percent of survey respondents were making a utilitarian trip. Of these, 92 percent considered themselves to be regular commuters. By comparison, an equivalent peak period survey on the Burke-Gilman off-road trail north of the University of Washington (UW) found only 56 percent to be making a utilitarian trip, with some 86 percent of the utilitarian tripmakers considering themselves to be bicyclists who commuted regularly (Niemeier, Rutherford, and Ishimaru, 1995b). Of course, the CBD location of the bicycle lane survey would tend to give more emphasis to commute travel even with the comparable timing.

Bureau of Transportation Statistics (BTS) 2002 data indicate that only 5 percent of persons who bicycled in the previous month did so as part of a work or school commute. (In the "Overview and Summary" section, see "Analytical Considerations"—"National and Regional Non-Motorized Transportation (NMT) Data"—"Most-Recent Trip Versus Trip-Day Travel Data" for a discussion of the limitations of using "most recent trip" information like this.) Of those who were commuting, 11.0 percent reported primarily using bike lanes. The comparable bike lane usage figure for recreational bicycle trips was 5.6 percent (Dill and Carr, 2003). Whether this differential is the result of preference or of facility orientation is not known.

A comparison of parallel-facility user characteristics is provided in the case study "Special Mini-Studies in Montgomery County, Maryland" under "More . . ."—"Off-Street Versus On-Street NMT User Mix." It focuses on weekend and off-peak use of an on-parkway bike route (not a bike lane) versus a proximate off-road trail, both in the same parkland. Within these limitations, markedly different usage patterns are shown for the two types of facilities. Although total facility NMT volumes were similar, the on-parkway bike route attracted many more bicyclists in cycling gear, fewer females, and virtually no children, to say nothing of the fact that all walkers and joggers (save one) used the trail. Numerical comparisons are given in the case study and equity implications are explored in the "Related Information and Impacts" section under "Economic and Equity Impact"—"Equity Issues"—"Equity of Access." The case study, taken in conjunction with other evidence, is certainly suggestive of the proposition that many investigations of facility preference have been too aggregate. Examination of the preferences and needs of distinct user groups is beginning to show promise for identifying different bicycling patterns and reducing occurrence of conflicting findings, thereby providing a basis for better facility planning.

Bicycle Lane Implementation

Before-and-After Counts and Surveys. Most before-and-after evaluation studies report increased bicycle volumes on streets where bike lanes have been introduced. In those that also examine off-facility data, however, it becomes apparent that a portion of the demand attracted to bicycle lanes is simply shifted from presumably less desirable routes. Count-based studies tend to leave as an open question the extent to which introducing bike lanes will result in higher total bicycling demand.

Two of the locations with comprehensive before-and-after evaluations, Davis, California, in the United States, and Toronto, Ontario, in Canada, are featured in the "Case Studies" section of this chapter. In each of these examples, the introduction of bike lanes on a single street or multiple streets resulted in increased cycling along those streets, but a substantial portion of the increase was found attributable to shifts in route choice rather than changes in the prevalence of bicycling (Lott, Tardiff, and Lott, 1979, Macbeth, 1999).

Table 16-11 summarizes before-and-after bicycle survey or count data for implementation of bicycle lanes. Although some of the individual counts cover as little as 1 hour before implementation,

Table 16-11 Summary of Before and After Studies of Individual and System Bicycle Lane Provision Examples

Study (Date)	Process (Limitations)	Key Findings
1. Lott, Tardiff, and Lott (1979) (see also case study "Anderson Road Bicycle Lanes — Davis, California")	Bicycle lanes were introduced on Anderson Road in Davis, CA, after a basic bicycle lane grid was already established. Interviews, including 108 "after" with retrospective questions, covered 5 blocks each side of Anderson. Peak period counts were made before and after. (Differing findings from interviews vs. counts.)	Of 57 interviewed cyclists using other streets in the before condition, 44% had changed route to Anderson Road. The 1-hour AM and 2-hour PM counts showed overall bicycling growth on Anderson of 7%, compared to growth on 2 parallel roads with bike lanes of 9% to 12%. Overall cycling growth was ascribed to season and school calendar.
2. Barnes, Thompson, and Krizek (2006) (see this subsection including Table 16-12)	In Minneapolis-St. Paul 3 major bike lane facilities and 4 major off-road trails were opened 1990-2000. Commute trip bike mode share changes were computed for TAZs within 1 mile (1.5 miles for facility termini). (Work purpose trips only.)	Average bike mode shares inside the commutersheds were 4 to 5 times the shares in the rest of the Central Cities to start with. The trail and lane commutershed bike shares increased by averages of 1.38 percentage points each, up 64% in the case of bike lanes. [a]
3. Cleaveland and Douma (2009) (see this subsection including Table 16-13)	Commute trip bike mode share changes were computed for Census block groups within 1.55 miles of bike facilities opened 1990-2000 in 6 additional U.S. cities. (Work purpose trips only, on-street facility types not reported for all cities.)	In the city of Chicago, the implemented on-street facilities were bike lanes. There was also promotion and a major bike rack installation program. Bike lane commutershed bike shares increased by an average of 0.32 percentage points, up 91%. [a]
4. Macbeth (1999) (see case study "Bicycle Lanes in the Downtown Area — Toronto")	Between 1993 and 1997 bicycle lanes were installed on 6 streets in the central area of Toronto. Before and after bicycle and vehicle counts were performed. (Diversion of cyclists to bike lanes was not fully explored.)	Bicycle volume increases averaged 23% on the 6 streets where bicycle lanes were installed, while citywide cycling remained static or possibly declined. Declines were most noticeable on streets without bicycle lanes.
5. Fertig (1996)	In the city of Santa Barbara, CA, bicycle counts were made at 62 locations in 1973 and 1996. None had bicycle lanes in 1976 and 23 had bike lanes in 1996. The 12-hour 1973 counts were adjusted to 2-hour PM counts to allow comparison with 1996. (No adjustments for secular trends other than population.)	Total cyclists counted at 62 street locations increased by 48% on average over the 23-year period without population growth adjustment or 19% with adjustment. Adjusted growth at locations with bike lanes in 1996 was 46% to 47% (with or without conversion to one-way street traffic) vs. a 1% decline where bike lanes were not installed.
6. Chaney (2005)	A 2-mile stretch of Valencia Street in San Francisco was restriped from 4 through lanes to 2 through lanes, 1 turn lane, and 2 bike lanes. (One 1 hour PM peak count before/after.)	Valencia Street bicycle usage increased from 88 to 215 (up 144%) in the 1 hour PM peak. No investigation of possible bicyclist diversion to Valencia. There was parking on both sides before/after.
7. Chaney (2005)	Part of 10 blocks of Polk Street in S.F. was restriped from 3 through lanes (2 SB, 1 NB) to 2 vehicle lanes, 2 bike lanes, and 2-sides parking, while the other (narrower) part became 2 wide lanes (2-hour AM, PM count locations not reported.)	Polk Street bicycle usage (average of several before/after counts) rose from 37 to 52 (up 41%) in the 2-hour AM peak, while 2-hour PM peak usage increased from 43 to 55 (up 28%), apparently in the wide-lanes section. No diversion investigation.

(continued on next page)

Table 16-11 (Continued)

Study (Date)	Process (Limitations)	Key Findings
8. Chaney (2005)	A 3-block 1-way section of Fell Street in S.F. was restriped from 3 through lanes and 1 tow-away lane to 3 vehicle lanes, 1 bike lane, and parking on both sides (2-hour PM peak counts, only 1 "after" count.)	Fell Street bicycle usage in the 2-hour PM peak rose from 25 on south side traffic lanes, 9 on north side lanes, and 37 on sidewalks (71 total) to 82 in south side bike lane, 5 in traffic lanes, and 7 on sidewalks (94 total, up 32%). [a]
9. Chaney (2005)	Before/after provision of bike lanes on Oriental Blvd. in Brooklyn, 11-hr. weekday and 8-hr. weekend counts were made in May, July, and Sept. (No diversion investigation.)	The average weekday bicycle, skater, and scooter totals were 68 before and 103 after 1 year, up 52%. Corresponding weekend average totals were 61 before and 65 after, up 7%.
10. Chaney (2005)	Non-standard 3-foot bike lanes were implemented along a 2-3 mile beachfront state highway in Fort Lauderdale, FL. Before and after counts, 4 15-min. Saturday afternoon counts each, were obtained in February and May. (Fewer tourists in May.)	"Before" 1-hour 2-way totals were 344 pedestrians, 39 bikes in street, 29 bikes on sidewalk, 68 total bikes. "After" totals were 206 pedestrians, 28 bikes in lane/street, 23 bikes on sidewalk, 51 bicycles total. Ratio of bicyclists to pedestrians increased from 1:5 to 1:4. [a]
11. Davies (2007) (see also "Related Info…" – "Time to Establish… Use")	One hour AM peak bicycle counts made on St. Kilda Rd. in Melbourne, Australia, starting 1 year before bicycle lane implementation. (No details about the facility or context.)	Bicyclist count grew from 42 the year before opening to 76 the year after, up 81%. Reached 160 after 5 years (almost 4 times the before count) and 511 after 10 years, with 1/5 "before" injury rate.
12. Boarnet et al. (2005b) (see also "NMT Policies and Programs" – "School-child-Focused…")	Of 10 CA schools surveyed to ascertain 2002-03 SRTS impacts, one had received a bike lane in addition to improved sidewalks. Before/after 2-day counts were made of child cyclists. (Volumes deemed too small for inferences to be drawn.)	Child bicyclist volumes before and after the installation of on-street bicycle lanes were 4 and 14 cyclists, respectively, during regular school access/-egress hours. The authors concluded "that there was little observed impact on bicycling."

Notes: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

[a] Percentage increase(s) or ratios and some totals calculated by the Handbook authors.

Sources: As indicated in the first column.

and 1 hour after, the 12 quantitative studies present a nearly-consistent pattern of apparent bicycle usage or count growth from the "before" to the "after" condition.

The first three table entries cover studies that either made use of project-specific survey results or utilized decennial U.S. Census journey-to-work data. Excluding the Davis, California, case where results are somewhat ambiguous (1st entry), the 2 investigations that examined travel mode shifts in response to bicycle lanes are those in Minneapolis-St. Paul and Chicago (2nd and 3rd table entries). These studies found average increases of 64 percent and 91 percent, respectively, in work commute travel bicycle share with the introduction of bicycle lanes. The response in Chicago was almost certainly amplified by publicity and bicycle parking enhancements (Barnes, Thompson, and Krizek, 2006, Cleaveland and Douma, 2009). Aside from the influence of concurrent actions in Chicago, the mode shift findings may be viewed as particularly robust, because they are not inflated by effects of route choice shifts.

The 4th through 9th Table 16-11 entries, if one combines the three San Francisco studies into one data point, offer straightforward combined count-based examples from four North American cities (see Table 16-11 for sources). (Deliberately held aside in this array of cities are the Fort Lauderdale, Florida, example with counts in different seasons relative to tourist activity, the California Safe Routes to School (SRTS) results for children, and the overseas example from Melbourne, Australia.) The average bicycle count increase per city among these four, on streets with bike lanes added, ranges from 23 percent in downtown Toronto to 70 percent in San Francisco. The simple average across the four cities is a 48 percent increase in bicyclists on affected streets.

The Melbourne St. Kilda Road bike lane results (11th table entry), comparing year-before and year-after counts, show a somewhat higher increase at 81 percent. What is particularly notable in the case of Melbourne is the continued strong growth for a number of years after implementation (Davies, 2007). In addition to the 5- and 10-year results in Table 16-11, a 14-year record of St. Kilda Road bicycle volumes and injury crashes is provided in the "Time to Establish Facility Use" discussion within the "Related Information and Impacts" section (see Table 16-114).

A key weakness in most of the count-based studies, already alluded to, is the lack of information on what travel changes actually make up the increases in cycling on streets where bicycle lanes have been installed. The added bicycles represent an unknown combination of diversions from parallel routes (route shifts), trips previously made by other means (mode shifts), and even possibly some trips diverted to new destinations (destination choice shifts) and trips not previously made (induced travel), all manifestations that may occur when a travel route is improved. The count-based studies also lack information on the purposes of the bicycle travel before and after.

Three of the studies do provide some information on route diversion/shifting. The Anderson Road research in Davis (1st entry in Table 16-11) found 57 cyclists, among those interviewed between Anderson Road and the parallel previously existing bike routes, who reported use of routes other than Anderson Road in the before condition. Among these cyclists, 44 percent had shifted to Anderson Road after implementation of the new bicycle lanes (Lott, Tardiff, and Lott, 1979). Note that this is different than making a statement about the proportion of Anderson Road bike lane users who had diverted from other routes, a value that could not be meaningfully computed with the Davis survey findings obtained.

The downtown Toronto bicycle lane study (4th table entry) did not quantify route diversion effects, but found the 23 percent average bicycle count increase—on streets where bike lanes had been installed—in a context of citywide lack of change, or possibly decline, in bicycle usage. This outcome strongly implies shifting of pre-existing bicycle trips from streets without bike lanes to streets where they were installed. Anecdotal evidence of pronounced cycling declines on unmodified streets adds support for the implication (Macbeth, 1999).

The before-and-after bicycle count analysis in Santa Barbara (5th entry in Table 16-11) provides similar but more explicit evidence of route shifting. With a 46 percent adjusted average growth in bicycling on streets with bike lanes installed during the 23-year analysis period, paired with a 1 percent decline on streets with no such lanes (Fertig, 1996), bicyclist route shifting is clearly demonstrated. Nevertheless, it is obvious that an overall increase in bicycling per capita also took place. What cannot be determined, in the absence of full screenline counts or equivalent, is exactly what the overall growth was or what proportions of bicycle count growth are attributable to route shifts versus other responses such as mode shifts.

Longitudinal Commute Mode Share Research. The 2nd entry in Table 16-11 encapsulates the first of two before-and-after studies found to have information directly bearing on whether or not mode shifts to bicycle riding are brought about by bicycle lane introduction. In this research, 1990 and 2000 bicycle mode shares were obtained from U.S. Census journey-to-work data for the traffic analysis zones (TAZs) within the commutershed of three bicycle lanes and four off-road trails opened during the decade within the city limits of Minneapolis and St. Paul. The analysts experimented with alternative buffer zone and trip definitions for delineation of the commutershed. During this experimentation, it was discovered that many of the trips most affected were longer than the 5-mile limit initially imposed. Accordingly, the commutershed definition used for the final results covered all work purpose trips over 1 mile in length, generated within 1 mile of the facility or within 1.5 miles of the ends of the facility, but with inter-facility trips allowed. Table 16-12 gives the facility mileage and bicycle share results for the three bicycle lanes and four off-road trails (Barnes, Thompson, and Krizek, 2006).

Table 16-12 Before and After Commutershed Work Trip Bicycle Mode Shares for Three Bicycle Lane and Four Off-road Trail Provision Examples in Minneapolis-St. Paul

Bicycle Facility	Facility Mileage	1990 Bike Share	2000 Bike Share	Percentage Point Change	Percent Increase
Park/Portland Bike Lanes	4.0/4.2	3.49%	4.54%	1.05%	29.9%
Summit Ave. Bike Lane	4.6	1.00%	2.36%	1.36%	135.0%
University/4th Bike Lanes	1.6/0.8	6.10%	7.82%	1.72%	28.2%
Cedar Lake Trail [a]	7.8	2.50%	3.55%	1.05%	41.9%
Kenilworth Trail [a]	1.8	1.73%	3.04%	1.31%	76.0%
West River Parkway	8.0	5.48%	7.18%	1.70%	30.9%
U of MN Transitway [a]	1.9	6.37%	7.83%	1.46%	23.0%
Center Cities - All Work Trips	n/a	1.15%	1.39%	0.23%	20.2%

Notes: All facilities listed were implemented during the 1990-2000 period.

Trips under 1 mile in length excluded, except in "Center Cities - All Work Trips" row.

[a] Frequency of intermediate access points limited by topography or built environment.

Source: Barnes, Thompson, and Krizek (2006), with elaboration by the Handbook authors.

One circumstance that immediately stands out is that the 1990 "before" mode shares in the corridors slated for bicycle lanes and for off-road trails are substantially higher than for the Minneapolis-St. Paul Center Cities as a whole. This remains true even if commutershed trips of less than 1 mile are included for better comparability, although the differential is reduced. This finding will be referred back to in the discussion of causality in the "Bicycle Lane System Coverage" discussion to follow.

The Minneapolis-St. Paul research not only provides bike lane results, but also allows a comparison of the effect on commute trip bicycle mode shares of the three on-street bicycle lanes relative to the four shared use, off-road trails. As can be seen from Table 16-12, the increases in commutershed bicycle mode share ranged from 1.05 to 1.72 percentage points for the three bike lanes and from 1.05 to 1.70 percentage points for the four trails. The simple average bicycle commute mode share gain was 1.38 percentage points for both the three bike lanes and the four trails. Because the starting shares in the bicycle lane corridors tended to be lower, these gains translate to a 64 percent average increase for the bicycle lane commutersheds and a 43 percent increase for the off-road trail commutersheds. The absolute mode share gains in commuter bicycling were, however, essentially identical.

The results may also be compared to bicycle mode share growth in areas outside the facility commutersheds. In St. Paul, excluding trips under 1 mile in length, the 1990–2000 secular growth amounted to only 0.22 percentage points of commute trip bicycle mode share, a 50 percent increase over the low 0.453 percent 1990 share. In Minneapolis, the comparable statistics are 0.23 percentage points of commute trip bicycle mode share gain, a 24 percent increase over the 0.942 percent 1990 share (Barnes, Thompson, and Krizek, 2006).

Subsequent research applied the same general study approach in six additional U.S. cities and regions. Commutersheds were, however, defined as extending 2.5 kilometers (1.55 miles) from the various bicycle facilities studied and there may have been other analytical differences. Table 16-13 tabulates the findings for all types of facilities studied, by city/region. On-street facilities were analyzed in four of the cities, but only in Chicago were they explicitly identified as being bicycle lanes.

Table 16-13 Before and After Commutershed Work Trip Bicycle Mode Shares for Various Bikeway Types in Six Additional U.S. Cities and Regions

City/Region and Bicycle Facility Type	Statistical Significance	1990 Bike Share	2000 Bike Share	Percentage Point Change	Percent Change
Austin – signed routes	Yes	0.87%	1.19%	+0.32%	+36.8%
Austin – off-road trails	Yes	2.64%	3.52%	+0.88%	+23.9%
City of Austin, TX, overall	Yes	0.76%	0.95%	+0.19%	+25.0%
Chicago – bike lanes	Yes	0.35%	0.67%	+0.32%	+91.4%
City of Chicago, IL, overall	Yes	0.28%	0.50%	+0.22%	+78.6%
Colorado Springs – off-road paths	No	0.72%	0.76%	+0.04%	+5.6%
City of Colo. Springs, CO, overall	No	0.49%	0.55%	+0.06%	+12.2%
Madison – on-street bikeway	No	1.30%	1.62%	+0.32%	+24.6%
Madison – off-road paths	No	5.83%	5.70%	-0.13%	-2.2%
City of Madison, WI, overall	No	3.40%	3.28%	-0.12%	-3.5%
Salt Lake City – on-street bikeways	No	1.54%	1.53%	-0.01%	-0.6%
Salt Lake City – off-road paths	No	1.67%	1.27%	-0.40%	-24.0%
City of Salt Lake City, UT, overall	No	1.52%	1.49%	-0.03%	-2.0%
Orlando area – off-road trails	No	0.77%	0.61%	-0.16%	-20.8%
Orange County, FL, overall	Yes	0.66%	0.46%	-0.20%	-30.3%

Notes: All bikeways studied were implemented during the 1990-2000 period, but not all bikeway segments implemented during the period were deemed relevant for inclusion in the study.

Source: Cleaveland and Douma (2009), with elaboration by the Handbook authors.

The Chicago bicycle lanes were implemented during a period of increased bicycling advocacy and awareness campaigns. Implementation was also more-or-less concurrent with a major bicycle rack installation program (see 6th entry, Table 16-36, in the “Point-of-Destination Facilities” subsection under “Bicycle Parking and Changing Facilities”). The bike rack program and promotional campaign effects are impossible to disentangle from the bike lanes mode share effects. It may be noted, however, that the percentage point bicycle mode share gains were 45 percent greater within the defined bicycle lane commutersheds than for the city of Chicago as a whole (Cleaveland and Douma, 2009). While the bicycle work commute share percentage point gains were more modest along Chicago bicycle lanes than in Minneapolis, averaging 0.32 percentage points, the percentage increase was higher on average and the absolute numbers of cyclists involved were presumably appreciable given that radial routes to Chicago's CBD were involved.

The off-road path findings in Table 16-13 are discussed in the "Shared Use, Off-Road Paths and Trails" subsection under "Shared Use Path Implementation"—"Other Path Information," as are possible area-specific causes of the smaller to negligible work commute mode share impacts found for most types of facility introductions in the smaller and more spread-out urban areas. The on-street facility findings, other than the Chicago bike lanes already discussed, are examined further under "Bicycle Lane Variations, Bicycle Boulevards, and Other Signed Bicycle Routes."

The researchers in the six-region study take pains to emphasize that the Census-based results say nothing about effects on trips for errand-running or recreation/exercise, or even about student commuting to major universities as are found in Austin and Madison (Cleaveland and Douma, 2009). Neither this nor the Minneapolis-St. Paul research provides information on route shifting or induced bicycle travel. (Route shifting would not directly affect the reported mode share changes.)

Substantial route shifting is almost certain to have occurred in combination with such major mode shifts as were identified in most of the cities where on-street facility bicycle mode shift effects were examined. Thus, the average volume of commuter cyclists on the treated streets presumably increased by a larger percentage—likely a substantially larger percentage—than the 25 to 135 percent mode share gains identified in all but Salt Lake City. On the other hand, induced travel and destination shifts are probably negligible in the context of work purpose travel, the focus of the research.

Additional Information. Other relevant information can be gleaned from several of the studies. In San Francisco, the three examples reported on in Table 16-11 (averaging a 70 percent growth in bicycling along the affected streets) took place in a broader context involving 10.5 miles of new bike lanes. In this larger context, before-and-after analyses showed increases in bicycle counts ranging from 23 percent to 148 percent with an average of 50 percent (Morris, 2001). On the 2-mile Valencia Street corridor (6th entry in Table 16-11), the one-year evaluation that showed a jump in cycling volume from 88 to 215 bikes per hour also identified a slight reduction in vehicular Average Daily Traffic (ADT), from 22,200 to 19,700, concurrent with the 25 percent reduction in number of vehicular traffic lanes. Reported injury crashes in the corridor among road users, including pedestrians, bicyclists, and auto occupants, decreased by 15 percent (San Francisco Bicycle Coalition, 2001, BikeSummer '99, 1999).

Availability of both weekday and weekend before-and-after data from Oriental Blvd. in Brooklyn (9th entry in Table 16-11) indicates that the relative weekday impact of bicycle lane implementation was some 7 to 8 times the weekend increase in bicycling, skating, and scooter use. The Saturday-only data from the Fort Lauderdale, Florida, beachfront (10th entry) shows the proportion of NMT volumes made up by cyclists using the street (not the sidewalk) as increasing from 9.5 to 10.9 percent with the implementation of bike lanes (Chaney, 2005). This is a rather modest increase, essentially the same order of magnitude as the 7 percent Brooklyn weekend cycling increase.

The California SRTS studies (12th entry in Table 16-11) found no statistically significant evidence of an effect on bicycling to school with bicycle lane installation (Boarnet et al., 2005b). In Davis, California, after installation of bike lanes on Anderson Road (1st entry in Table 16-11), only seven bicyclists were estimated to be of age 11 and under, while 41 were judged to be between 12 and 17 years of age, out of 1,577 on Anderson during 3 peak-period hours. That is 0.4 percent and 2.6 percent, respectively, a total of 3 percent children and adolescents (Lott, Tardiff, and Lott, 1979). These findings from Brooklyn, Fort Lauderdale, and California could be the beginning of a still very tentative thesis that bicycle lanes offer relatively little attraction for increased cycling at times or by groups likely to be characterized by presence of youngsters and high proportions of bicyclists with modest skill levels.[17]

The Fell Street counts in San Francisco (8th entry in Table 16-11) and the counts in Fort Lauderdale (10th entry) provide information on efficacy of bicycle lanes in attracting cyclists off of parallel sidewalks. These findings are examined in the "Sidewalk Use by Bicyclists" discussion at the close of the "Sidewalks and Along-Street Walking" subsection, along with similar information by bicyclist age category from the Davis research.

Not covered in Table 16-11 are Portland or Corvallis, Oregon, both of which have very extensive bicycle lane systems relative to their size. Portland's dramatic results are addressed further on, in the "Pedestrian/Bicycle Systems and Interconnections" and "NMT Policies and Programs" subsections. Corvallis, a community of roughly 50,000 population, early on had the highest bicycle commute mode share in the state of Oregon, at 8 percent. Some credit the fact that over 90 percent of the collector and arterial streets have striped bike lanes (RTC and APBP, 1998). Better established is the finding that crashes in the community involving bicycles dropped from 40 in the year before the lanes (October 1980 through September 1981) to 16 in the year following lane installation (Environmental Working Group et al., 1997).

Also not listed in Table 16-11 are results for multiple bike lane installations in Hull, England. Six monitored locations exhibited cycling increases from before to after bike lane introduction ranging from no change to 138 percent growth. The average increase was approximately 36 percent. This average lies within the range of North American city averages. Roughly paralleling the Corvallis experience, a 45 percent reduction in bicycle casualties was observed. This reduction was accompanied by an 11 percent decline in pedestrian casualties (Booz Allen Hamilton, 2006).

Bicycle Lane System Coverage

Table 16-14 summarizes research on the overall effect of bicycle lane coverage on prevalence of bicycle riding. The first four study entries are progressively more advanced works done on a national level by examining facility extent and bicycle commute shares in 18 to 90 U.S. cities. Limitations to be kept in mind with respect to these four studies are that all use city-level aggregate data, focus only on adults, and address neither non-work-purpose utilitarian travel nor recreational/exercise activity. Also, the first two use a combined bikeway coverage measure including both on-road bicycle lanes and shared use, off-road paths and trails. The 3rd study began by exploring a combined measure but found the strongest relationship for bicycle lanes alone. The 4th study explicitly demonstrates strong roles for bicycle lanes and for off-road paths.

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[17] At least two areas in addition to the California example have installed bicycle lanes as an element of safe-routes-to-school infrastructure (Petal, Mississippi, and Auburn, Washington), but with usage results unreported (National Center for Safe Routes to School, 2010).

Table 16-14 Summary of Research Findings on the Relationships of Bicycle Lane and Other Facility Prevalence with Cycling Activity

Study (Date)	Process (Limitations)	Key Findings
1. Goldsmith (1992)	Tabulated and averaged bicycle commute mode share for U.S. cities grouped by ratio of bikeway to arterial street miles. (No statistical tests, work purpose trips only.)	Bikeway/arterial ratio of less than 0.035:1 (8 cities) associated with 0.63% bicycle share versus 6.80% for 10 cities with a ratio over 0.035:1 (or 1.96% share omitting the 6 "university towns").
2. Nelson and Allen (1997)	With 16-city data from Goldsmith (1992) (Davis and Palo Alto omitted), plus the percentage of college students among residents, conducted a cross-sectional analysis relating facility miles per 100,000 population to bike commute mode share. (City-level aggregation, work trips only.)	The derived linear relationship found 0.069% more commuter cycling for each additional bikeway mile per 100,000 population. Fewer rain days/year and higher ratios of college students were also positively related with bike use. Temperature and terrain were weak/ambiguous variables.
3. Dill and Carr (2003)	With Census 2000 Supplemental Survey data, plus bike lane and off-road path and other data, undertook a cross-sectional analysis for 42 large cities relating bicycle infrastructure and other measures to commute trip bicycle mode share. New York City had a "dummy variable" (negative) in the final model. (City-level aggregation, work purpose trips only.)	Combined bike lane/path measures significantly related to cycle share but bike-lane miles per sq. mile itself was the strongest infrastructure variable. In the 42-city model each additional bike-lane mile per sq. mile was associated with roughly a 1 percentage point gain in commuter cycling share. Rain days and vehicle ownership were negatives; state spending on NMT was a positive.
4. Buehler and Pucher (2011) (see this section for more information)	Further expanded on the Nelson and Allen (1997) and Dill and Carr (2003) approaches, using 2006-2008 3-year average American Community Survey (ACS) cycling level data plus bike lane and path supply data for 90 of the 100 largest U.S. cities, collected by others directly from each city. Three forms of regression were used along with alternative dependent variables: bike commuters per 10,000 residents and work trip bicycle mode share. (City-level aggregation, work purpose trips only.)	Multiple regression coefficients on bike lanes, and on paths, highly significant. Bike lane coefficients a little different in each model set than bike path coefficients, but differences never statistically significant. Inelastic demand shown, e.g.: 10% more bike lanes = 2.5% more bicycle commuters (per 10,000 population); 10% more bike paths = 2.6% more bike commuters. Days over 90º F and higher bike fatality rates were negatives; western U.S. location, overall denser/older housing/fewer cars, and higher student ratios were positives.
5. Moudon et al. (2005) (see "Ped…cycle Friendly Neighborhoods" for more information)	Cross-sectional analysis of cycling activity, socio-demographics, attitudes, and perceived plus objectively measured environmental variables in King County, WA. (Evidence of neighborhood "self-selection" in 1/3 of cyclists.)	Objectively measured presence of bike lanes was not significantly related to cycling at least once a week, though a perception of combined trail and bike lane presence did have a positive relationship with cycling, as did objectively measured closeness of trails.

Table 16-14 (Continued)

Study (Date)	Process (Limitations)	Key Findings
6. Ewing et al. – 2004 as summarized by Davison and Lawson (2006)	Utilized objectively measured cross-sectional data to model the effect on walk/bike school access of sidewalk characteristics, bike lanes or paved shoulders, accessibility, and density.	Student cycle-to-school shares showed a significant negative relationship with estimated bike time to school. Failed to find any relationship between bicycle lane availability and cycling to school.

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Goldsmith (1992) and Nelson and Allen (1997) combined bicycle lanes and off-road facilities in their quantitative (observed) measure of facility prevalence.

Sources: As indicated in the first column.

All four national research efforts found a strong positive association between bicycle facility coverage and bicycle use for commuting to work. The quantitative relationships derived, and other factors found to have an influence, are enumerated in the "Key Findings" column of Table 16-14. The parameters examined and the detailed results obtained vary among the studies, limiting any additional specificity with which overall conclusions can be drawn. Nevertheless, the three studies that developed research models (2nd through 4th table entries) all demonstrate positive but inelastic commuter bicycling demand for additional bicycle facilities (Goldsmith, 1992, Nelson and Allen, 1997, Dill and Carr, 2003, Buehler and Pucher, 2011).

The 4th Table 16-14 entry, the national study covering 90 cities and utilizing 2006–2008 journey-to-work travel data, was able to estimate separate, highly significant model coefficients for both bike lanes and paths (miles per 100,000 population in all cases). Six different final research models were developed, including both ordinary least squares regressions and binary logit proportions models, and estimating bicycle commuters per 10,000 population in four cases and bicycle commute trip mode shares in two cases. Adjusted or pseudo R^2 values ranged between 0.60 and 0.62, indicating a good fit with the data in each case. With a bicycle fatality rate variable (significant), 10 percent more bike lane miles (per 100,000 residents) were associated with 2.5 percent more bicycle commuters (per 10,000 population) and 10 percent more bike paths were associated with 2.6 percent more bike commuters. The overall study results indicate an elasticity of +0.25 for the positive association of both bike lanes and off-road paths with bicycle commute levels in U.S. cities.

In two of the six models for the 90-city research, the fatality variable was omitted because of concerns about causality and fatality-rate approximation. Without the fatality variable, path mileage was estimated to be about 1/3 more important than bike lane mileage for describing bicycle commuters per 10,000 population. For estimating bicycle commute mode shares, the importance of lanes and paths reversed, with bike lanes exhibiting the higher coefficient. As indicated in Table 16-14, estimated differences in relative importance of bike lane extent and bike path extent were in no case statistically significant (Buehler and Pucher, 2011).

The authors reporting on the nationwide city-level cross-sectional analyses all emphasize that while the positive relationship found between bicycle facility coverage and work trip usage levels is strong, it does not prove causality. Additional bicycle facilities may beget more commuting to work by bicycle, or there may have been inherently higher bicycle volumes in some areas to start with, leading to successful agitation for and construction of more bicycle facilities (Nelson and Allen, 1997, Dill and Carr, 2003, Buehler and Pucher, 2011).

Indeed it was observed above, with respect to the 1990–2000 decade in Minneapolis-St. Paul, that the corridors where bicycle lanes and off-road trails were built tended to have substantially higher bicycle commuting shares to start with. Growth in bicycling mode share did occur in parallel with implementation of the new facilities, but it was fractional compared to the preexisting differential in bicycle commuting between the corridors gaining facilities and other areas. The Twin Cities researchers noted this as a demonstration of "the risks inherent in trying to deduce the impact of facilities by trying to compare [. . .] different places" (Barnes, Thompson, and Krizek, 2006).

It is reasonable to assume that both effects play a role in the relationships found in the cross-sectional analysis research: better bicycle facility coverage producing heightened levels of bicycle commuting, and higher volumes of bicycling supporting more facility implementation (Nelson and Allen, 1997). Nevertheless, survey data on alternative or prior modes of travel of users of new NMT facilities do show that mode shifts play a role in facility usage (see, for example, "Related Information and Impacts"—"Travel Behavior Shifts").

The King County, Washington, research entered as the 5th study in Table 16-14 provides the only bicycle lane system coverage findings in the table applicable to bicycling for all purposes, including the work commute, other utilitarian travel, and recreational/exercise activity. In this study, a perception of bike lane and/or trail presence was found to have a positive relationship to actual bicycling activity, but not objectively measured presence of bike lanes. The objective facility presence measure that did have a significant relationship was measured closeness to off-road trails, not bicycle lanes (Moudon et al., 2005).

This finding can be regarded as offsetting study findings such as presented in the 3rd entry of Table 16-14, namely, that the strongest relationship is between bicycle lane coverage and (commute) mode share. Indeed, the totality of evidence presented in this subsection suggests that either bicycle lanes or off-road paths may attract the most bicycling depending on circumstances. An alternative interpretation may prove to be, however, that the strength of off-road paths lies more in supporting other trip purposes other than commuter cycling. Bicycling to work is the only component of cycling activity addressed by much of the bicycle lane research available, limiting conclusions at this point.

The final entry in Table 16-14 reports results of cross-sectional modeling of school access NMT facility characteristics and mode use. This study failed to find any relationship between bicycle lane availability and cycling to school (Davison and Lawson, 2006). Although this study represents only one data point among the relatively few evaluations of bike lane use by schoolchildren, it does combine with the findings discussed with reference to Table 16-11 to lower expectations of success in employing bike lanes for school access—particularly in the case of elementary and intermediate schools—or for use with any population characterized by low prevalence of cyclists with high experience levels. An additional cross-sectional child-focused study from the same review does not shed much additional light on the issue. It found Australian adolescents to walk and bike more where roads were perceived to be safe, but this logical finding was paired with others less intuitive, such as the odd finding that boys were more likely to cycle where it was less easy (Davison and Lawson, 2006).

Bicycle Lane Variations, Bicycle Boulevards, and Other Signed Bicycle Routes

On-street bicycle facilities and provisions, other than conventional bicycle lanes, are addressed in the following discussion. At the high end of the cost and space-requirement spectrum are cycle tracks and buffered bike lanes. At the other end of this spectrum are wide curb lanes, bicycle boulevards, and streets that have been simply signed as bike routes. The available traveler response research on these options is relatively limited, either because they are somewhat new concepts—especially in a U.S. context (cycle tracks and bicycle boulevards)—or because they exist mostly "below the radar" (wide curb lanes and signed bicycle routes).

Cycle Tracks. Physical separation, in contrast to only painted traffic lines and colors, is used in constructing on-street cycle tracks. This separation is accomplished with raised traffic separators, bollards, or on-street parking, or by raising the cycle track itself to introduce a grade differential. Buffered bike lanes are included in the Portland, Oregon, analysis introduced here. They employ a buffer strip between bicycles and motor vehicles that is marked with traffic paint (NACTO, 2011).

A before-and-after study of cycle tracks in Copenhagen conducted 1,000 interviews and 1,500 counts, and analyzed 8,500 crashes. Usage of bike lanes and cycle tracks in Copenhagen is 95 percent bicycles and 5 percent mopeds. Installation of conventional bike lanes was accompanied by a 5 to 7 percent increase in cycle/moped traffic and no change in vehicular traffic volumes on affected streets. Construction of cycle tracks was, in contrast, accompanied by an 18 to 20 percent increase in cycle/moped traffic and a 9 to 10 percent decrease in vehicular traffic on the streets involved.

Copenhagen cyclists were found to feel much safer on conventional bike lanes than in mixed traffic, and even more secure on the cycle tracks. For example, 11 percent of cyclists felt "very safe" in mixed traffic, 32 percent felt so in bicycle lanes, and 46 percent felt very safe on the cycle tracks (Jensen, Rosenkilde, and Jensen, 2007). Actual safety results could, however, be described as mediocre. Safety and cyclist-interaction conclusions from this and the other cycle track studies covered here are summarized in the "Related Information and Impacts" section under "Safety Information and Comparisons"—"Facility Type Safety Comparisons"—"Cycle Track Versus Other On-Road Cycling Safety."

Montreal has been a major early adopter of cycle tracks in North America, with a longstanding network. A detailed safety study developed comparisons of bicycle usage between the six studied cycle tracks and mostly parallel "reference streets." The reference streets had no bicycle facilities. Simultaneous 2-hour counts were used for the comparison. The cycle tracks were found to have 2-1/2 times the bicycle traffic of the reference streets. Cycle track 2-hour volumes, time of day not indicated, ranged from 109 to 1,193, averaging 668 bicycles. As covered in the "Cycle Track Versus Other On-Road Cycling Safety" discussion, the average risk of injury for bicyclists on the cycle tracks was found to be 72 percent of the risk per bicyclist cycling in the mixed traffic of the reference streets (Lusk et al., 2011).

Portland, Oregon's 2009 installations of a cycle track and a pair of buffered bike lanes were analyzed too soon after implementation for rigorous bicycle volume analysis. Among survey respondents, 70 percent felt the SW Broadway cycle track had made bicycling easier and safer as compared to the prior bike lane configuration. The proportion of bicyclists on Broadway cycling in mixed traffic, rather than on the available bicycle facility, fell from 12 to 2 percent. Surveyed bicyclist reaction to the SW Stark and State Streets buffered bike lanes was similar, with 9 in 10 indicating preference for the buffered lanes as compared to standard lanes. This one-way couplet had not had bicycle lanes previously. Stark/State bicycle counts were up at least 75 percent in the "after" condition (Monsere, McNeil, and Dill, 2011).

A Burrard Bridge trial reallocation of roadway and sidewalk space in Vancouver, British Columbia, Canada, adds additional insight given that the resulting bicycle provisions, while unusual, fit the definition of cycle tracks. The physical arrangement is described in the "Pedestrian/Bicycle Systems and

Interconnections" subsection under "River Bridges and Other Linkages"—"Other River Bridges." Two different analysis approaches indicated that the change from mixed-use sidewalks to segregated cycle-track equivalents increased bicycling by 26 percent (count-based results) to perhaps a doubling of bicycle-use incidence by bridge neighbors (survey results). Importantly, the count-based increase was composed of a 31 percent increase for bicycle crossings by women versus a 23 percent increase for men, suggesting that increased bicycling comfort levels had attracted more cycling by females in particular (City of Vancouver, 2009a).

Wide Curb Lanes. Wide curb lanes can be considered a variation on marked bicycle lanes and have been supported by some as an alternative. They do not have lane-line or barrier separation of bicycles from vehicles, but do feature added lateral road width compared to a normal traffic lane. They do not require quite as much street width as adding a standard bike lane. The extra width enables more comfortable passing of bicyclists by motorists. Bike routes on roads with wide curb lanes are sometimes designated using signs and/or chevron pavement markings. Earlier, in Table 16-11, the 6th entry provided one example wherein a 28 to 41 percent bicycle count growth was observed with a San Francisco project (Polk St.) that involved bike lanes for part of the distance and wide curb lanes for the remainder (Chaney, 2005).

It has been noted in opinion survey findings that people express a preference for marked bike lanes over wide curb lanes. A comparative analysis of bicycle lanes versus wide curb lanes concluded that either facility was acceptable, but recommended that where adequate road space was available regular marked bicycle lanes be used, given their apparent popularity (Hunter et al., 1999). The appropriateness of this conclusion is further supported by the bicyclist and motorist positioning studies presented earlier, at the start of the "Popularity, Preferences, and Route Choice" discussion.

Bicycle Boulevards. An approach introduced in some cities to providing on-road bikeways is "bicycle boulevards." Bicycle boulevards are a shared-roadway strategy applied on low-volume, low-speed streets enhanced for cycling with preferential traffic calming, intersection crossing assists, pathfinder signing, and other treatments to provide a "bicycle arterial" that is mostly stop-free (Alta Planning + Design, 2009a, Ciccarelli, 2010). Vehicles and bicycles are, for the most part, not physically separated. Streets used may be local streets with a history of low vehicular volumes and speeds, streets deliberately traffic calmed, or both. For example, Berkeley's grid system of seven bicycle boulevards evolved from a 1969 traffic calming plan and system. It was converted in 1999 by providing traffic diverter pass-through linkages, substituting alternative traffic calming devices for boulevard-facing stop signs, and adding other bicycling enhancements. Additional techniques commonly used to provide bicycle boulevard connectivity for through-traveling cyclists include linking isolated street segments with short bicycle paths or bridges and providing traffic signals or special geometric design aids for crossing busy streets (Pedestrian and Bicycle Information Center, 2010).

Bicycle boulevards may hold a greater attraction for the average cyclist than conventional bicycle lanes. This has been quantified for adults in the case of Portland, Oregon (Dill and Gliebe, 2008, Broach, Gliebe, and Dill, 2009a and b, Broach, Gliebe, and Dill, 2011), as covered under "Popularity, Preferences, and Route Choice"—"GPS- and Network-Based Revealed Preference Research." It is interesting to note that Emeryville, California's, Horton-Overland Bicycle Boulevard was a bicycle facility solution adopted after consideration of needs of "design cyclists" (a takeoff on highway "design vehicles") of varying skills and preferences (Pedestrian and Bicycle Information Center, 2010).

The Portland studies have led to observation that "there is something more to a bike boulevard than low traffic volumes, improved street crossings, and 'flipped' stop signs. The something more may be explained by attributes [. . .] such as parking or traffic speeds, or perhaps something more subtle like perceived safety in numbers or simplified navigation." The Portland researchers have taken care to note the need for further research and especially for replication of the GPS route choice studies in other regions (Broach, Gliebe, and Dill, 2011).

Table 16-15, below, encapsulates the few available reportings offering bicycle boulevard usage information. The 1st table entry is believed to be the earliest U.S. bicycle boulevard, on Bryant Street, in Palo Alto, California. As indicated, initial-phase before-and-after observations found an 85 to 97 percent increase in bicycling on the street. The increase was greater than citywide upward trends, but with evidence of bicyclist diversion from parallel streets. Bryant Street serves several schools. Making a later comparison between a 1997 8-hour count of 385 bicycles and the 1982 12-hour volumes ranging

Table 16-15 Summary of Studies of Individual Bicycle Boulevard Provision Examples

Study (Date)	Process (Limitations)	Key Findings
1. Ciccarelli (2010) (see this section for more information)	Bryant Street in Palo Alto, CA, was converted to a bicycle boulevard in 2 segments. The 1.9-mile southern section (1981) included a new traffic signal, with right-turn-only vehicle diverters on Bryant, and a pair of NMT-only bridges over a creek. The 1.2 mile northern section (1992) penetrates the CBD and has no street closure element. (Before/after counts for southern section only.)	May 1981 and April 1982 12-hour counts found 85% and 97% bicycling increases at 2 locations on Bryant St. Volumes ranged from 475 to 725/day. Bike volumes on 2 nearby multilane streets declined by 35% and 54%. Vehicle traffic volumes near the 2 street closures went from 953 to 457 and from 481 to 170, with diversions to adjacent streets. A May 1997 8-hour intersection count found 385 Bryant St. bikes.
2. Chaney (2005), City of Vancouver (2009c) (see this section for more information)	Three Vancouver, BC, bicycle routes with many bicycle boulevard characteristics, 5.5 to 14 km. long and implemented in the 1990s, have had multiple-location before and after counts published in the form of average 24-hr. weekday volumes estimated from 1- or 2-hour counts. (No diversion investigations.)	Average 24-hour weekday "after" bicycling ranged from 39 to 1,086 on individual segments. Average "after" for Adanac Bikeway was 743 (4 locations, up 272% in 5 years), average for Off-Broadway was 351 (5 locations, up 76% in 2 years), "after" average for Midtown/Ridgeway Bikeway was 114 (7 locations, up approximately 333%). [a]
3. Alta Planning + Design (2009a)	The Lincoln-Harrison bicycle boulevard in Portland, OR, 3 miles long, started with traffic calming in the 1980s and 1990s, with wayfinding signage and pavement markings in 2005.(No information on study methods.)	"After" bicycle "extrapolated total count" of 1,900 in 2008, up 755% since 1996 (presumably including secular growth associated with development of Portland's overall bicycle facility network).
4. VanZerr (2010) (see this section for more information)	Portland, OR, dwellings facing the SE Salmon St. bicycle boulevard between SE 12th and SE 35th Aves. received invitations to an on-line computer survey: 78 households (31%) responded. (No bike volume data, potential response-rate biases.)	Of residents choosing to respond, 6% typically cycled 6-7 days/week; 29%, 4-5 days; 18%, 2-3 days; 18%, 1 or fewer days; 28%, never. Typical destinations were social/recreational (82%), shopping/errands (61%), work (59%). Bicycling rates exceeded U.S./local norms.

Notes: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

[a] Averages and percentage increases calculated by the Handbook authors. Only those count locations with data clearly for both "before" and "after" conditions are included.

Sources: As indicated in the first column.

from 475 to 725, the Bryant Street PBIC case study author surmised that commuter and other utilitarian bicycling had declined in the two decades since the peak of the 1970s gas crises, and that more parents were chauffeuring their children to school by auto (Ciccarelli, 2010). The 1982 count data in Table 16-15 may be used to estimate that the first phase traffic mix on the Bryant Street bicycle boulevard was, at least near street closure locations, roughly two bicycles for every single motorized vehicle.

The 2nd table entry presents before-and-after count results for three "local-street Bikeways" in Vancouver, British Columbia, Canada. These are signed bicycle routes on mostly residential, mostly narrow streets, enhanced with sufficient traffic-calming and bicycle-preference engineering features to be properly considered as bicycle boulevards. A few short elements of off-road paths and "paper street" path segments were apparently included at the time of implementation, but it is believed that there were no sections of bicycle lanes as of the dates of the "after" studies (Chaney, 2005, Alta Planning + Design, 2009a, City of Vancouver, 2009c, Navin and Anderson, 2009).[18]

Before-and-after bicycle counts, taken at multiple points on each Vancouver "Bikeway," show weighted-average 2- to 5-year cycling increases per Bikeway of 76 percent, 272 percent, and approximately 333 percent. These increases include not only effects of each new Bikeway but also a general upward trend in bicycling within Vancouver proper (Chaney, 2005). Bicycle trips within and to Vancouver increased by 180 percent between 1994 and 2004 (City of Vancouver, 2009b), thus the upward secular trend would have been on the order of 18 percent per year. It is of interest to note that these fairly modest but carefully selected, augmented, and well-integrated Bikeway routes seem to be full players in an apparently very successful citywide bicycle facility grid.

Portland, Oregon, is an example of a city within the United States that has implemented bicycle boulevards on a number of streets. The 3rd and 4th entries within Table 16-15 pertain to the Lincoln-Harrison and SE Salmon Street bicycle boulevards. The Lincoln-Harrison facility attracts an estimated 1,900 bicycle trips daily (Alta Planning + Design, 2009a). No count information is provided for SE Salmon Street, but it is 1/2-mile south of and parallel to the Lincoln-Harrison bicycle boulevard, and thus part of the same Portland bicycle facility network. It is included in the tabulation for the related information obtained in a survey of dwellings facing Salmon Street. For example, asked if they enjoyed living on a bicycle boulevard, two out of three survey respondents liked it "A lot," while only one in nine responded "Not at all." The rest of respondents were indifferent or liked it "A little."

The bicycling activity reported by responding Salmon Street residents (see Table 16-15) seems to far exceed national averages. Some 59 percent of respondents fronting the Salmon Street bicycle boulevard reported cycling at least 1 day a week (VanZerr, 2010). Comparisons must be made with caution, given that survey response within households of Salmon Street survey respondents was a personal choice among household members rather than random or pre-defined selection. (The 31 percent survey response rate pertains to contacted dwellings, not individuals.) Still, comparison is of interest considering that the 2001 NHTS found only 4.5 to 12.7 percent (among covered Metropolitan Statistical Areas) of surveyed individuals to have cycled sometime during a week (Krizek et al., 2007).

[18] The term "paper street" refers to linear segments of land dedicated/acquired for use as street right-of-way but never built upon for the purpose. Their use for paths connecting between built streets does not violate their utility as impediments to undesired through traffic.

The Salmon Street study author identifies potential survey biases, but if there were no response bias at all in the survey, the identified bicycling rate would be nearly 7 times national averages. The Salmon Street analysis itself reports a work commute bicycling rate comparison that suggests the Salmon Street rate may be on the order of 10 times the citywide bicycle commute mode share (VanZerr, 2010), remarkable even if definitional differences and bias issues exaggerate the differential. (More information on national bicycling rates is found in the "Related Information and Impacts" section under "Extent of Walking and Bicycling"—"Extent of Bicycling.")

Housing choice "self-selection" may be a factor for bicycle boulevards. Among responding Salmon Street residents, 18 percent indicated that bicycle boulevard status was a positive factor in housing choice. No one selected the "negative factor" questionnaire option. Persons residing on the street prior to bicycle boulevard designation constituted 33 percent of respondents, 29 percent didn't know it was a bicycle boulevard when they moved in, and 20 percent knew but didn't factor it into their housing choice decision. An analysis was made of the combined effect of self-selection—positive factoring of the bicycle boulevard into the housing location decision—and a perception, also reported in the survey, that living on a bicycle boulevard makes bicycling more likely. Four combinations were identified and group average days per week of bicycling were calculated (VanZerr, 2010):

- Persons who self-selected and also perceive the bicycle boulevard presence makes them more likely to bicycle (15 percent of respondents) bicycled 3.59 days/week on average.
- Persons who did not self-select (for whatever reason) but do perceive bicycle boulevard presence as making them more likely to bicycle (32 percent of respondents) bicycled 2.44 days/week on average.
- Persons who self-selected but do not perceive the bicycle boulevard presence makes them more likely to bicycle (4 percent of respondents) bicycled 2.39 days/week on average.
- Persons who neither self-selected nor perceive bicycle boulevard presence makes them more likely to bicycle (50 percent of respondents) bicycled 1.92 days/week on average.

The limited quantifications of bicycle volume increases with bicycle boulevard introduction compare favorably with increases reported for bicycle lanes. The tripling of on-street bicycle volumes on average for the three early facilities in Vancouver, and the huge increase reported over time for the Lincoln-Harrison bicycle boulevard in Portland (Table 16-15), are much more than the four-city growth average for bicycle lanes of approximately 50 percent derived earlier from Table 16-11. On the other hand, absolute peak-hour "after" volume counts reported for the Vancouver facilities (not published for the more heavily used Lincoln-Harrison facility in Portland) show a moderate facility average of about 50 cyclists per peak hour (Chaney, 2005). This bicycle usage is about 1/3 less than the average for the four bike lane cases for which peak period or one-hour volumes are provided in Table 16-11 (San Francisco and Fort Lauderdale).[19]

The point here is neither to offer a precise bicycle volume growth estimate for either bicycle lanes or boulevards, from this small sample, nor to establish bicycle lane or boulevard volume averages.

[19] Peak period bike lane volumes are given for Anderson Road in Davis within case study Table 16-134, but this is a statistical outlier, where both the "before" bicycle volumes (with no special bicycle treatment) and the "after" volumes were an order of magnitude higher relative to the more typical bicycle volumes reported here.

More volume data should become available from the "National Bicycle and Pedestrian Documentation Project" or similar endeavors as they mature (see the "Additional Resources" section). The bottom line is that, on the basis of aggregate growth and volume measures, both bicycle lanes and bicycle boulevards show roughly equivalent promise in terms of volumetric traveler response to on-road facilities. Area characteristics may, of course, dictate bicycle lane versus bicycle boulevard strategy selection as a result of physical restraints and opportunities. These same area characteristics may also influence usage. Bike lanes are typically placed on arterial or collector streets and in downtowns, while bicycle boulevards are most suited to low vehicular volume, mostly residential, continuous or interconnected local streets.

It should also be borne in mind that additional research may show one or the other treatment to be more effective for individual disaggregate categories of existing or potential cyclists. In this connection, evidence that Portland's bicycle boulevards are especially attractive to female cyclists is presented in the "Underlying Traveler Response Factors" section (see "Trip Factors"—"Bicycle Trip Distance, Time, and Route Characteristics"—"Bicycle Route Choice").

Signed Bike Routes. One study encountered addresses commute mode shifts to bicycling in commutersheds of newly signed bike routes. Austin, Texas, implemented roughly 20 bike route segments during an analysis period of 1990–2000. City staff worked with the local bicycling community to identify routes already favored by cyclists as being bicyclist-friendly. The typical such route is a residential street running parallel to major arterials. The analysis was part of the six-city commute mode shifts study summarized in the 3rd entry of Table 16-11. It produced the results entered in Table 16-13. The signed bike route commutersheds in Austin, which together encompassed roughly one-half or more of the city's geographic area, exhibited an 0.32 percentage point gain in bicycle commute mode share relative to 0.19 percentage points for the city as a whole. The corresponding bicycle share growth rates were 37 percent around the bike routes and 25 percent citywide. Commute mode changes were also reported for two cities implementing "on street bikeways," –0.6 percent in Salt Lake City and +24.6 percent in Madison, Wisconsin (Cleaveland and Douma, 2009).

The other bit of information on signed bike route attractiveness comes from the follow-up Portland bicyclist route choice model development process. They were tested as a facility type and it was concluded that unimproved signed bike routes were "insignificant factors" once other variables were accounted for (Broach, Gliebe, and Dill, 2011).

As is the case with bicycle lane count-based studies, the bicycle boulevard and route studies provide only partial or no information on diversion of bicyclists to the facility relative to bicycle trips resulting from mode shifts, shifts in destination, or induced cycling. (Some diversion information is available for Palo Alto—see the 1st Table 16-15 entry.) Similarly, no surveys of bicycle boulevard or route user makeup have been encountered beyond the survey responses by adjacent residents along the Salmon Street bicycle boulevard and the one set of in-parkland bike route observations provided in the Montgomery County, Maryland, case study. Primary cycling destinations of the Salmon Street residents have been included in Table 16-15.

Shared Use, Off-Road Paths and Trails

The off-road, shared use facilities addressed in this subsection are the counterpart to the combination of sidewalks, on-road bicycle lanes, and shared-roadway bicycle-preference treatments covered in previous subsections. Shared use paths accommodate pedestrians (inclusive of manual and motorized wheelchairs), cyclists, and other non-motorized wheeled users, including in-line skaters when pavement and design conditions allow (AASHTO, 1999). Despite the popular "bike path" appellation, such facilities are very rarely if ever restricted to bicycles alone in the United States. As noted earlier in Footnote 3 of the "Overview and Summary," although "path" is the preferred technical term for urban applications, local-area usage of the term "trail" has been adhered to where known.

The subsection title, "Shared Use, Off-Road Paths and Trails," is intended to convey that pedestrian-only walking and hiking trails are, except in special cases, not covered. Neither are on-road separated facilities such as cycle tracks and buffered bike lanes, these having been included in the "Bicycle Lane Variations, Bicycle Boulevards, and Other Signed Bicycle Routes" discussion immediately preceding.

Preferences, Route Choice, and Walk/Bikesheds

The opportunity for cyclists to route their bicycle trips over specially designed facilities, such as bike paths, bike lanes, or bicycle boulevards, is demonstrably an encouragement to cycling. Each of these facility types designates physical space for bicycle use and addresses two key underlying traveler response factors: perceived safety and travel time. Different cyclists may prefer to use different facility types for different trip or recreational/exercise purposes. Bicycle lane versus off-street path preferences have been examined in the preceding "Bicycle Lanes and Routes" subsection. The comparative assessments are primarily contained in the "Popularity, Preferences, and Route Choice" discussion, but there is related information under "Bicycle Lane System Coverage" as well.

Comparative Preferences Recapitulation. Much of the overall body of research on bicyclist preferences for off-road path use as compared to bicycle lane use has produced seemingly inconsistent results. Also, a majority of the research has focused only on the bicycle-to-work commute, not other uses. A tentative conclusion that either facility type may be equally useful and attractive for bicyclists overall seemed to fit study results produced prior to findings emerging from GPS-and-network-based research in Portland, Oregon (Tilahun, Levinson, and Krizek, 2007).

The Portland findings, at this point not yet replicated elsewhere, indicate a bicyclist preference hierarchy that applies to both work purpose and other utilitarian trips so long as alternative facility types afford adequately direct routings. In this hierarchy, off-road paths are the most preferred facility type, followed by bicycle boulevards, in turn followed by conventional bicycle lanes or quiet residential streets, and with all of these being more preferred than bicycling on moderately or very busy streets with no special treatment (Dill and Gliebe, 2008, Broach, Gliebe, and Dill, 2009a and b, Broach, Gliebe, and Dill, 2011). Limited experience with cycle tracks and other separated on-street facilities is promising but does not yet allow estimation of their place within this hierarchy.

U.S. off-road paths and trails serve a broader clientele than bicycle lanes and other on-road bicycle facilities, which obviously cannot serve NMT users such as pedestrians or joggers the way multi-use paths do. The choice for users on foot is not between paths, bike lanes, and streets, but between paths, sidewalks, and sides or shoulders of streets and roads. This is a choice afforded very little research, although it has been shown that path proximity will lead to more path use (but not necessarily more walking). (For more information, see discussion in connection with Table 16-19, 1st and 4th entries.)

A relevant circumstance affecting all facility types is that selection of a facility type for implementation will often be dictated by individual geographic, physical, and/or traffic conditions. Those, in turn, will be determined by the potential trip origins and destinations proposed to be served.

There is reason to be concerned that in GPS- and network-based studies, important differences in preferences among disparate user groups may have failed to surface in the aggregate-data and often commuter-focused analyses that predominated. Because these issues are covered elsewhere, treatment of them in this subsection is limited to additional information focused exclusively or substantively on path use. Reference should be made back to the "Bicycle Lanes and Routes" subsection for a more comprehensive overall discussion from the perspective of bicycling. In addition, the "Underlying Traveler Response Factors" section further explores differences among distinct user groups. See the "Trip Factors" subsection (discussion of Table 16-67) as well as "User Factors."

The 2002 national survey on pedestrian and bicyclist attitudes and behaviors found that bicycle and walking paths and trails were "most used" in undertaking the respondents' most recent trip in the case of 6 percent of all walk trips and 13 percent of all bicycle trips (NHTSA and BTS, 2002). (For the full tabulation see Table 16-96 under "Related Information and Impacts"—"Facility Usage and User Characteristics"—"Frequency of Facility Usage by Facility Type.") In contrast, a survey of Florida residents making at least 1 bike trip in the past 7 days found that 27 percent of their trips were mostly on bike paths and another 18 percent were partially so (NuStats International, 1998). As previously noted, with regard to this type of information, the facility choices reported could be the result of either facility-type preference or facility orientation/availability with respect to travel needs, or both.

Route Deviation to Use Paths. Portland, Oregon, bicycle facilities region-wide in 2007 included some 550 miles of bike lanes (almost 78 percent of all bicycle facility mileage), 30 miles of bicycle boulevards (4 percent), and 130 miles of separate bike paths (18 percent). In this context, 52 percent of all utilitarian bike travel took place along bicycle facilities. The bicycle-miles breakdown among bike-facility types was 54 percent on bike lanes, 20 percent on bicycle boulevards, and 26 percent on shared use trails, evidencing a disproportionate attraction to bicycle boulevards and off-road trails. Exercise and other loop trips were less oriented to bicycle facility use in general and to use of bike lanes and bicycle boulevards. They were slightly more oriented toward shared use trails. Route choice plots showed substantial exercise and recreational travel to be taking place on undifferentiated roads in more rural parts of the area (Dill and Gliebe, 2008).

Various surveys have been reported to indicate willingness to incur extra travel to bicycle on off-road shared use paths (Guttenplan and Patten, 1995). Estimates based on the Portland GPS/network-based studies (see Table 16-10 and associated discussion in the "Bicycle Lanes and Routes" subsection) indicate that the average cyclist will travel substantially out of the way to use an off-road trail in preference to other options. The estimated willingness to deviate is 26 percent out of the way if the other option is a quiet street, and 57 percent out of the way if the other option is a moderate-traffic street without a bike lane. These Portland estimates are derived on the basis of bicycle trips for utilitarian travel purposes such as commuting and running errands (Broach, Gliebe, and Dill, 2009b).

In comparison to the Portland utilitarian-travel-based estimate of 26 to 57 percent, research in Minneapolis on bicycle travel for all purposes—weekends as well as weekdays—estimated that bicyclists are traveling an average of 67 percent longer to include an off-street trail facility in their route. Findings were derived from routing information provided by cyclists intercepted in a 13-station survey. Trips employing other than bicycle access to reach the trails were excluded (Krizek, El-Geneidy, and Thompson, 2007), as was the case in the Portland studies. Although the study locations and route determination methodologies of the two studies differed, the most obvious potential explanation for the greater amount of route deviation observed in Minneapolis is the inclusion of substantial recreational travel in the data set. At the end of this discussion, estimates of the price elasticity of demand for recreational use of off-road trail facilities based on distance of travel to the facility are presented.

Path Walk/Bikesheds. Some studies have translated willingness to travel extra distance to use off-road paths into quantification of path use as a function of distance from the path. The quantifications use various metrics, hindering comparison, but a path commutershed and walk/bikeshed phenomenon clearly exists. (The term commutershed is used here in the context of work purpose trips and the term walk/bikeshed is applied in the context of trips for all purposes.)

An examination of journey-to-work bicyclist origins obtained in a 1993 weekday peak-periods intercept survey on Seattle's Burke-Gilman off-road trail plus a second intercept survey on a bike lane in the north fringe of the CBD found 24 percent of all commuters to have originated within 0.4 km. (1/4 mile) of the trail, 37 percent within 0.8 km. (1/2 mile), and 53 percent within 1.2 km. (3/4 mile).[20] An examination of commute times for both trail users and non-trail users found travel time means of 29 minutes in the first 1/4-mile band, 35 minutes in the second 1/4-mile band, and 31 minutes in the third (farthest from the trail) 1/4-mile band. This led the researchers to conclude that commuters in the second band were traveling out of their way to use the trail, but that most commuters from beyond 1/2 mile of the trail were unwilling to incur the longer travel distance. On this basis they suggested a trail commutershed boundary for bicyclists of 1/2 mile, as measured from the trail (Shafizadeh and Niemeier, 1997).

A random sample of adults in Arlington, Massachusetts, was surveyed to explore patterns of Minuteman Trail use for any recreational or transportation physical activity including both walking and bicycling. The trail is a shared use rail-trail facility traversing Arlington and two other towns in the northwest Boston suburbs. An "Arlington Physical Activity and Bikeway Survey" obtained self-reported information on trail use, all types of recent physical activity, and health and socio-demographic status, along with perceived neighborhood environment, distance to trail, need to cross busy streets for access, and need to traverse steep grades for access. Survey respondent addresses were geocoded, allowing independent geographic information system (GIS) calculation of access distances, major street crossings, and grades.

A Minuteman Trail user was defined as any respondent making any use of the trail in the preceding 4 weeks. Predictive models incorporating the significant variables provided estimates of odds ratios for utilizing the trail of 0.58 (based on GIS trail access measures) and 0.65 (based on perceived access measures) for every 1/4-mile increase in access distance (Troped et al., 2001), suggesting that residents were 35 to 42 percent less likely to make use of the trail for each added 1/4-mile.[21] This estimate would indicate that persons living in the bands between 1/2 and 3/4 miles from the trail, and not having an extra busy street or steep grade to traverse, would have roughly 1/3 to 2/5 the likelihood of using the trail as someone living within the first 1/4 mile of the trail. The researchers did not suggest walk/bikeshed boundaries, but 1/2 to 3/4 mile each side of the trail would seem appropriate.

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[20] Given land mass, water body, highway, bridge, and bike facility geography at the time, these two surveys likely intercepted a large portion of all commuter bicyclists from north Seattle.

[21] An "odds ratio" quantifies the relation between two odds in order to illustrate the amount by which the probability of a certain outcome differs, if at all, between two groups. Generally, an odds ratio is calculated as the odds of the outcome (trail use, in this case) for the affected group (1/4 mile further away) divided by the odds of the outcome for the group not so affected (not 1/4 mile further away). An odds ratio of 1.0 implies equal likelihood, an odds ratio of more than 1.0 implies greater likelihood, and an odds ratio of less than 1.0 (in this case, 0.58 to 0.65) implies lesser likelihood (in this case, of trail use among those 1/4 mile further away).

The previously-introduced intercept-survey-based analysis of users of Hennepin County off-street trails within Minneapolis likewise covered all travel purposes over both weekdays and weekends, but was restricted to users making their entire trip via bicycle. Over half the cyclists traveled less than 2.5 km. (1-1/2 miles) from their homes to use the trails. Over 3/4 were within 5.0 km. (3 miles). Decay functions were fitted to the percentage of trips coming from different distances for different travel purposes. The decay functions for each travel purpose dropped off sharply at first, tending toward flattening out at one side or the other of 5.0 km. However, the functions for work/school and shopping trips dropped off more sharply than the function for recreational trips (Krizek, El-Geneidy, and Thompson, 2007). The Minneapolis findings would seem to imply a broader bikeshed than the postulated Seattle bicycle commutershed or Arlington walk/bikeshed.

These studies address either bicyclist path users or a mix of walkers and bicyclists. Addressing walkers per se, the Minneapolis researchers note that "the pedestrian literature widely cites that people are willing to walk a quarter of a mile or so" and trace this finding back to the early 1980s (Krizek, El-Geneidy, and Thompson, 2007). Certainly the 1/4-mile walk access limit has served for many decades as a rule-of-thumb for local bus route planning (see Chapter 10, "Bus Routing and Coverage"). Of course, this determination regarding bus access may or may not be an equivalent circumstance, especially since path use for walking involves not only access but also the walking on the path itself.

Path Orientation and Value. It deserves repeating here that facility-type preferences, while important in the choice of whether and where to walk or cycle, are subordinate to origin and destination access needs in the case of utilitarian active transportation. Utilitarian NMT usage is greatly influenced by both alignment with travel needs and how direct and logical the routing is (Alta Planning + Design, 2009a). The importance of providing connectivity to places people want and need to go led one early study report to question whether separated paths could possibly "inspire bicycle commuting" given the propensity of bike path alignments to "follow scenic corridors and [. . .] not necessarily lead to major destinations" (Goldsmith, 1992). The findings reported on below suggest that while this concern applies to some shared use, off-road paths and trails, it does not pertain to others well oriented to utilitarian travel needs. Many cases lie somewhere in-between. Also, one aspect not to be overlooked is that attractiveness of off-road paths for recreation and physical exercise provides quality of life and health benefits that may be of sufficient value to compensate, in terms of public benefits, where path alignment cannot support utilitarian usage as well.

Studies of path economics, as noted previously, have used path access distances to develop calculations of the price elasticity of demand for recreational use of off-road path facilities. For example, studies of 2003–04 use of the Washington and Old Dominion (W&OD) Trail in the Virginia sector of the U.S. National Capital Region produced price elasticities derived on the basis of cost to access the trail, which itself is free to the public. A 2003 mileage cost rate of $0.131/mile was applied to round-trip access mileage and the result was related to frequency of trail use. Two different estimating formulations were used. These gave travel cost price elasticities, calculated at the means for recreational users not living directly on the trail, of –0.34 and –0.22.[22] Other studies covering different paths have produced price elasticities of –0.21 to –0.43, and –0.68 (Bowker et al., 2004). The average of –0.38 suggests a sensitivity

[22] A travel cost trail use elasticity of –0.3, for example, indicates an 0.3 percent decrease (increase) in trail use in response to each 1 percent increase (decrease) in cost, calculated in infinitesimally small increments. (See also Footnote 12 in the "Street Crossings" subsection.)

to cost that is close to some other important transportation price elasticities, most notably the average fare elasticity for public bus transit ridership.

Shared Use Path Implementation

Facilities that are altogether new when implemented, such as most shared use paths are, present an analytical challenge in that there is no route-specific "before" data with which to compare. Faced with this constraint, available studies have employed a variety of techniques to explore travel or physical activity changes in response to path provision. Table 16-16 presents a summary of shared use path studies that have employed retrospective or "what if?" questioning, time-series work commute mode share observations, or some form of adaptive before-and-after data. A few additional studies with "after" statistics that contribute useful information, even without pairing with "before" data, are included.

Table 16-16 Summary of Retrospective and Before and After Studies of Individual Shared Use Path Implementation Examples

Study (Date)	Process (Limitations)	Key Findings
1. Indiana University (2001) (see case study "Six… Trails — Indiana Trails Study" for more)	In 6 Indiana locales, 1 trail each (5 opened in late 1990's, 1 in 1980's), were studied in 2000 with counts, user interviews, and surveys. Trip-based user data and perspectives were obtained. (No basis for direct measurement of NMT increases.)	August weekday trail volume ranged from 1,620 (Indianapolis, Monon Trail) to 170 (Greenfield, Pennsy Trail); 2,350 to 190 on weekend days. From 14% to 19% reported engaging in their activity only because of the trail, while 70% to 87% engaged more in their activity.
2. Welzenbach (1996), Greenways Incorporated (1992) (see this section for more information)	Chicago region shared use paths include early rails-to-trails conversions like the Illinois Prairie Path, opened in the late 1960s and serving 18 cities and villages in 3 counties with multiple branches (55 miles circa 1990). In 1995, 54 segments of 18 paths representing 196 miles were surveyed, obtaining responses from 4,589 (42%) of on-path walkers/cyclists. (Runners/skaters not interviewed.)	Purpose distributions were: Work (including station access) 9%; non-work utilitarian (incl. school), 15%; recreation, 31%; other (incl. recreational site access), 45%. Auto was alternate mode for 43% of work, 37% of non-work utilitarian, and 24% of other-purpose trips. An earlier, separate analysis of Census tracts along 5 key linear paths found 1980 Census work purpose shares to be 15.6% bicycle mode, vs. 1% regionally.
3. Puget Sound Regional Council (2000), Moritz (1995 and 2005a and b) (see this section and "Ped./ Bicycle Systems and Interconnections" for more)	The shared use Burke-Gilman and Sammamish River Trails were opened in the late 1970s and joined, in 1993, into a 27-mile trail serving UW and the north fringe of central Seattle. Multi-location 7 AM - 7 PM trail user counts/surveys have been taken at 5-year intervals starting in 1980. (Major exogenous factors; multiple on-path survey points give duplicate observations of long trips.)	Tuesday (Saturday) 4-station trail count averages grew from 400 (1,900) in 1980 to 2,200 (3,600) in 1995 then dropping, partially rebounding to 2,000 (2,300) in 2005. The drop was in cycling (2/3 to 4/5 of the total). The pedestrian count has grown fairly steadily. The work/ school proportion has grown from 1/10 to between 1/4 and 1/2, with a proportional decline (but stabilization in the absolute) of recreation/exercise users.
4. Guttenplan and Patten (1995), Ewing (1997) (see this section for more information)	The Pinellas Trail along Florida's West Coast is a 47-mile rail trail, connecting Tarpon Springs and St. Petersburg. Users were surveyed at 8 locations from 6:30 AM to 6:00 PM during a November 1993 weekday, filling out the survey only once. (Survey not keyed to a count).	Some 35% of users surveyed reported using the trail for utilitarian transportation purposes such as commuting to work or school, or shopping. Of those using the trail to get to work or school 87% did so at least 2 days a week, with 60% using it 5 days a week. Trail use approaches 100,000 people a month.
5. Barnes, Thompson, and Krizek (2006) (see also "Bicycle Lanes and Routes" and Table 16-12)	In Minneapolis-St. Paul 4 major off-road trails and 3 major bike lane facilities were opened 1990-2000. Commute trip bike mode share changes were computed for TAZs within 1 mile (1.5 miles for facility termini). (Bike/work trips only.)	Bike mode shares at the outset, inside the commutersheds, averaged 4 to 5 times the shares in the rest of the Central Cities. The trail and bike lane commutershed bike shares each increased by averages of 1.38 percentage points, up 43% in the case of off-road trails. [a]
6. Cleaveland and Douma (2009) (see "Bicycle Lanes and Routes" and Table 16-13 plus this section for more information)	Commute trip bike mode share changes were computed for Census block groups within 1.55 miles of bike facilities opened 1990-2000 in 6 U.S. cities. Off-street paths were included in Austin, Madison, Colorado Springs, Salt Lake City, Orlando. (Bike/work trips only.)	Off-road trail commutershed bike shares in Austin, TX, increased by an average of 0.88 percentage points, up 24%. [a] Work commute mode share outcomes for the off-road paths in the other cities were not statistically significant. The research examined neither walk trips nor non-work trips.

Table 16-16 (Continued)

Study (Date)	Process (Limitations)	Key Findings
7. Pedestrian and Bicycle Information Center (2010), Roback (2004)	The Interurban Trail of Ozaukee County, Wisconsin, north of Milwaukee and south of Sheboygan, is a 30-mile north-south mostly off-road paved rail-trail essentially completed in September, 2002. The 2005 county population was about 85,000. (Counts/penetration surveys only.)	The sum of 7-day, 14-hour counts made at 2 locations in August, 2004 was 8,825 users in 1 week. A summer 2003 Community Health Survey found 25% of respondents countywide to have used the trail. The corresponding rate from a random Comprehensive Planning Citizen Survey in March 2005 was 53%.
8. Chaney (2005) (see this section for more information)	An interim section of the Hudson River Trail in Manhattan between West 12th and 55th was replaced with a straight 15-foot wide pathway. Counts were made in May, 2001, 1 month after completion. "Before" counts were in September, 2000. (No NMT type differentiation.)	Weekday 6-hour NMT user volumes (7:30-9:30 AM, 12-2 PM, 4:30-6:30 PM) increased from 731 to 2,056 (up 181%) at W. 17th and from 319 to 1,248 (up 291%) at W. 34th. Weekend 6-hour volumes (10 AM-4 PM) increased from 1,986 to 4,498 (up 126%) at W. 17th and from 868 to 3,474 (up 300%) at W. 34th.
9. Pedestrian and Bicycle Information Center (2010)	A 1.2-mile path was constructed to connect Delaware Valley College to Doylestown, PA, penetrating a barrier created by a bypass road. (No analysis of reasons for low usage.)	Counts found 10 people on average on various parts of the path each day, or about 3,000/year. Part of the path is wedged between a high traffic barrier and fence [and may be unattractive].
10. Five additional studies examined by Pucher, Dill, and Handy (2010) (see this section for more information)	A review was carried out of 5 additional studies of paths before and after construction or introduction of bicycles. In 1 instance, trail opening was combined with a marketing campaign. (Results summary was limited to cycling outcomes.)	In 2 studies no changes were observed in levels of cycling of nearby residents, while increases in numbers of cyclists were found in 2 studies, and an increase in minutes of cycling by residents within 1.5 km. was seen in the case where marketing was applied.

Notes: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

[a] Percentage increase(s) or ratios and some totals calculated by the Handbook authors.

Sources: As indicated in the first column.

Indiana Trails. The 1st study entry in Table 16-16 is of particular interest, not only because of retrospective survey questions probing changes in physical activity. It is also uniquely informative because of the manner of positioning surveyors to obtain trip-based user information, i.e., trail visit data, rather than trail-traffic-based characteristics information. In addition, it offers the perspective of being a statewide study of selected individual trails in differing locales. This study and the survey technique and its implications are more fully described under "Six Urban, Suburban, and Semi-rural Trails—Indiana Trails Study" in the "Case Studies" section.

Certain trail user and use characteristics identified in the Indiana Trails study are somewhat atypical compared to most trails (see Tables 16-137 and 16-138 in the case study). It is not clear whether this simply reflects regional or other locational differences or whether it arises from obtaining actual trip-based data, eliminating a bias toward interception of and reporting on longer trips more than shorter ones. The usual male dominance of trail use is found on only half the trails, with the facilities in Greenfield and Portage exhibiting almost equal balance, and a moderate female dominance (54 percent female) on the Monon Trail in Indianapolis. The percentage of users on foot, walking or running, is almost 60 percent or more on 4 trails, 50 percent on the Prairie Duneland Trail in Portage, and only dominated by cycling—together with skating—on the semi-rural Cardinal Greenway rail-trail in Muncie (Indiana University, 2001).

A range of 14 to 19 percent of surveyed users on the individual Indiana trails indicated that their engagement in their chosen trail use activity was because of the trail's availability. Another 70 to 80 percent indicated that they were walking, running, cycling, or skating more because of the trail.

The Indiana trails fall in the category exhibiting low usage for work commuting, with the highest work purpose share (5 percent) found on the Indianapolis Monon Trail. Interestingly, however, a companion survey question indicates that some users are "killing two birds with one stone," getting to work while gaining exercise, while reporting their trail use purpose as health/exercise or recreation (Indiana University, 2001). The actual Monon Trail use for commuting may thus be higher, although the percentage of trip makers reporting entering and exiting at the same point was 91 percent, placing a logical upper limit on utilitarian-purpose trip making of 9 percent.[23]

In discussions of travel purpose of trail users, it is well to remember overall context. Commuting to work is not the dominant purpose of trip making overall in the United States. The 2001 NHTS found only 15 percent of all U.S. person trips by all motorized and non-motorized travel modes to involve commuting to or from work. Work-related trips and school/church trips added 3 percent and 10 percent, respectively. Other non-work travel purposes accounted for 45 percent, excluding social/recreational trips, which were another 27 percent of all U.S. trip making (Bureau of Transportation Statistics, 2003a).

Greater Chicago Paths. Examples of paths and trails with higher reported commuting utilization than Indiana in the year 2000 are provided by the Chicago area. Chicago area paths overall, as per the 2nd entry of Table 16-16, exhibited a 9 percent work purpose share for walking and cycling in 1995 surveys. Another 15 percent of surveyed users had various other utilitarian purposes including school access. The reported 9 percent work purpose share includes trips to and from rail stations, almost exclusively commuter rail or rapid transit. The high proportion of "other" trips, 45 percent overall, includes walking and cycling to specific recreational sites and to visit friends and relatives. This study and most other studies reported on below obtained path-traffic-based data rather than user-based data, given the on-path intercept survey methods utilized.

Individual Chicago area path use for work purpose travel ran as high as the 22 percent proportion found on the North Shore Trail. Recreational/exercise use of the North Shore Trail was only 19 percent (Welzenbach, 1996, Greenways Incorporated, 1992). The North Shore Trail, the Illinois Prairie Path, and other principal Chicago area shared use paths are on the roadbeds of former commuter-oriented electric railways or other radial railroads, giving them natural alignment with work and other utilitarian travel demand.

Average one-way bicycle trip lengths identified in the Chicago surveys were 3.6 miles for work trips, 3.2 miles for non-work utilitarian trips, and 4.7 miles for other trip types, excluding recreational trips. (The modest differences among trip types may have minimized potential trip-length biases insofar as trip purpose distributions are concerned.) One-quarter of all survey respondents reported that

[23] The obscuring of utilitarian travel by "primary purpose" survey question responses of "exercise" or the like may be more widespread than realized. Interviewers on the Iron Horse Regional Trail in the San Francisco East Bay area also reported a tendency to give "recreation" as a trail trip purpose when, in fact, respondents had actual utilitarian destinations but chose to use the trail as an exercise opportunity (East Bay Regional Park District, 1998). Some newer research efforts have turned to instructing interviewees that any trip with a purposeful destination should be classified according to that purpose and not the motivation for engaging in active transportation (Dill and Gliebe, 2008).

their alternative mode for their trip, assuming the path did not exist, was auto (Welzenbach, 1996). While the implications for vehicular travel mitigation are substantive, it must be recognized that the "auto" mode terminology can encompass both auto driver—implying a car removed from the road—and auto passenger.

Seattle Urban/Suburban Trails. The 3rd entry into Table 16-16 offers a further perspective on distributions among NMT modes of trail traffic and on allocations of trail traffic among work, other utilitarian, and recreational/exercise purposes. The Burke-Gilman and Sammamish River Trails data also open a window on trail use changes over time as a pair of facilities and a bikeway system mature. These two Seattle-area trails—now joined end to end—wrap around the north end of Lake Washington to connect central Seattle's north fringe with northeast Seattle, including the University of Washington, and suburbs east and north of the lake in northern King County (Puget Sound Regional Council, 2000, Moritz, 1995).

Table 16-17 summarizes the counts and observed NMT mode distributions from the Tuesday and Saturday counts taken every 5 years, showing the proportions of cycling, walking, skating, and other modes. The table title deliberately identifies the NMT mode distributions as "classification count" results, because the taking of on-trail observations does not result in a direct assessment of user characteristics, but rather in an assessment of observed volume characteristics. Although as many as eight intercept count stations were employed for individual years, the data in Table 16-17 are limited to that from the four stations (three for 1980) with consistently available NMT mode observations.

Table 16-17 Seattle Area Burke-Gilman/Sammamish Trail Four-Station Classification Count Averages Over Time, 1980–2005, Late May, 7:00 AM–7:00 PM

Year	Bikes	Percent	Peds. [a]	Percent	Skate [b]	Percent	Other [b]	Percent	Total
Tuesday									
1980 [c]	260	64%	129	32%	—	—	18	4%	407
1985	790	64%	429	35%	—	—	20	2%	1,238
1990	624	67%	300	32%	—	—	11	1%	936
1995	1,590	72%	452	21%	144	7%	6	0%	2,192
2000	1,057	63%	530	31%	97	6%	6	0%	1,690
2005	1,357	68%	584	29%	48	2%	13	1%	2,002
Saturday									
1980 [c]	1,617	83%	278	14%	—	—	42	2%	1,937
1985	1,747	78%	384	18%	—	—	59	3%	2,190
1990	2,235	81%	497	18%	—	—	32	1%	2,764
1995	2,874	79%	496	14%	272	7%	3	0%	3,645
2000	1,464	71%	506	24%	85	4%	20	1%	2,076
2005	1,650	72%	574	25%	46	2%	21	1%	2,291

Notes: The four count stations are Gas Works and Sheridan Beach (Lake Forest Park) on Burke-Gilman, and Woodinville and Redmond on the Sammamish Trail (see also table-Note C).

[a] The pedestrian count includes walkers, joggers, and runners.

[b] Skaters were entered as "Other" in 1980, 1985, and 1990.

[c] The Gas Works Park count station was not open in 1980, thus the counts and percentages for 1980 are actually 3-station averages, with only one station on the Burke-Gilman Trail.

Sources: Moritz (2005a and b), with averaging and pre-2005 percentages by the Handbook authors.

The sharp growth in trail use by bicycles in the 1985–1995 period has been ascribed to the interconnection of the Burke-Gilman and Sammamish River Trails, accomplished in two stages, in 1988 and 1993 (Moritz, 1995, Puget Sound Regional Council, 2000). This attribution of cause is backed up by counts taken in 1990 and 1994 at each end of the final "Missing Link," as described in the "Pedestrian/Bicycle Systems and Interconnections" subsection that follows. However, it can be seen that a drop-off in cycling was observed in 2000 and found to continue into 2005. Walking, on the other hand, grew fairly steadily in absolute terms over the quarter-century of observations. Skating jumped from less than 1 percent of all trail traffic in 1990 to 7 percent in 1995 and then declined. Possible reasons for the drop-off in bicycling on the combined trails after 1995 include:[24]

- There may have been precipitation forecasts, cooler weather, or other not fully recognized exogenous factors that affected usage on the survey days. Adverse weather on the count Saturday in 2005 forced premature closure of one-half of the count stations (Moritz, 2005a and b).
- The novelty of a continuous 27-mile scenic urban trail may have somewhat worn off for recreational users.
- The trail may have become a victim of its own success, with complaints of crowding on the trail encouraging choice of alternative routes and activity venues (Puget Sound Regional Council, 2000).
- Greater development of trails and other bikeways throughout the region may have led to a better distribution of use by those with a choice, particularly cyclists accessing a trail by motor vehicle for purposes of exercise or recreation.

Proportions of survey respondents reporting use of a car for trail access in 1985 ranged from 59 percent on Saturdays to 54 percent on weekdays. A 22 percent decline from 1985 to 2000 in this proportion for Saturday respondents and a 50 percent decline for Tuesday respondents (Moritz, 2005b) meshes with the postulate that some earlier users of the Burke-Gilman and Sammamish River Trails may by 2000 have been taking advantage of new alternative facilities. (Information on access mode is not available for 1980 or 2005.) Whatever the reasons for trail use variations, the average May 7:00 AM to 7:00 PM trail volumes in 2005 stood at over 2,000 for both Tuesday and Saturday trail traffic, indicating higher overall use than any other survey year except 1995 (see Table 16-17).

Table 16-18 summarizes trip purpose findings from the Tuesday counts/surveys. Because the 2005 data were obtained only at four intercept stations, both all-station and four-station results are shown to the extent available. Not only were the reported all-station and four-station surveys taken using different approaches, the all-station locations were more heavily weighted toward areas of denser urbanization, likely the major factor in the higher work/school commute percentages reported for the all-station surveys. Although this circumstance somewhat clouds the results, there is a fairly consistent and substantive upward trend in the proportion commuting within each overlapping set of time-series data (all-station and four-station). Clearly weekday utilitarian use of the trails was increasing as a proportion of total use, with a corresponding percentage decline in recreational/exercise use (Puget Sound Regional Council, 2000, Moritz, 2005a and b). In absolute terms, however, it appears that the number of recreational/exercise users at first grew substantially and then stabilized, with the number of Tuesday recreational/exercise users in 2005 being likely about as high as any survey year except 1995.

[24] Postulates offered in the following two series of bullets are those of the Handbook authors except in the case of the individual bullets containing a citation.

Table 16-18 Seattle Area Burke-Gilman/Sammamish Trail Average Tuesday Trip Purpose Percentages Over Time, 1980–2005, Late May

Trip Purpose	1985	1990	1995		2000		2005
	All-Sta. Survey	All-Sta. Survey	All-Sta. Survey	4-Sta. Verbal	All-Sta. Survey	4-Sta. Verbal	4-Sta. Verbal
Work/School Commute	10%	44%	47%	28%	48%	26%	32%
Recreation/Exercise	90%	53%	48%	67%	45%	70%	58%
Shopping	1%	1%	3%		4%		
Other/Multiple Responses	0%	2%	2%		3%		
Other/Shopping				3%		1%	2%
Number of Respondents	968	1,905	1,611	6,060	1,245	6,103	7,663
Sample Size	150	1,905	1,611	6,060	1,245	6,103	7,663

Notes: The all-station surveys, with six to eight intercept survey stations, had all but two survey stations on the more urban Burke-Gilman Trail. Survey hours were 7:00 AM to 7:00 PM.

The all-station surveys utilized a mail-back survey approach. The four-station approach instead sought a verbal trip purpose identification from passing trail users. Survey hours were 6:00 AM to 7:00 PM.

Sources: Moritz (2005a and b), with calculation of four-station percentages, "no response" excluded, by the Handbook authors.

The Saturday surveys from 1985 to 2000 show trends fairly consistent with the weekday survey respondent trip purpose patterns. The recreation/exercise proportion declined from 98 to 79 percent. Work/school commuting increased from 2 to 12 percent, shopping increased from nil to 6 percent, and other/multiple responses increased from nil to 3 percent (Moritz, 2005b).

One can only speculate as to reasons for the shift over time toward trail use for commuting:

- Closure of the "Missing Link" in 1993, extension in 1993/94 of the Burke-Gilman component into Freemont and Ballard (nearer central Seattle), and interconnection with an expanding network of King County NMT facilities, may together have made the Burke-Gilman/Sammamish River Trails progressively more useful for commuting and other utilitarian uses.
- NMT commute-mode choice-making may be a more "sticky" decision process than recreational or exercise decisions, with change not occurring quickly, but perhaps involving evolution of workplace culture—with choices to cycle or walk/run to work by avant-garde employees being gradually followed by fellow workers and progressively receiving more employer support.
- NMT congestion on the trail may be dampening casual recreational use more than use for commuting.
- Sharp growth in student population and employment at the University of Washington, en route on the Burke-Gilman Trail, may be showing up in trail commuting increases.[25]

[25] Between 1991 and 2005, for example, student enrollment was up 40 percent and faculty and staff totals were up almost 30 percent (see "University of Washington's U-PASS Program—Seattle, Washington" under "Case Studies" in Chapter 19, "Employer and Institutional TDM Strategies").

The Burke-Gilman/Sammamish River Trails surveys have identified quite high trip lengths. May 1990 reported Tuesday and Saturday on-trail trip distance medians were 5 and 14 miles, respectively (Moritz, 1995). One analysis of the May 1990 survey calculated that the prevalence of commute trips among bicyclists within the trail traffic was over five times the proportion of commute trips among intercepted walkers (Guttenplan and Patten, 1995). Non-bike commuters had a median Tuesday trip length of 2 miles, while bike commuters exhibited a median trip length of 4 miles (Moritz, 1995).[26]

Other Path Information. The Pinellas Trail (4th entry in Table 16-16) provides a further example of significant path use for utilitarian transportation. In 1993 over 1/3 of weekday use was found to be for work, school, or shopping access. The trail provides a direct route toward central St. Petersburg, Florida, and passes several major employment sites and 5 schools, in addition to its recreational role of connecting numerous parks and natural areas. The trail cross-section, except in constricted areas, provides a 10-foot paved way for bicycles and a separated 5-foot paved way for pedestrians. A number of grade separations, only one of which was part of the former railroad infrastructure, cross busy arterials (Guttenplan and Patten, 1995). Researchers in an area of variable path quality have observed that "commuter cyclists for the most part use only higher quality paths" (Aultman-Hall, Hall, and Baetz, 1997). Apparently the Pinellas Trail provides the required quality in addition to meeting the utilitarian trip requirement for directness and linkage of residential areas with professional employment, schools, and other activity sites.

This requirement is also met by two Washington, DC, area trails surveyed in September 1993: the inner Rock Creek trail in the District of Columbia itself, with 67 percent transportation use, and the W&OD Trail of Northern Virginia, with 51 percent. Two outlying more rural trails outside of Baltimore, the Northern Central and Baltimore and Annapolis rail trails, were found to be primarily used for recreation and exercise (Guttenplan and Patten, 1995). This pattern of higher transportation use in urban locations parallels that found in Indiana. More information on W&OD trail use and economics, with greater emphasis on weekend activity, is located in the "Related Information and Impacts" section under "Economic and Equity Impacts"—"Commerce Impacts of Off-Road Paths."

The 5th and 6th research entries in Table 16-16 reflect a quite different analytical approach, providing before-and-after perspectives by examining U.S. Census journey-to-work trip data for the Census years prior and subsequent to facility implementation. These key studies were fully described in the preceding "Bicycle Lanes and Routes" subsection under "Bicycle Lane Implementation"—"Longitudinal Commute Mode Share Research" (see especially Table 16-12) but apply with equal importance to shared use paths. The journey-to-work mode share impact findings for paths are summarized here along with contextual factors that may help explain why the new paths in some urban areas were more successful in attracting work commute trips than in other areas:

- The Minneapolis-St. Paul research identified increases in work-commute bicycle shares averaging 1.38 percentage points in the commutersheds of both new bicycle lanes and new shared use trails. The corresponding bicycling percentage increase for the trail corridors of 43 percent was numerically less than the increase for bicycle lane corridors only because trail corridor shares were higher to start with. The four trail commutersheds had a simple average before-trails bicycle commute mode share of 4.02 percent, and a 5.40 percent average after the decade of trails implementation (Barnes, Thompson, and Krizek, 2006). The studied Twin Cities trails are in attractive locations for

[26] Since these data are from multiple on-trail intercept locations, as contrasted to the Indiana surveys discussed above, they represent a snapshot of use characteristics of trail traffic at points along the facility, not a reporting of average trail user characteristics. Average trail users would be making somewhat shorter trips (intercepted less), and thus likely would exhibit more use of the walk mode.

commuting, are oriented toward downtown and university employment areas, and are integrated into a well-establish network (Cleaveland and Douma, 2009).

- In Austin, TX, the 1990–2000 bicycle work-commute mode-share gain along new trails was 0.88 percentage points, representing a 24 percent increase, reaching 3.52 percent. The studied trail locations are close-in to the downtown, and other favorable characteristics noted for the Twin Cities are present in Austin as well (Cleaveland and Douma, 2009).

- Results for Colorado Springs were not statistically significant. The 1990–2000 gain in bike work commute mode-share was 6 percent overall along new trails. The north trail did well, with a tripling of bike mode share, but the south trail dragged the average down. Colorado Springs lacked an overall bike facility network (Cleaveland and Douma, 2009).

- In Madison, WI, there was a statistically insignificant decrease in work-trip bicycle shares where new paths were implemented of –2 percent. The bicycle share was already very high, almost 6 percent, and the paths involved largely parallel existing bicycle infrastructure in a fully developed network. The paths provide corridor cyclists more options (Cleaveland and Douma, 2009), and may well be important for non-commuter user groups such as children and recreational cyclists.

- Bicycle work-commute mode share also decreased along new paths in Salt Lake City, by a statistically insignificant 24 percent. The path segments were located in low-density areas peripheral to the core of the city. The researchers noted that both path and on-street bike facility implementation in the 1990–2000 decade was poorly publicized, and hypothesized that the improvements were hardly noticed in amongst preparations for the 2002 Winter Olympics (Cleaveland and Douma, 2009).

- Areas along new trails in the Orlando region showed a statistically insignificant 21 percent decline in bicycle commute share, actually less than for Orange County, Florida, as a whole. These new trails were mainly in low density areas far from downtown, with poor connections to other bicycle facilities. As in the other urban areas examined in this study, the research approach did not allow examination of the value of these trails for walking, non-work utilitarian travel, or recreation/exercise (Cleaveland and Douma, 2009).

The Ozaukee Interurban Trail, built primarily along the former electric interurban railway that once linked towns between Milwaukee and Sheboygan, Wisconsin, has not been researched in depth. Two surveys, however, provide information on what proportion of county residents report having used the 30-mile north-to-south-border trail. As can be seen from Table 16-16, 7th entry, 1 in 4 residents reported use of the trail when queried roughly 10 months after full opening (with 1 detour). Some 30 months after opening (still with 1 detour) the proportion was found to be just over 1 in 2 (Pedestrian and Bicycle Information Center, 2010, Roback, 2004), representing about 45,000 of the residents of Ozaukee County.

The Hudson River Trail in New York City offers an example that is both instructive and tricky to interpret. The trail provides a broad promenade most of the length of Manhattan. In 2002 permanent trail replaced an interim section between West 12th and West 55th that varied between 5 and 10 feet wide, entailed 90-degree turns, and was bordered by chain link fencing and concrete barriers. "After" condition peak and midday periods 6-hour NMT volumes ranged from 1,248 to 2,056 on weekdays, depending on location, and 6-hour weekend volumes ranged from 3,474 to 4,498. The presence of a counted interim facility in the "before" condition gave a basis for computing growth. Volumes doubled to tripled at West 17th and quadrupled at West 34th (Chaney, 2005). Numerical details are provided in the 8th entry of Table 16-16. System interconnection effects introduce a confounding factor. The usage increases reflect not only the direct effect of trail-improvement but also the interconnectivity effect of providing a better linkage between the preexisting fully developed sections.

The 9th Table 16-16 entry simply serves to illustrate that "build it and they will come" is not always a certainty. Preliminary circa 2004 counts on the Doylestown Bike & Hike path found an average of 10 users per day on various parts of the facility (Pedestrian and Bicycle Information Center, 2010). Lacking analysis of reasons for the low usage, it may be speculated that one section next to a busy highway—shoehorned between a high concrete traffic barrier and a chain link fence—is too unattractive, or that underlying travel demand may simply be low. Alternatively, path traffic may have been slow in developing.

The 10th and final table entry summarizes a review of five additional paths from the perspective of impacts on bicycling. Results are nearly a tie between studies finding no impact (2) and studies finding an increase in cycling (3) (Pucher, Dill, and Handy, 2010). Two of these studies are independently covered within this chapter. The case involving marketing is addressed under "Walking/Bicycling Promotion and Information"—"Transportation Mode Shift Promotions"—"Promotion of New Options" and finds cycling growth in the context of small numbers of bicyclists and a trail with some physical drawbacks (Merom et al., 2003). The other is 1 of the 2 studies finding no discernible impact on amount of cycling.

The study in question examined a short paved pathway—1 mile in length—not part of a path network and not oriented to any notable destinations. The location is a residential area of West Valley City, Utah, a Salt Lake City suburb. The canal-side trail does feature sidewalk tie-ins, providing a 2.5-mile loop, and is in fact used primarily by pedestrians (71 percent) and joggers (13 percent), with relatively few cyclists (16 percent). A before-and-after study of trail-neighbor activity levels indicated that opening and establishment of the trail did not lead to counteraction of a downward trend in walking and bicycling activity. Trail users were mostly from outside of the trail neighborhood study area. The trail offered a new exercise route option, but for most, not an occasion to change activity mode. Among trail users interviewed in an intercept survey, 87 percent had previously engaged in their chosen activity before opening of the trail. On the other hand, almost 94 percent walked, biked, or jogged to reach the trail itself. Average distances from home to the trail were 1.2 miles for walkers, 1.8 miles for bicyclists, and 4.6 miles (sic) for joggers (Burbidge and Goulias, 2009).

Five more studies involving multi-use, off-road paths, all focusing on physical activity effects, are examined under "Public Health Issues and Relationships" in the "Related Information and Impacts" section. (See Table 16-123 within the discussion "Health Benefits for Adults of Enhanced NMT Systems and Policies"—"Adult Physical Health Effects of Non-Motorized Transportation Features.") Two of the studies, the 6th and 10th Table 16-123 entries, found additional physical activity for persons with good trail access in North Carolina and suburban Boston, Massachusetts. The 7th table entry simply establishes that about 2/3 of Minneapolis area trail users meet or exceed minimum physical activity guidelines through use of the trails. The 8th Table 16-123 entry summarizes a before and after study finding that two new West Virginia trails attracted both habitual and new exercisers, and that physical activity increases were seen for both groups. Only in the study entered as the 9th table entry, which examined a trail extension and suffered from unintended survey timing (2 months after trail extension opening), were findings inconclusive (see Table 16-123 for sources).

Shared Use Path System Coverage

The role of shared use path systems, as with other NMT facility networks, has been examined not only on the basis of facility-level effects but also with cross-sectional and comparative studies, both aggregate and disaggregate. There have been four nationwide aggregate analyses in the 20 years from 1992 to 2011 that have investigated the impact of bike lane and path system extent on bicycling rates, using U.S. Census journey-to-work or comparable ACS data. These were detailed in the previous "Bicycle Lanes and Routes" subsection under "Bicycle Lane System Coverage." The first two used combined bike lane and path measures of system extent, finding positive associations of system coverage with bicycling to work. The third, on the basis of 42 large cities, found positive associations for bike lane system extent and path system extent individually, but strongly so only in the case of bike lanes.

The newest and most comprehensive, covering 90 of the 100 largest U.S. cities, utilized three alternative forms of regression analysis. Each form treated bike lane extent and path extent (relative to population) as separate explanatory variables along with proportion of students in the population; urban characteristics; region (west, southeast, etc.); weather; and (in some formulations) safety. Good statistical fits were obtained, with R^2 values of 0.57 to 0.67. The relative role of bike lanes and paths varied among model formulations, but not with statistically significant differences. Both types of bicycle facilities had positive associations of system extent with bicycle commuting, with estimated elasticities of about +0.25 in each case, inelastic but statistically and programmatically significant (Buehler and Pucher, 2011).

Key limitations of the national studies include lack of examination of effects on walking, irrelevant for bike lanes but important for paths, and lack of findings concerning both effect on non-work utilitarian travel and use for recreation and exercise. Table 16-19 summarizes six path system coverage or proximity studies that help fill some of these gaps.

Table 16-19 Summary of Research Findings on the Relationships of Shared Use Path Proximity and Prevalence with Walking and Cycling Activity

Study (Date)	Process (Limitations)	Key Findings
1. Moudon et al. (2007) (see "Ped…cycle Friendly Neighborhoods" for more information)	Cross-sectional analysis of walking activity, socio-demographics, attitudes, and objectively measured environmental variables covering 608 adults in King County, WA. (Cycling activity not examined.)	No significant relationship found between trail proximity and overall amount of walking activity, but additional analysis suggested that proximity increased the likelihood of choosing trails for walking routes.
2. Moudon et al. (2005) (see "Ped…cycle Friendly Neighborhoods" for more information)	Similar to Moudon et al. (2007) but focused on cycling (at least once a week versus less), with addition of perceived environmental variables. (Some evidence, for 1/3 of cyclists, of neighborhood "self-selection" for recreational facility accessibility.)	A moderately strong relationship was found between measured trail proximity and overall cycling activity. Increased likelihood of trail use for recreation/exercise and use of the bicycle mode for trail access was also identified with trail proximity.
3. Krizek and Johnson (2006)	Cross-sectional analysis of effects of proximity to bicycle facilities, using Minneapolis and St. Paul component of the year 2000 regional survey of weekday household travel. (Only 86 sampled trip makers, spread across the two cities, reported bike trips.)	Found a partially significant positive relationship between weekday bicycle trips and bike lane proximity (strongest before considering demographics), but no significant weekday relationship with off-road trail proximity or proximity of both facility types together.
4. Duncan and Mummery – 2005 as summarized in Saelens and Handy (2008)	Analyzed survey in Rockhampton, Queensland, Australia, of incidence of recreational walking vis-à-vis perceived and objective measures. (Few measures found significant.)	Higher likelihood of recreational walking during past week with home location <0.4 km. (<1/4 mile) from a footpath. Frequent walking found to be correlated with poor perceptions of footpath conditions.
5. Brownson et al. – 2000 as summarized per SR 282	Conducted cross-sectional mail survey and logistic regression analysis for a rural community sample. (Apparently most descriptors were self-reported, with prior activity not investigated.)	Asphalt surface increased incidence and frequency of use. Greater trail length and location within 5 miles increased frequency. Trail length of 1/4 to 1/2 miles was associated with greater incidence of use.
6. Lansing, Marans, and Zehner – 1970 as reported in Nelson and Allen (1997)	U.S. Bureau of Public Roads examined schoolchild bicycle use in new communities with differing numbers of bicycle paths. (No information on methods.)	About 22% of schoolchildren walked or biked to school in new communities with no bicycle path, compared to 29% for 1 path and 49% for 2. [Paths may be a surrogate for good NMT design.]

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column. The notation "SR 282" is shorthand for Committee on Physical Activity, Health, Transportation, and Land Use (2005) together with Handy (2004).

The studies in Table 16-19 represent regional and community cross-sectional research, along with a comparative study, focused on learning about path system coverage effects from analysis of systems in place. The studies range in complexity from detailed statistical evaluations to a multi-community comparison of schoolchild travel modes conducted by the Bureau of Public Roads (BPR), predecessor to the U.S. Department of Transportation.

Of the six tabulated studies, four reported significant findings of higher NMT activity with more or closer paths. These higher levels of activity, reported as statistically significant (or being obviously so), involved cycling in Seattle (2nd table entry); walking in Rockhampton, Queensland, Australia (4th entry); and both walking and cycling in a U.S. rural community (5th entry) and among U.S. schoolchildren in new communities (6th entry). Of the two studies failing to identify statistically significant NMT activity, one focused on walking (Seattle, 1st table entry) and one on cycling (Minneapolis-St. Paul, 4th entry). The Seattle pedestrian study did find more trail-walking in households proximate to trails, but no statistically significant indication that it represented additional walking activity overall (see Table 16-19 for sources).

The research effort that failed to identify more cycling activity in proximity to Minneapolis-St. Paul trails of all types (Krizek and Johnson, 2006, 3rd Table 16-19 entry) stands in contrast to the facility-specific time-series analysis of Minneapolis-St. Paul work purpose cycling included as the 5th entry in Table 16-16 (Barnes, Thompson, and Krizek, 2006). The all-trails cross-sectional analysis may be an example of a manifestation noted in the "Analytical Considerations" discussion of the "Overview and Summary," wherein less analytically robust research has been found less likely to show significant relationship of NMT activity to a stimulus (Ogilvie et al., 2007). It attempted to draw inferences from a small sample scattered across a broad geographic area. The trail-specific research in Table 16-16 (5th entry), which found significant shifts to bicycle commuting with the introduction of trails, had the advantage of a larger data set (the U.S. Census) and could use it essentially as a cluster sample, with comparative data from non-commutershed areas.

Only the BPR study, the 6th entry in Table 16-19, addressed mode choice outright. The higher schoolchild NMT mode shares reported in the presence of shared use paths has, for purposes of comparison with the other research, been taken as a surrogate for more walking and cycling activity. New-community schools with two paths (and perhaps better NMT design overall) had over twice the proportion of walking and bicycling to school as schools with none. Schools with one path were in-between in NMT share (see Table 16-19 for source).

Not quite fitting in with the more conventional studies of Table 16-19, but instructive in its own right, is unusual research on the effects of NMT infrastructure investments in the Baltimore and Sacramento regions. Regional travel survey utilitarian walking and bicycling shares for 1993 and 1991, respectively, were determined by traffic analysis zone (TAZ). These early 1990s shares were applied to 2001 and 2000 travel by all modes, determined from correspondingly newer regional travel surveys. By this means, trend estimates of walking and bicycling trips, by TAZ, for 2001/2000 were calculated. A negative binomial regression was then constructed to model the actual (observed) 2001/2000 utilitarian walking and bicycling by TAZ as a function of (1) the trend estimates, (2) income changes, (3) density changes, and (4) NMT infrastructure investment during the intervening period. Research difficulties included NMT spending categories that could not be isolated and the need to rely on funding timing as a surrogate for construction timing.

In the resulting Baltimore and Sacramento walk and bike trip models, income and density changes were found either to have insignificant effect or to operate in the expected direction. Income increases, where significant, were associated with walking/bicycling decline and—in the one instance of density significance—density increase was associated with increased bicycling activity in Sacramento.

Expenditures on trails showed a positive, although not statistically significant relationship with walking in both cities. A positive relationship with bicycling in Baltimore was statistically significant for both 1/4 and 1/2 mile buffers along trails that were financed. In Sacramento, the relationship with bicycling for spending on trails was both insignificant and of an illogical sign, although there was a significant positive relationship for bike lane expenditures. (Bike lane expenditures could not be examined in Baltimore.) These findings pertain to utilitarian walking and bicycling only, and the researchers point out that trail expenditures could be having significant effects on recreational/exercise activity, not addressed in the study (Ewing, Handy, and McCann, 2010).

Pedestrian/Bicycle Systems and Interconnections

Lack of NMT system interconnectivity forces detours on pedestrians and bicyclists and throws up barriers in their way. The inherently slower speeds of walking and cycling, relative to driving, give heightened sensitivity to route circuitry in travel between places. There is evidence pedestrians and bicyclists appreciate and respond to direct connections, and that barriers to direct pedestrian and bicycle travel deter use of active transportation. Unfortunately, cities and suburbs are full of unconnected links and physical barriers such as sidewalks that end abruptly, cul-de-sacs and dead end streets, bike paths that go nowhere in particular, and streams, rivers, busy highways, and expressways without suitable crossings (David Evans and Associates, 1992).

Pertinent NMT research ranges from the common finding that minimization of time and distance is a primary objective of utilitarian walkers and cyclists, to the specific outcomes of creating connections in practice that are presented in this subsection. The totality of this research continues to underscore the critical role of good interconnections in encouraging choice of non-motorized modes of travel (Kuzmyak et al., 2011). Studies are even beginning to show that route directness, as compared to mere nearness, is among walking inducements (Moudon et al., 2007).

Concepts useful to appreciating the role of systems and interconnections are presented in the "Underlying Traveler Response Factors" section, within the "Environmental Factors" discussion. There, in the "Systems Environment" subtopic, the relevance of accessibility and the contribution to accessibility of connectivity are developed. The "Surroundings Environment" subtopic examines the influence of system link quality ("Facility Compatibility Measures") and "Ambiance," but with the caveat that quality of individual links can make little contribution if the links are not well joined together.

System interconnections make relatively large contributions in terms of completing the pedestrian and bicycle network with fairly short physical distance linkages. Examples include pedestrian and bicycle (ped-bike) bridges across major barriers including freeways, railroads, ravines, and rivers; short connections eliminating "missing links;" and cut-throughs allowing pedestrians and bicycles to pass directly through discontinuous street networks, such as between ends of cul-de-sacs, through large blocks, and across traffic-calming vehicle diverters.

Bridges and bridge improvements obviously represent larger capital expenditures than short segments of walkway or the provision of cut-throughs. Perhaps for this reason, the demand response studies of non-bridge interconnection projects have not been as widely reported. As a result, the individual interconnections portion of this subsection necessarily focuses mainly on the response to more expensive bridge provision and upgrading projects. This circumstance should not be taken to infer that less capital-intensive connections are of little importance. Information on path gap closures, facility extensions, and "Interconnections of Modest Scale" will be found toward the end of the "River Bridges and Other Linkages" discussion.

Overall Systems and System Expansions

Recognizing the contribution of all interconnected NMT system elements, overall system effects—enabled in part by connectivity measures—are reviewed first. This review is accomplished by recapping and adding to key overall systems studies presented elsewhere within this chapter, either in preceding facility impact or in upcoming policy impact discussions. Key studies covered are shown in Table 16-20.

Table 16-20 Summary of Research Findings on Relationships between Pedestrian/Bicycle Facility Density/Interconnectivity and Non-Motorized Travel Activity

Study (Date)	Process (Limitations)	Key Findings
1. Goldsmith (1992), Nelson and Allen (1997), Dill and Carr (2003), Buehler and Pucher (2011) (see "Bicycle Lanes and Routes" and Table 16-14 for more information)	One descriptive analysis and three cross-sectional analyses relating various measures of bicycle facility density (bike lanes and off-road paths only) to citywide bicycle mode shares for the U.S. journey to work. (City-level aggregation, work trips only, causality not established, no explicit measure of connectedness.)	• Bikeway/arterial ratio < 0.035:1 associated with 1/3 the bike share of cities with ratio > 0.035:1 ("university towns" omitted). • Each additional bikeway mile per 100,000 population associated with 0.069% more commuter cycling. • Each added bike-lane mile per sq. mi. associated with ± 1% more commuter cycling. • 10% more of *either* bike lanes *or* bike paths associated with 2.5%-2.6% more bicycle commuters.
2. Pinjari, Bhat, and Hensher (2008) (see "Underlying Traveler Response Factors" — "Choice of Neighborhood…" for more)	Modeled residential location and activity time-use choices of 2,793 regional survey sample households in Alameda County, San Francisco East Bay, controlling for residential sorting (a.k.a. self-selection). Zonal-level environment variables included bike facility densities. (Bicycle ownership levels treated as givens.)	Even after controlling for residential self-selection (very significant), good bicycle facility densities were found to be associated with more physical activity such as walking, cycling, and jogging. The model predicted that a ten-times increase in bicycle facility density would produce an overall 17% increase in time of recreational facility use.
3. Birk and Geller (2006) (see also "River Bridges…" and "[NMT] Policies and Programs")	Portland, OR, bikeways increased from 78 miles in 1991 to 256 miles in 2004, a 228% increase. Bike facilities were improved or added on 4 central area bridges. (Bicycle data only, results cannot be separated from overall auto use reduction policy effects.)	An extrapolation from bridge counts suggests a 210% increase in bike trips between 1991 and 2004, eclipsing population increases. Over the 1990-2000 decade, the citywide bike mode share for work purpose trips increased from about 1% to 3%. (See cross-referenced discussions for ca. 2008 data.)
4. Queensland Transport – 2007 via Davies (2008) (see this section and "NMT Policies and Programs" for more)	With development starting ca. 1985, Brisbane's shared use path system extended 7-1/2 miles from the CBD in 1 corridor by 1995 and 3 corridors by 2000, with a major new bridge in 2001 (see Fig. 16-3). (Investigation based on Australian census was limited to journey-to-work trips.)	For travel to the CBD and CBD fringe from surrounding areas, walk to work shares increased almost threefold and bike shares sixfold from 1986 to 2006, reaching 17.4% walk and 3.0% bike (see Figs. 16-2 and 16-3). Housing expansion in the core area may well have contributed to increased walking.

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column.

Facility Density and Connectivity. The 1st entry in Table 16-20 summarizes four key studies on the relationship between extent of bicycle system coverage and choice of the bicycle mode for commuting to work. These studies are individually described in Table 16-14 of the "Bicycle Lanes and Routes" subsection, where they are first introduced. The accompanying text notes limitations of these studies with regard to their aggregate data, focus on work trips only, and lack of demonstration of causality. To this must be added their consideration only of bicycling and their use of facility-quantity ratios as bicycle supply measures. While the supply measures are robust as far as they go, they do not specifically quantify the degree of system connectivity of interest here.

All four studies looked at the contribution of both bicycle lanes and off-street paths and found positive association of system extent with bicycle commuting. The newest study found the two types of facilities essentially equal in their importance to the commuter cyclist. Despite their acknowledged limitations, the four studies make a substantial case that system extent is a significant and positive factor in the decision to bicycle by the studied population, namely, adults choosing between bicycling and other travel modes for the work commute (Goldsmith, 1992, Nelson and Allen, 1997, Dill and Carr, 2003, Buehler and Pucher, 2011).

The 2nd entry in Table 16-20 highlights a study that, while not national, took a broader analytical perspective by examining participation in all types of active transportation—including walking, cycling, and jogging—for all purposes including recreation. Working with a large survey sample for Alameda County, inclusive of Berkeley, Oakland, and other cities of the San Francisco East Bay to the south and east, it first of all identified residential self-selection effects. Individuals with higher bicycle ownership and interest in physical activity were found to locate more in neighborhoods with greater density of bicycle facilities. Then, with this phenomenon separately accounted for, the research proceeded to produce estimates that increasing facility density is linked with modest positive changes in individual participation in active transportation (Pinjari, Bhat, and Hensher, 2008).

NMT system studies that more explicitly address system connectivity are found in the "Pedestrian/Bicycle Friendly Neighborhoods" subsection, primarily within the "Design" subtopic, but also in the "Walk Elasticities for Land Use and Site Design Parameters" discussion and tabulation (see Table 16-42). Of particular interest under "Design" is the 8th entry in Table 16-40, covering a study notable for focusing exclusively—other than taking demographics into account—on the degree to which the street system, and by inference the pedestrian system, is tightly interconnected. The study tested a composite walkability score, assembled from three different measures of system connectivity, and related it to walking activity. A higher incidence of walking in counties with higher scores was found in this connectivity research (Saelens and Handy, 2008).

System Development Integral with Policy/Program Realization. Two system expansions are included in Table 16-20 from among those examined as part of the upcoming "NMT Policies and Programs" subsection. They are further expanded upon there under "New World Program Examples"—"Portland, Oregon" and "Brisbane, Australia." These two examples are selected for highlighting here because of their noteworthy illustration of NMT interconnected-system effects. Both are also separately examined under "River Bridges and Other Linkages" because of notable river bridge program components.

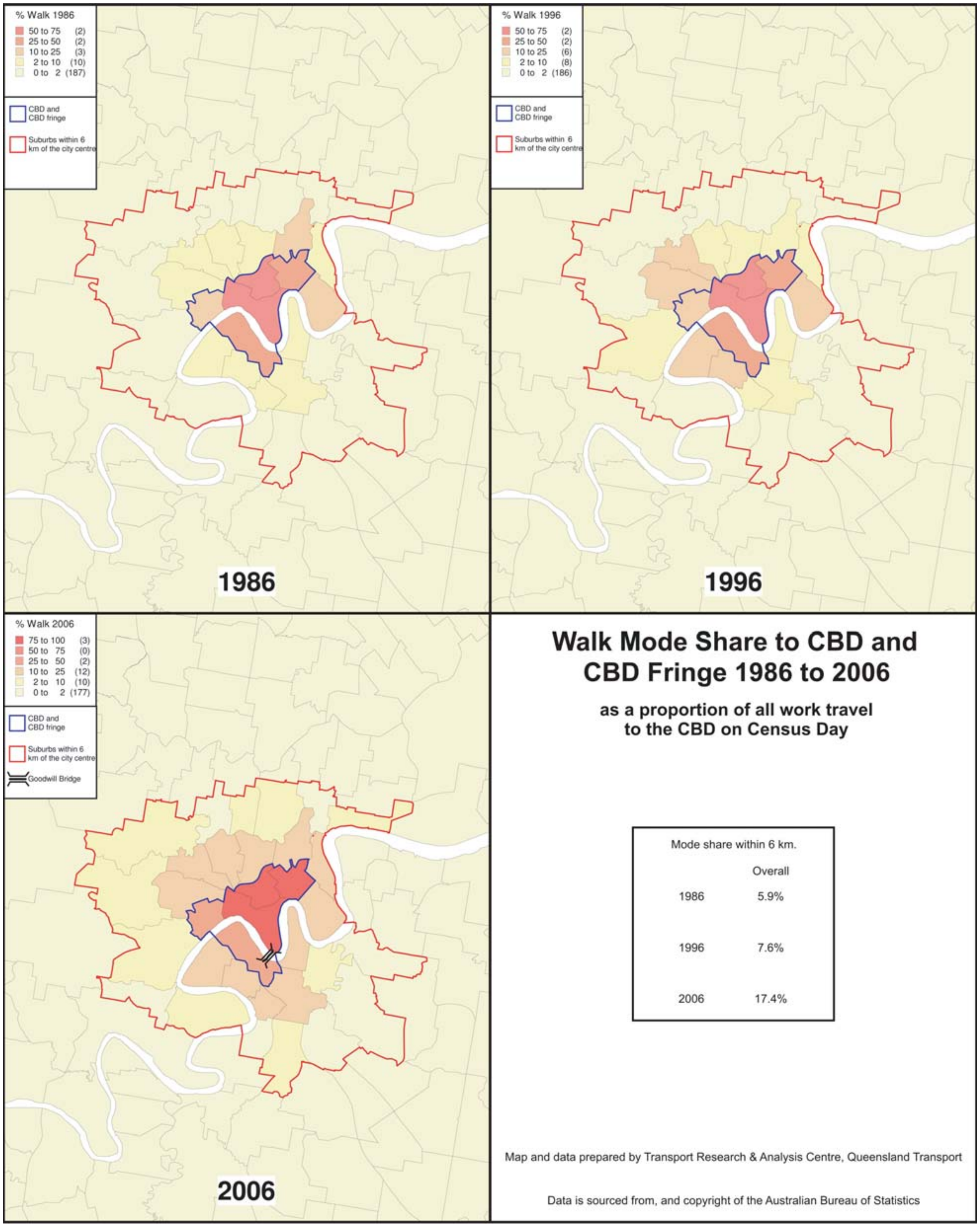
Portland's NMT system expansion program has been heavily, but not exclusively, focused on bicycle facilities. Monitoring has been primarily on the basis of bicycling data. NMT system implementation has run in parallel with the more recent stages of long-established policies designed to dampen auto use, and gained momentum starting in the late 1980s (City of Portland, 2004). Miles of bikeways increased from 78 miles in 1991 to 256 miles in 2004, a 228 percent increase. Starting in 1992, major pedestrian and bicycle improvements were made to four key central area bridges, as covered below in the "River Bridges and Other Linkages" discussion. Bikeways in Portland include bike lanes, bicycle boulevards, and shared-use paths.

These improvements were accompanied by an estimated 210 percent increase in bicycle trips from 1991 to 2004, as extrapolated from river crossing counts. This extrapolation appears to be corroborated by citywide U.S. Census commute trip data. From 1990 to 2000 the overall bicycle share of work purpose trips increased threefold, from approximately 1 percent to 3 percent, with larger increases in the dense, flat, neighborhoods of the inner city. In the "NMT Policies and Programs" subsection, Figure 16-7 maps both the distribution of the bicycle commute mode share increases and the growth of the bikeway network (Birk and Geller, 2006). The accompanying "New World Program Examples"—"Portland, Oregon" discussion provides system extent and bridge count updates through 2009.

Brisbane's NMT system expansion has not only addressed both walking and bicycling but has also been monitored on the basis of both types of use. Figures 16-2 and 16-3 illustrate the response over time as expressed in walking and bicycling shares for trips to the CBD. Brisbane's current system of off-road, shared use paths and on-road bicycle facilities was begun in the mid-1980s, coincident with the first mode share plot in each figure. "Bikeways" had been constructed by ca. 1995 in one radial corridor and by ca. 2000 in three corridors, as mapped in Figure 16-3.[27] Shortly thereafter, the total on- and off-road bikeway network totaled over 550 km. (342 miles), complementing the more than 3,950 km. (2,454 miles) of sidewalks and other footpaths in the city. By 2008–09, the bikeway network totaled more than 760 km. (472 miles), consisting of 54 percent off-road paths and 46 percent on-road bicycle facilities (Queensland Transport, 2007, Brisbane City Council, 2009a and b).

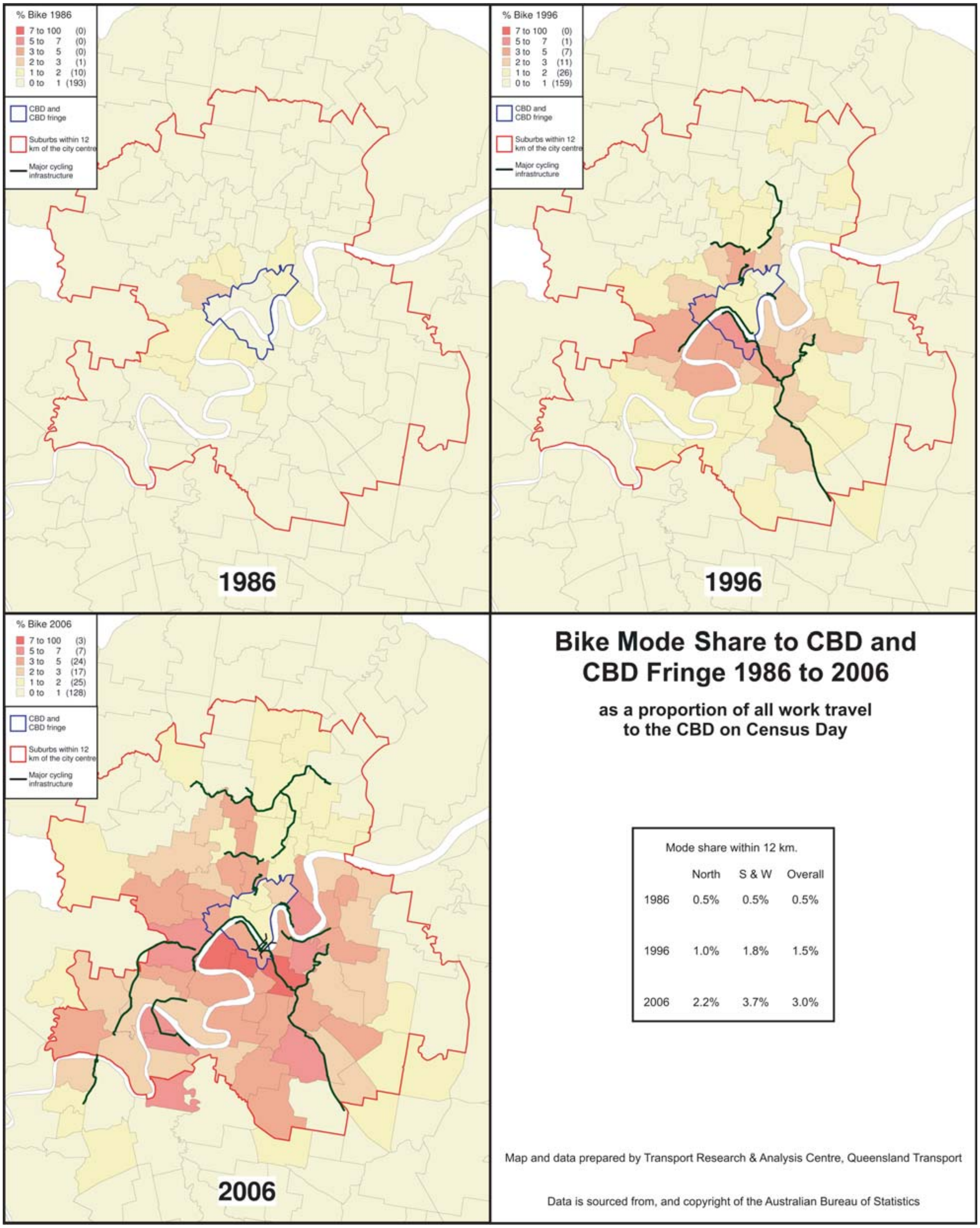
[27] Brisbane includes its shared use paths under the broad term "bikeway," along with on-road bicycle facilities. There are apparently a few sections of off-road bikeways that are bicycle-only.

Figure 16-2 Work-purpose walk mode share to Brisbane CBD and CBD fringe, 1986–2006.



Source: Modelling, Data and Analysis Centre, Transport and Main Roads, Queensland Government (formerly Queensland Transport), Australia [2007] via Davies (2008).

Figure 16-3 Work-purpose bicycle mode share to Brisbane CBD and CBD fringe, 1986–2006.



Source: Modelling, Data and Analysis Centre, Transport and Main Roads, Queensland Government (formerly Queensland Transport), Australia [2007] via Davies (2008).

Figures 16-2 and 16-3 depict the walk mode shares and bicycle mode shares, respectively, for journey-to-work trips from individual analysis districts to the Brisbane CBD and CBD fringe in 1986, 1996, and 2006. Overall shares to the CBD and fringe for these and intermediate years are tabulated, and additional interpretation is provided, in the "NMT Policies and Programs" subsection under "New World Program Examples"—"Brisbane, Australia" (see in Table 16-45). Work trip walk shares to the CBD from within roughly a 6 km. (3-3/4 mile) radius have increased from 5.9 to 17.4 percent over the 20 years, likely with the aid of additional downtown housing. Bike work trip shares to the CBD from within roughly a 12 km. (7-1/2 mile) radius have increased from 0.5 to 3.0 percent (Queensland Transport, 2007, Davies, 2008). The Goodwill Bridge across the Brisbane River is a key component of the NMT network. It is shown in both Figures 16-2 and 16-3. Bridge use response data are given in the "River Bridges and Other Linkages" discussion.

River Bridges and Other Linkages

Table 16-21 covers the primary sources of findings for river bridge NMT improvements, new ped-bike bridges, and other new linkages within pedestrian and bicycle systems. As previously indicated, the more capital intensive a project, the more likely it is that traveler response data is available. Despite that, more modest projects may well be of high importance in their own contexts.

Willamette River Bridges, Portland, Oregon. A central, critical element in Portland's bicycle facility system development has been improvements to the Willamette River Bridges (1st entry, Table 16-21). The geography and overall context involved are described under "NMT Policies and Programs"—"New World Program Examples"—"Portland, Oregon." The Willamette River separates the historic core of downtown Portland on the west from the Lloyd District on the east, in many ways an expansion of downtown functions, and extensive surrounding traditional residential areas. A number of bridges span the river, but for many years, the accommodation of pedestrians and bicycles was severely constrained.

Several of the bridges, starting in the 1990's, have undergone renovations or improvements designed primarily for the benefit of bicyclists and pedestrians. Emphasis has been placed not only on upgrading the on-bridge accommodations, but also on creating pedestrian- and bicycle-friendly approaches and expanding the feeder network of off-road trails and on-street bike boulevards and lanes. Table 16-22 and its accompanying notes list the on-structure improvements during a 12-year span and provide additional context by giving mileage by year of Portland's bicycle facilities.

Table 16-21 Summary of Studies on the Travel Effects of Providing Pedestrian/Bicycle Bridges and Other Linkages Between and Within Ped/Bike Systems

Study (Date)	Process (Limitations)	Key Findings
1. Birk and Geller (2006), Birk (2003) (see this section and "NMT Policies and Programs" for more)	Descriptive analysis of Portland, OR, Willamette River bridge bike count changes in response to 1993 painting of bike lanes on Burnside Br., 1998 sidewalk resurfacing on Broadway Br., 1999 shared-use sidewalk widening on Hawthorne Br., and 2001 opening of Steel Br. lower-deck ped-bike crossing. (Bike counts only, extrapolated from peak, outcomes confound by multimodal program.)	The 4-bridge total bicycle count, up in 1992–93, dipped in 1995, then climbed consistently upward, on through 2004, up 211% in 13 years. Bike lane effects do not stand out in Burnside Br. yearly counts. Broadway Br. count growth appears most influenced by feeder network improvements. The projects on Hawthorne and Steel Bridges were accompanied by 45% and 361% bridge-specific 2-year bike count increases.
2. Abrahams (2002) [a] (see this section and "Travel Behavior Shifts" under "Related Info…" for more)	Surveyed weekday peak period users of Goodwill Bridge, a ped-bike facility over the Brisbane River close to downtown Brisbane, Australia, 8 months after bridge opening. A descriptive analysis was prepared. (No formal count in parallel with survey for survey control.)	Queensland Government 2-week daily counts 5 months after opening ranged, excluding a rain day, from 4,726 (25% cyclists) on a Saturday to 10,854 (18% cyclists) on a Tuesday. Of ped-bike users, 40% diverted from a less-safe crossing. Another 42% made complex, often multimodal, mode shifts.
3. RTC and APBP (1998), Historical Marker Database (2010)	A former railroad bridge connecting downtown fringes of Lewiston and Auburn, Maine, via a former textile mill district was restored for NMT use. (Findings limited to total use.)	Three years after opening to bicyclists and pedestrians this facility over the Androscoggin River was in use by over 350 people a day. It is part of a historical walk but not an overall trail system.
4. Lipton (1979), Zehnpfenning et al. (1993), Bicycle Federation of America (1993)	Users of the Greenway Bridge across the Willamette River in Eugene, OR, were surveyed 2-3 months after 1978 opening. (Counter failures. Relied on behavior-change perceptions.)	Of surveyed bicyclists, 14–28% were cycling because of the ped-bike bridge, and 30% thought it as quick or quicker to cycle given the bridge. Summer weekday 1982 count of 1,100 cyclists.
5. UK Department for Transport – 2004 as summarized in Booz Allen Hamilton (2006)	The 2001 ped-bike Millennium Br., in York, England, links traffic-free path sections and walking/cycling routes across the River Ouse. (Route expansion clouds interpretation.)	Use of routes on both banks grew from 1999 to 2002 by 73% for walkers, 31% for cyclists, and 59% for both together. Utilitarian trips up 141%, going from 25% to 38% of all NMT trips involved.
6. Barnes, Thompson, and Krizek (2006) (see "Bicycle Lanes and Routes" — "Bicycle Lane Implementation" for more information)	Two ped-bike bridges were opened, and bike lanes were added to 2 road bridges, crossing the portion of the Mississippi River alongside downtown Minneapolis and the University of Minnesota. The 1990 and 2000 Census results were used to examine effects. (Evaluated commute trip bike shares only.)	Bike shares for Minneapolis-St. Paul trips crossing that segment of the river increased by 1.20 percentage points, up 36% (from 3.34%) during this decade of bridge improvements and improved bicycle connections. Bike shares for trips not crossing the river went up just 0.34 and 0.86 percentage points (west and east sides of river, respectively).
7. City of Vancouver (2009a and b), Mustel Group Market Research (2009) (see this section for more information)	On Burrard Bridge across False Cr., into downtown Vancouver, BC, lane and sidewalk use changes separated and protected bicycle and pedestrian flows. Daily "after" counts were compared to prior information. Random telephone interviews, 300 before and 300 after, 80% focused on most affected areas, were conducted. (Prior count datanot presented, survey emphasized perceptions.)	Most pedestrian feedback positive, but some objections to inconvenience of relegation to one sidewalk. No significant change in pedestrian volumes. Cyclist reaction was enthusiastic. Cycle volumes were up 26%, July 13 through September 30, 2009, especially on weekends. Women cyclists up 31% versus 23% for men. Incidence identified in interviews of walking the bridge was a wash but doubled for cycling.

(continued on next page)

Table 16-21 (Continued)

Study (Date)	Process (Limitations)	Key Findings
8. Harkey and Zegeer (2004)	An historic bridge across Town Lake in Austin had 3.5-foot sidewalks. NMT fatalities occurred in 1991 and 2000. A parallel high-amenity ped-bike bridge was constructed with trail connections. (No examination of diversion or induced trail use.)	With the nearest alternative crossing 1 mile away, the historic Lamar Bridge had some 700 to 1,000 NMT crossings per day before opening of the ped-bike Pfluger Bridge. The new bridge was initially used by 4,000 to 5,000 NMT crossings, a number said to be rising.
9. Rails-to-Trails Conservancy (2010)	The Walkway Over the Hudson, on a spectacular 1.25-mile former rail-road bridge, opened October 3, 2009, from Poughkeepsie, NY, to the west side. (Info. limited to news item.)	Despite short-term lack of connection to regional trails, the shared use bridge attracted 300,000 visitors in first 1-1/2 months (including 50,000 opening day crowd) versus a 267,000/year forecast.
10. McCarthy (2009)	A new cable-stayed bridge over the Cooper River and Charleston, SC, harbor opened in mid-2005 with a 12-foot wide, 2.7-mile path. Interviews were completed in Jan.-July, 2007, with 373 local area adult users, at multiple times of day, weekdays and weekends. (No count information, lower interview success with cyclists, connections not in place.)	Of users approached, 17% were tourists (not interviewed). Interviewees included 57% walkers, 26% runners/joggers, and 17% cyclists, and were 56% female and 89% white. Utilitarian trips were 10% of total, with the top-ranked reason for bridge path commuting "To fit exercise into the Routine." Increased activity was self-reported by 67% of all users and 75% of regular walkers.
11. Moritz (1995 and 2005a and b) (see this section and "Shared Use, Off-road Paths and Trails" — "Shared Use Path Implementation" for more information)	The Burke-Gilman/Sammamish River Trails were joined into a 27-mile trail linking north Seattle and UW with multiple north King Co. suburbs. The 3-mile gap was half closed in 1988 and fully closed in 1993. Counts covering 12 hours were taken near each end of the final gap in 1990 and 1994. (1994-1995 bicycle volumes on the two trails were not sustained in 2000 or 2005.)	Tuesday bicycle volumes, 7 AM - 7 PM, rose at Sheridan Beach (closest in) from 617 (1 day) to 1,136 (2-day average), up 84%, and at Kenmore from 330 to 1,079, up 227%. Saturday volumes declined at Sheridan Beach from 2,485 to 2,260, down 9% (presumably due to drizzle), but rose from 1,803 to 2,548, up 41%, at Kenmore. Overall Tuesday volumes on the trails dropped 24% 1985-1990 but rose 134% 1990-1995 (see Table 16-17).
12. Langdon (2010), Transport and Main Roads (2004-2009), data analysis by the Handbook authors	The Western Freeway and Centenary Bikeways in Brisbane, Australia, were separated by a "missing link" until joined into a single radial route in late 2006. Biannual 7-day counts are taken at 2 sites north and 2 sites south of the link. (The induction-loop counters used counted bicycles only and may have missed some.)	Cycle traffic exhibited minimal 2003-2006 growth at the 3 count sites closest to the "missing link."[b] With connection made, 2006-2007 growth was 54% (weekdays) and 59% (weekends). The 2007-2009 annual growth was 13% and 10% per year, bringing 2009 24-hour volumes to over 200 on each side of the former gap.
13. Barnes, Thompson, and Krizek (2006) (see also "Bicycle Lanes and Routes" — "Bicycle Lane Implementation")	A Minneapolis-St. Paul study of impacts of introducing 3 major bike lane facilities and 4 major off-road trails involved experimentation to find the best facility commutershed description for analysis. (Analyzed work purpose trips only, study not focused on system interconnection.)	With a 5-mile length limit imposed on trips to be analyzed, new facilities in St. Paul (both <5 miles long) showed no bike share increase in their corridors. After relaxing the limit to allow inclusion of multi-facility trips, the bike share for TAZs along St. Paul facilities was shown to have increased by 37%.

Table 16-21 (Continued)

Study (Date)	Process (Limitations)	Key Findings
14. Canada Mortgage and Housing Corporation – 2008, as summarized in Victoria Transport Policy Institute (2011b) (see this section for more information)	Measures of walking and driving directness to nearby retail and recreational destinations were utilized to identify Seattle, WA, area neighborhoods where pedestrian system connectivity was better, equivalent, or inferior to the connectivity via automobile. (Research methodology/details not reported.)	Where neighborhood pedestrian connectivity exhibited greater directness than vehicular connectivity, the walk mode share was 18 percent. Where pedestrian and vehicular connectivity were about the same, the walk share was 14 percent, and where pedestrian connectivity was inferior, the walk share was 10 percent.

Notes: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

[a] Goodwill Bridge trip diversion and mode shift estimates presented here reflect adjustment by the Handbook authors for differential pedestrian versus bicyclist survey response rates (see text Footnote 69 in the “Travel Behavior Shifts” subsection of the “Related Information and Impacts” section).

[b] The northernmost count site, farthest from the “missing link” and closest to the Brisbane core, exhibited a post-2006 growth too large in absolute terms to be attributable in any major way to joining of the paths across the missing link. It has thus not been included in the gap closure impact assessment.

Sources: As indicated in the first column.

Table 16-22 Willamette River Bridges Daily Bicycle Traffic Vis-à-vis Improvements

Year	Bikeway Miles	Bridge Projects [a]	Broadway Bridge	Steel Bridge	Burnside Bridge	Hawthorne Bridge	Bicycle Total
1992	83		755	230	1,075	1,500	3,560
1993	86	Burnside [b]	735	220	1,010	1,920	3,885
1994	103		690	220	980	1,940	3,830
1995	113		527	200	620	1,910	3,257
1996	143		950	350	1,065	2,165	4,530
1997	166		1,205	475	1,375	2,170	5,225
1998	182	Broadway [c]	1,854	460	905	2,471 [d]	5,690
1999	213	Hawthorne [e]	1,476	360	920	3,154	5,910
2000	221		1,405	410	1,080	3,125	6,020
2001	234	Steel [f]	1,680	1,250	965	3,729	7,624
2002	250		1,712	1,891	965	3,682	8,250
2003	253		1,683	1,860	965	4,055	8,563

Notes: [a] Various staged bicycle access improvements on the approaches to the Broadway, Burnside, and Hawthorne Bridges are, in the interests of brevity, not listed. Certain of the volume changes appear to relate directly to these improvements.

[b] Burnside Bridge restriped to provide on-street bicycle lanes. Original 10-foot sidewalk width unchanged.

[c] Broadway Bridge slippery sidewalk surfaces replaced at original 10-foot width (8.5-foot clear space).

[d] Hawthorne bridge closed to bicycles for reconstruction. Count conducted on Morrison Bridge detour. The prior and following year Morrison Bridge bicycle count was 100 cycles.

[e] Hawthorne bridge reopened with shared-use sidewalks widened from 6 feet to 10.5 feet.

[f] Steel Bridge 12-foot pedestrian and bicycle facility opened alongside lower (railroad) deck, connecting to an extended Eastside Esplanade and pre-existing facilities. Until this point the only NMT accommodation was one 5-foot upper (highway) deck shared use sidewalk.

Daily bicycle volumes mostly extrapolated from 2-hour weekday peak period (Birk, 2003).

See accompanying text for 2004-2008 summary bikeway miles and bridge bicycle traffic data.

Sources: Birk and Geller (2006), Birk (2003).

Table 16-22 also provides daily bicycle volumes on each of the four principal bicycle-carrying bridges in the central Portland area. These volumes are primarily estimated from 2-hour weekday peak period counts and thus tend to emphasize commuter use shifts. The ongoing process of access improvements, and the shifting of cyclists among bridges in response to improvements, makes interpretation of individual bridge volumes problematic. Nonetheless, the 1997 to 1999 2-year before/after increase of 45 percent on the Hawthorne Bridge in response to sidewalk widening, and the 2000 to 2002 2-year before/after increase of over 360 percent on Steel Bridge in response to a cantilevered lower-level ped-bike side-bridge, are particularly notable. What truly stands out, however, is the steady growth in the bicycle total for the four bridges, excepting only a dip in 1995 and a spurt concurrent with opening of the Steel Bridge facility. From pre-1992, with a four-bridge weekday volume total of 2,855 bicyclists, to 2004 with 8,875 total, cycling cross-river more than tripled. During the 1990s, excluding Steel Bridge, bicycle volumes went up 78 percent as compared to an 8 percent increase in vehicular traffic on the three bridges and a 14 percent growth in Portland's population.

The daily four-bridge bicycle crossing increase (including Steel Bridge) was 140 percent over the 12 years covered in Table 16-22. Introduction of the Steel Bridge lower-level crossing has introduced into the bridge-use mix a popular jogging and bicycling exercise loop via Steel and Hawthorne Bridges and connecting paths, likely only partially reflected in the weekday-peak-derived volumes (Birk and Geller, 2006, Birk, 2003). Bicycle route choice modeling prepared for inclusion in Portland's regional model, based on previously discussed bicycle-rider GPS tracking, found riders to view bridge-with-bike-lane passage 22 to 41 percent more favorably (i.e., more important to route choice) than an ordinary bike lane or cycling on a quiet street. (The lower percentage pertains to commute trips and the higher percentage to non-commute utilitarian trips.) Riders viewed bridge-with-separate-bike-facility passage 41 to 81 percent more favorably (Broach, Gliebe, and Dill, 2011). Since the Steel Bridge lower-level side-bridge was the only separate facility on a bridge at the time of the 2007 GPS research, these separate-facility values do not directly pertain to cycle tracks or buffered bike lanes on bridges, although they offer hints as to likely attractiveness.

As of 2008—after accelerated post-2003 growth—the Willamette River four-bridge weekday volume total had reached 16,700 bicyclists, approaching a sixfold growth from pre-1992. This record was despite a slowed increase in facility mileage, which expanded only from 262 miles in 2004 to 274 miles in 2008, not quite 3-1/2 times the pre-1992 system extent of 79 miles (Gotschi, 2011). Possible explanations for the continued increase in bicyclist river crossings, including Portland's ongoing individualized marketing program, delayed response to prior actions, and increasing gasoline prices, are explored in the "NMT Policies and Programs" subsection under "New World Program Examples"—"Portland, Oregon." Also provided there is discussion of an observed bicyclist-volume drop-off in 2009 that erased half the 2007–2008 growth.

Goodwill Bridge, Brisbane, Australia. The Brisbane River, positioned adjacent to the historic downtown core of Brisbane, Australia, forms a barrier somewhat like the Willamette River in Portland. It has, however, fewer crossings. The Goodwill ped-bike bridge (2nd entry, Table 16-21), opened in October, 2001, providing the first direct connection for walkers and cyclists between the south end of the CBD—along with the adjoining Queensland University of Technology—to South Bank Parklands, South Bank commerce, and surrounding residential and mixed-use areas. The new connection brought an additional south-of-the-river commuter railroad station into play as a destination station serving the CBD, and similarly provided a faster link for some bus riders than taking the bus all the way in. It also provided direct access to the south end of the CBD from less expensive south-of-river automobile parking. Table 16-23 provides Goodwill Bridge count data obtained 5 months after bridge opening (Abrahams, 2002). As in most cases with multi-day, multi-week NMT count data, the variation is notable.

Table 16-23 Goodwill Bridge Daily Pedestrian and Bicycle Traffic Over the Brisbane River

Day of Week	March 16-22, 2002			March 23-29, 2002		
	Walkers	Cyclists	Total	Walkers	Cyclists	Total
Saturday	4,704	1,630	6,334	3,559	1,167	4,726
Sunday	5,171	1,941	7,112	7,967	2,112	10,079
Monday	7,468	1,770	9,238	8,703	1,969	10,672
Tuesday	8,852	2,002	10,854	7,699	1,958	9,657
Wednesday	7,673	2,168	9,841	7,594	1,786	9,380
Thursday	7,517	1,881	9,398	6,342	1,174	7,516
Friday	5,147	1,251	6,398	2,757 [a]	578 [a]	3,335 [a]

Note: [a] Showers (all other days clear or overcast).

Source: Queensland Department of State Development as presented in Abrahams (2002).

The data obtained in these two weeks of counts show weekly use to have averaged 57,270 pedestrians and bicyclists. The weekday average was 8,629 with 81 percent walking and 19 percent bicycling. The Saturday and Sunday average was 7,063 with 76 percent walking and 24 percent cycling. These weekday averages are higher, and the weekend figures are lower, compared to counts made 1 month after opening when the facility was more of a novelty.

Tables 16-24 and 16-25 provide user gender, trip purpose, and bridge use motivations for weekday peak period Goodwill Bridge users as obtained from 397 respondents to a post-graduate student research survey. The hand-out survey was administered on a Wednesday in late June, a time of mild winter weather in Brisbane, just over 8 months after the official date of bridge opening. As the data in Table 16-24 suggest, the gender distribution was typical of Australia and North America, with a fairly even distribution of male and female pedestrians and a pronounced tilt toward males among cyclists. Age distributions were likewise within the range of commonly encountered findings. The proportion of survey respondents who were cyclists was roughly 30 percent, higher than the actual proportion, given both the 19 percent cycling share obtained in the earlier March counts and a reported survey response rate for walkers of about 25 percent as compared to 50 percent for cyclists.

Table 16-24 Goodwill Bridge Weekday Peak Periods User Gender and Trip Purposes

Bridge Use Mode	Survey Sample	Bridge User Gender		Bridge User Trip Purpose		
		Males	Females	Commute	Social/Shop	Sport
Walkers	276	50%	48%	82%	6%	16%
Bicyclists	121	73%	26%	72%	10%	17%

Notes: Bicyclist data includes 119 actual cyclists, 1 wheelchair user, and 1 roller-blader.

Gender was not identified for 2% of bridge users. Only persons 18 and older were surveyed.

Adult and late-teen school trips were included as commute trips.

Trip purpose was not obtained for 2%, and another 2% gave multiple trip purposes.

Source: Abrahams (2002).

The travel purpose distributions exhibit a high proportion of commuters among bridge users. The survey protocol included as "commuters" students attending classes. The heavy commuting use clearly reflects the peak-period timing of the survey. It is also the result of bridge location, next to the Queensland University of Technology and a part of the CBD, and the linkage the bridge provides with less expensive commuter parking and also commuter rail and bus services. The CBD sector involved had relatively low accessibility previously, and to public transportation in particular, with the main rail terminal located at the opposite CBD fringe (Abrahams, 2002).

One of the rare insight opportunities offered by this research is the separate identification and cross-tabulation of trip purpose and bridge use motive. The two were obtained in individual survey questions. The bridge use motive is also the walking and cycling motive, given that the crossing is NMT-only. Table 16-25 summarizes bridge use motive distributions, stratified by walkers versus cyclists and separately identified for commute trips as compared to trips for all purposes. Multiple motivation responses were allowed and given.

Table 16-25 Percentage Distributions of Motivations for Weekday Peak Period Goodwill Bridge Use, by NMT Mode and All Versus Commute/Non-Commute Purposes

Motivation (Reason)	All Walkers	Commute Walkers	All Cyclists	Commute Cyclists	All Respondents	All Commute	All Non-Commute
Quicker	52%	64%	76%	85%	59%	71%	32%
Cheaper	26	34	45	49	32	39	19
Safer	11	13	40	42	19	23	13
Environment	22	27	51	54	31	36	22
Exercise	56	59	60	58	57	59	61
Fun	45	39	48	46	46	40	69
Other	3	4	7	7	4	5	4

Notes: Multiple motivation choices allowed. Motivation not obtained for 2% of survey respondents.

All-mode combinations (last three columns) are affected by differential walker versus cyclist survey response rates. The motivation percentages are nevertheless presented unweighted, for lack of information to adjust all the summary categories in question. It appears that survey response rate adjustment would *lower* the all-mode combination motivation percentages, if at all, by 1 to 4 percentage points each, without substantively affecting relative standing among the individual motivations (i.e., motivation importance rankings). "Walkers" and "Cyclists" columns would be unaffected.

"Commute" includes both work commute and student commute.

Source: Abrahams (2002), with note on survey response rate effects by the Handbook authors.

Time savings ("Quicker") stand out in Table 16-25 as the most frequently cited motivation for Goodwill Bridge use by commuters. Cost savings ("Cheaper") were cited a little more than half as much, and likely pertain in significant measure to persons using less expensive parking to the south and finishing their commute by walking over the bridge. Most notable, however, is the importance of exercise not only to all respondents but to commuters as a distinct group. Moreover, "Fun" is noted by many, even commuters, as a bridge use inducement (Abrahams, 2002).

The exercise motive identification rate, at about 55 to 60 percent for both commuters and non-commuters, is another demonstration of the tendency to accomplish two things at once by exercising while also getting to work or satisfying other needs and desires. The fun motive response rate may in part reflect the relative newness of the bridge, but probably is also an indicator that bridge use is motivated in part by its being a stimulating destination in its own right and not simply a means to an end (see "Underlying Traveler Response Factors"—"Behavioral Paradigms").

The "safer" motivation—found most often with cyclists—apparently reflects comparison with the previously overcrowded NMT facilities on the next bridge over, the Victoria Bridge, where pedestrians and bicyclists share crowded sidewalks. Of surveyed Goodwill Bridge walkers and cyclists, 40 percent previously crossed on the Victoria Bridge. That figure includes 36 percent of Goodwill Bridge pedestrians and 60 percent of cyclists. This outcome was desirable from the perspective of authorities concerned with Victoria Bridge NMT facility safety (Abrahams, 2002). Identification of Goodwill Bridge survey respondent prior modes and bridge choice is another of the rare insights offered by this research. The prior modes reported are tabulated and discussed, in adjusted form, in the "Related Information and Impacts" section under "Travel Behavior Shifts."

The location of the Goodwill Bridge relative to the CBD, the adjoining university, and various components of the transportation network, fosters its use as a link in multimodal trips. The particular circumstances involved may not be common to many other urban scenarios, but the bridge user survey data nonetheless vividly illustrate the complexity of multi-mode travel that may compose substantial components of an urban NMT facility's usage. Only 3 percent of interviewed cyclists were in the process of making multi-mode trips, all involving two modes, but 52 percent of surveyed walkers were making a two-or-more-mode trip. Ignoring multi-mode bicycle trips and consolidating two- and three-mode walk trips,[28] it is found that 50 percent of multi-mode walkers used auto for their motorized link, 28 percent used train, 17 percent used bus, less than 1 percent each used ferry or taxi, and 4 percent used two motorized modes including auto/train, bus/train, and auto/bus (Abrahams, 2002).

Other River Bridges. Information on other river bridge provisions for pedestrians and/or bicyclists, though less complete, presents a broader range of circumstances and outcomes. Eight different river crossings are covered in the 3rd through 10th entries in Table 16-21. The first of these, the Lewiston-Auburn Railroad Bridge in Maine (3rd entry), is an example from the other end of the volume scale from the large-city river bridges of Portland, Oregon, and Brisbane, Australia. The short shared use rail-trail over the converted Lewiston-Auburn bridge crosses the Androscoggin River, connecting a city park at the south end of the Auburn downtown with the Lewiston-Auburn Railroad Park on the other side. Through the latter, and a former textile mill district, the south end of the Lewiston downtown may be reached (Historical Marker Database, 2010). The combined population of the two cities at the time of the 1995 bridge conversion was about 58,000. Within 3 years of opening as a new ped-bike river crossing, facility use was 350 people a day or more (RTC and APBP, 1998).

The Greenway Bridge in Eugene, Oregon (4th Table 16-21 entry), was opened across the Willamette River in 1978, providing a ped-bike-only linkage between a major shopping complex to the northeast and a residential area to the southwest. It also connects shared use trails on each side of the river. The CBD is about 2 miles away along the river to the south (Lipton, 1979). The new link reduced travel time and distance for many non-motorized travelers, such that when surveyed, approximately 30 percent of cyclists thought it as quick or quicker to make their trip by bicycle via the bridge as compared to driving an automobile (Zehnpfenning et al., 1993). Survey results sug-

[28] Only four surveyed cyclists made multi-mode trips, three involving commuter train use and one auto use. Most of the 14 percent of multi-mode walkers who reported use of three modes simply reached that total by reporting a walk at each end of their motorized link. Thus the summarization focuses on walkers and lumps two-mode and three-mode multi-mode walk trips together.

gested that 14 to 18 percent of weekday users and 28 percent of Saturday users would not have made their trip by bicycle without the Greenway Bridge. These trips were most commonly recreational trips; nevertheless, a reduction of more than 500 automobile trips per week by 1978 bridge users was estimated.

April–May 1978 Greenway Bridge weekday cyclist trip purposes were 32 to 41 percent recreation, 46 to 41 percent work and school, 10 to 12 percent shopping, and 11 to 7 percent personal business and other. On the same 2 days pedestrian trip purposes for three Willamette River crossing opportunities combined, from the Greenway Bridge south to the CBD and the University of Oregon, were 35 to 63 percent recreation, 28 to 16 percent work and school, 15 to 10 percent shopping, and 22 to 12 percent personal business and other (Lipton, 1979). Some 1,100 summer weekday cyclists were counted on the Greenway Bridge in 1982 (Bicycle Federation of America, 1993). This volume was likely substantially higher than the bicycle traffic during the 1978 surveys, taken when the bridge was new.

The Millennium Bridge in York, England (5th table entry), was built over the River Ouse in 2001, near the University of York campus and roughly 1 mile from the city center. Its location saves walkers and cyclists up to about 1-1/4 miles maximum. Annual usage of connecting bicycle and pedestrian paths and other routes at each end of the crossing increased from 430,000 walkers to 740,000, from 220,000 cyclists to 290,000, and from 650,000 overall to 1,030,000. These increases reflected both presence of the new ped-bike bridge and further development of the feeder route system. As indicated in the 5th entry to Table 16-21, utilitarian trips increased 141 percent compared to 59 percent for all trips. The increase in annual utilitarian trips was from 160,000 to 390,000, thus over one-half of all new trips were to and from destinations such as workplaces and shops (Booz Allen Hamilton, 2006).

The 6th study listed in Table 16-21 included, in its longitudinal impact analyses of various Minneapolis bicycle facilities, an examination of work trip mode shifts to bicycling likely to have been magnified by improvements to Mississippi River crossings northeast of downtown Minneapolis. Two separate former railroad bridges were converted to ped-bike bridges, and bicycle lanes were provided on two other bridges, while NMT provisions were unchanged during the decade on an additional two bridges. The increment of growth in percentage points for bicycle shares of work trips went up substantially more, as quantified in the table, for trips crossing the river relative to other trips within Minneapolis and St. Paul (Barnes, Thompson, and Krizek, 2006). Extrapolations to 24-hour volumes for 2007 from mostly 12-hour counts give scale to total weekday cross-Mississippi bridge usage near the Minneapolis downtown. Starting north of downtown and moving toward the southeast, bridges and their NMT volumes were 1,560 pedestrians and 1,200 cyclists on the Hennepin Avenue bridge, 690 pedestrians and 490 cyclists on the 3rd Avenue bridge, 2,120 pedestrians and 940 cyclists on the ped-bike Stone Arch Bridge, 940 pedestrians and 990 cyclists on the 10th Avenue bridge, and 250 pedestrians and 130 cyclists on ped-bike Bridge #9 (City of Minneapolis, 2007).[29]

The Burrard Bridge trial reallocation of space among bicyclists, pedestrians, and motorized traffic, the 7th case listed in Table 16-21, is unusual both in the low-cost approach to enhancing ease of bicycling and increasing bike and pedestrian safety, and in the information it provides on bicyclist response to

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[29] These counts were taken 41 to 57 days following the collapse of the I-35W freeway bridge, located between the Stone Arch and 10th Avenue bridges, with unknown effects on NMT volumes. (The Stone Arch and 10th Avenue bridges would make exceptional viewing platforms for "sidewalk superintendents.") Bicycle volumes were up 76% over 2003 on the Hennepin Avenue bridge, 96% on the 3rd Avenue bridge, and 34% on the Stone Arch Bridge. Comparisons were not published for pedestrians (City of Minneapolis, 2007).

the safety improvements in particular. Burrard Bridge is the westernmost of three crossings of False Creek from southern city neighborhoods into downtown Vancouver, British Columbia, Canada. In years immediately before the trial, the bridge carried nearly 2,400 pedestrians and 3,500 cyclists per day. Approximate mode shares for the 8,000 to 9,000 per-hour peak-period bridge users were 65 percent auto, 20 percent transit, 10 percent walk or bicycle, and 5 percent unspecified or rounding error.

The starting condition was six traffic lanes and two 2.6-meter (8.5-foot) sidewalks, each shared by pedestrians and cyclists. Space allocation was changed to have two southbound (outbound) traffic lanes, one southbound barrier-protected bicycle lane next to the west sidewalk (essentially a cycle track), two-way pedestrian-only flow on the west sidewalk, three northbound traffic lanes as before, and northbound bicycle-only flow on the east sidewalk. Bridge approach changes including signalization and bike lane adjustments accompanied the bridge modifications. The revised traffic patterns were in place starting July 13, 2009, after a weekend of implementation (City of Vancouver, 2009b). Helped by transit priority enhancements, bus travel times were affected very little, if any, and overall vehicle volumes and travel times exhibited no appreciable change. The largest traffic impact has been a peak-period travel time increase averaging 1-1/2 minutes for one particular traffic movement. Vehicular traffic diversion to next-over Granville Bridge was only a temporary phenomenon, while pedestrian and bicyclist diversion was not studied (City of Vancouver, 2009a).

Hospital emergency visits for Burrard Bridge cycling crashes during 20 summer weeks studied by the University of British Columbia dropped from four in 2008 to one in 2009 (City of Vancouver, 2010). Walkers and cyclists reported feeling safer and more comfortable with the changes, cyclists especially so. Counts showed no significant change in bridge pedestrian volumes, despite some complaints about being routed onto one sidewalk. Bicycle counts went up 26 percent, including a 40 to 70 percent increase in weekend use. (Post-Labor Day gains were more muted.) As indicated in Table 16-21, cross-bridge cycling went up more substantially for women (31 percent) than for men (23 percent). Anecdotal reports were suggestive of more cross-bridge cycling by children.

In the market survey interviews noted in Table 16-21, one question asked whether the resident had walked or cycled over the bridge at least once in the previous month. Incidence of reported cross-bridge walking went up 61 percent for the Downtown neighborhood while biking incidence was up 92 percent. Walking incidence for the Near Westside neighborhood, south of the bridge, went down 44 percent but biking incidence was up 119 percent. The net effect for all interviewees was a 6 percent decline in reported incidence of cross-bridge walking in the last month (16 percent before, 15 percent after) versus a doubling of reports of cycling across (9 percent before, 18 percent after) (City of Vancouver, 2009a, Mustel Group Market Research, 2009).

The 8th and 9th entries in Table 16-21 cover a crossing of Town Lake (an impounded section of the Colorado River) in Austin, Texas, and The Walkway Over the Hudson at Poughkeepsie, New York. Roughly a fivefold increase was seen in on-site Town Lake crossings when the ped-bike Pfluger Bridge opened parallel to the historic Lamar Street bridge with its dangerously narrow 3.5-foot sidewalks (Harkey and Zegeer, 2004). The Hudson River crossing was new as a ped-bike facility, although the former railroad bridge had been built in 1888 (Rails-to-Trails Conservancy, 2010). Initial counts on both bridges averaged on the order of 5,000 persons per day (visitor counts in the case of the Hudson River bridge; see Table 16-21). The Pfluger Bridge with its scenic connecting Town Lake Hike and Bike Trail system and The Walkway Over the Hudson itself may reasonably be adjudged recreational destinations in their own right—the Hudson River, "world's tallest pedestrian bridge," spectacularly so. As such, these bridges presumably reflect the role of conventional economic demand in explaining usage of highly attractive ped-bike facilities, as contrasted to the derived-demand theoretical basis for most urban trip making. These different demand concepts are discussed under "Behavioral Paradigms" in the "Underlying Traveler Response Factors" section.

The 10th entry in Table 16-21 involves another ped-bike crossing serving as an attraction in its own right, this one a 2.7-mile sidewalk/path constructed as an integral part of a new South Carolina bridge over the Cooper River and Charleston harbor, connecting Mt. Pleasant and Charleston. Its role as a tourist attraction was underscored when 17 percent of path users approached for interviews were found to live more than 20 miles distant. Neither of the pair of bridges replaced had safe NMT provisions.

Interviewees, limited to users living within 20 miles, included 57 percent walkers, 26 percent runners and joggers, and 17 percent bicyclists. They were fairly well distributed among age groups. Women constituted 56 percent of users and were more likely to be regular bridge walkers than men. Men were more likely to be regular bridge runners and much more likely to be bridge bicyclists. A motor vehicle was the mode of access of 73 percent of all users. Non-whites, mostly African American, were 11 percent of users and self-reported increased physical activity in 85 percent of all cases. Among white bridge users, 64 percent reported more physical activity because of the new facility. Of all interviewees, 10 percent were making work trips or running errands. Percentages varied by gender, with 6 percent of women and 15 percent of men reporting commuting. The top-ranked reason for bridge path commuting, at 4.8 on a 5-point scale, was “To fit exercise into the Routine” (McCarthy, 2009).

Path Gap Closures. Closure of the 3-mile “Missing Link” across the top of Lake Washington, between Seattle’s Burke-Gilman Trail and the Sammamish River Trail in northeast suburbs including Redmond, affords a trail-gap-closure mini-study. Joined, the trails form an inverted broad-based “U” shape. As indicated in the tenth entry of Table 16-21, the gap was half closed in 1988. The new off-road trail segment substituted for need to use a heavily trafficked four-lane state highway with poor shoulders. The gap was fully closed in 1993, with installation of a tunneled grade separation eliminating routing via a busy industrial street (Moritz, 1995).

The Table 16-21 “Key Findings” entry focuses first on 1990-1994 before-and-after bicycle statistics, noting Tuesday increases of 84 percent at Sheridan Beach (closest-in and busiest side of the new link) and 227 percent at Kenmore, and drizzle-affected Saturday changes of –9 percent and +41 percent, respectively. Corresponding Tuesday pedestrian count changes were –19 percent (closest-in location) and +163 percent, while Saturday changes were –11 percent and +150 percent (Moritz 1995 and 2005b). The pedestrian count outcomes seem to reflect an overall increase combined with redistribution to the new and to the previously less accessible sections of the combined trails.

Although the 1993 final gap closure received the most attention, the partial closure of 1988 can also be examined using 1985 and 1990 counts at the same Sheridan Beach and Kenmore locations. In this instance Tuesday bicycling counts changed by –28 percent and +61 percent, respectively, while increasing by 48 and 147 percent on Saturday. All pedestrian counts were up, with particularly sharp percentage increases at the least used end of the gap at Kenmore, where 1985 Tuesday and Saturday walkers from 7:00 AM to 7:00 PM totaled 10 or less, as compared to roughly 70 in 1990 and on the order of 200 in 1995. Across the 1985–1995 decade spanning the two-stage gap closure, Sheridan Beach total NMT usage went from 1,208 to 1,645 on the weekday and from 2,026 to 2,964 on the weekend day. Kenmore total usage increased from 210 to 1,540 on the weekday and from 743 to 3,204 on the weekend day (Moritz 2005b).

Sorting through these variations, which may be only partially attributable to the gap closure, the overall trail traffic growth stands out clearly. Growth was more modest at the end of the gap with the higher initial volumes, with little change in the cycling/walking ratio. Volumes at the end of the gap with the lower initial volumes rose sharply, with a somewhat larger gain for pedestrians, to nearly match counts at the higher-volume end. The observed weekday growth seems most related to the final gap closure. Weekend growth, on the other hand, seems more evenly divided between the partial and final gap closure periods. The findings of huge positive impact are muddied somewhat by inability of the combined trails to sustain the trail traffic levels achieved in 1995 on through the 2000 and 2005 count years, an outcome discussed more extensively in the previous "Shared Use, Off-Road Paths and Trails" subsection under "Shared Use Path Implementation"—"Seattle Urban/Suburban Trails."

A second example of path interconnection is provided by the joining of the Centenary and Western Freeway Bikeways in Brisbane, Australia, in late 2006 (12th entry, Table 16-21). Brisbane's "missing link" was a little over a kilometer of difficult terrain. When joined, a shared use through facility was formed linking southwest Brisbane and the central area to the north. The count station immediately south of the missing link showed the largest changes. Weekday 24-hour bicycle counts averaged 62 in 2004 through 2006 with no growth. Closing the gap led to a 142 percent growth from 2006 to 2007, followed by growth averaging 24 percent per year from 2007 through 2009. Weekend cycle volumes were 60 in 2004, grew about 9 percent per year through 2006, gained 164 percent from 2006 to 2007 with gap closure, and had growth averaging 14 percent per year from 2007 through 2009 (Langdon, 2010, Transport and Main Roads, 2004–2009).

The 2009 24-hour bicycle volumes at this site just south of the former missing link averaged 205 weekdays and 239 weekends. Weighted average results for this count station combined with the stations roughly 2-1/2 km. north and south are given in Table 16-21. The count station 5 km. north and closer to the CBD recorded 2009 biannual 24-hour volume averages of 640 bicycles on weekdays and 512 on weekend days (Transport and Main Roads, 2004–2009). Although the annual bicycle counts were not accompanied by pedestrian counts, importance of the interconnected path to walkers may be inferred from circa 2010 staged construction to widen and upgrade congested sections of the overall "bikeway" from a shared use path to separate pedestrian and bicycle pathways.

Manhattan's Hudson River Trail provides an example of an intermediate path segment so vastly upgraded that the improvement plays a major interconnectivity role. NMT volumes on the link doubled to quadrupled, depending on location and day of week (Chaney, 2005), as more fully detailed in the above-mentioned "Shared Use, Off-Road Paths and Trails" subsection under "Shared Use Path Implementation"—"Other Path Information," including the 8th entry of Table 16-16.

Facility Extension Effects. The methodology development stage of Minneapolis-St. Paul research described under "Bicycle Lane Implementation"—"Longitudinal Commute Mode Share Research" in the "Bicycle Lanes and Routes" subsection provides special insight into the difference between opening an isolated bicycle facility segment and making extensions to an existing bicycle network. The relevant research steps, and the unexpected findings, are summarized in the 13th entry of Table 16-21. In effect, the results of testing the initial research approach showed that two new facilities in St. Paul apparently generated no net increase in work commute bicycling self-contained within the new-facility corridors themselves. The entire commuter cycling increase within the facility corridors of 37 percent (an 0.45 percentage point mode share increase) was introduced by trips traveling beyond the new St. Paul facilities via (or within the corridors of) the pre-existing bicycle facility network. That network connects with the University of Minnesota and downtown Minneapolis (Barnes, Thompson, and Krizek, 2006).

Another way of looking at this outcome is that if the two new St. Paul facilities had been built as isolated segments, one a shared use trail 1.9 miles long and the other bicycle lanes 4.6 miles in extent, the impact on commute trip bike shares would have been negligible. Since they were built as part of an interconnected system, their effect was substantial.

Interconnections of Modest Scale. The introduction to this "Pedestrian/Bicycle Systems and Interconnections" topic notes the paucity of impact studies of lower-cost NMT connections, as important as they may be. Three sets of observations offering clues as to the importance of local-scale interconnections are presented here. The most definitive, the Seattle-based research included as the 14th entry of Table 16-21, is presented last.

Paired community research in the San Francisco area sheds some light, although only through inference, on the importance of such connections. The analytical comparison in question, covering the Rockridge and Walnut Creek communities, is more fully reported in the "San Francisco East Bay Pedestrian Versus Auto Oriented Neighborhoods" case study of Chapter 15, "Land Use and Site Design," and is also summarized in the upcoming "Pedestrian/Bicycle Friendly Neighborhoods" subsection.

Rockridge has a traditional neighborhood design overall. The gridlike street network has irregularities, however. The pedestrian network makes up for the irregularities with fairly small blocks and also a number of pedestrian path interconnections. While the effect of these interconnections cannot be isolated, they presumably contribute to the relatively high walk and bike mode shares in Rockridge tabulated in the Chapter 15 case study. The Walnut Creek comparison neighborhood has a more auto-oriented design, but similar demographics and regional rail rapid transit service. Both have substantial commercial development, and work-purpose-trip rail mode shares are almost identical. However, for all walk/bike and bus transit categories of travel, Rockridge NMT and bus mode shares are over 2 times—and up to 7 times—those found in Walnut Creek (see Table 16-39, 14th entry) (Cervero and Radisch, 1995). Without the path interconnections, it is doubtful that Rockridge's level of active transportation usage could be attracted.

Within the earlier "Street Crossings" subsection, the 4th Table 16-5 entry records a dramatic pedestrian flow increase from roughly 50 persons/day to 1,000/day at a Ft. Pierce, Florida, intersection converted to an urban traffic circle with extensive pedestrian safety features and amenities. The intersection forms the gateway between the historic downtown and the beachfront. As noted in the table, the intersection improvement was part of an overall program to slow traffic, widen sidewalks, enhance the pedestrian environment, and revitalize the downtown.

Supported by the increased foot traffic, new pedestrian-oriented retail has opened in previously vacant spaces. A key element of the pedestrian improvements was redeveloping part of a parking lot into beachfront-park pedestrian and bicycle access from the gateway intersection (Harkey and Zegeer, 2004). Pedestrian travel patterns were not determined, but an obvious supposition is that the pedestrian flow increase through the upgraded intersection reflects strengthening of a pedestrian linkage between the business area and the beachfront. This is a linkage that had previously been severely degraded by inhospitable intersection traffic conditions and a beachfront parking lot barrier effect.

NMT and motorized-travel levels of connectivity are often not the same, and may be manipulated to favor walking and bicycling. Unfortunately, limited-access-highway and major-arterial barrier effects, along with sidewalk deficiencies, more often result in the opposite condition. There are enhanced subdivision and new-town designs that use pathway connections and NMT connectivity via small- and medium-sized parks to restrict through traffic while allowing relatively direct pedestrian and bicycle flow (Victoria Transport Policy Institute, 2011b, Stover and Koepke, 2002). Neighborhood traffic calming designs utilizing traffic diverters and other barriers to through traffic provide an equivalent higher-NMT-connectivity condition if passage for bicycles is provided and sidewalks are good.

Walk mode choice effects of differing relationships between motorized and NMT connectivity were explored by the Canada Mortgage and Housing Corporation (see the 14th entry of Table 16-21). The actual research was conducted in urban neighborhoods of varying character in the Seattle, Washington, region. Utilizing measures of walking and driving directness to nearby retail and recreational destinations, they determined that when pedestrian and vehicle connectivity were both high, the pedestrian mode share was about 14 percent. Where pedestrian connectivity offered greater directness than vehicular connectivity, the walk mode share was higher (18 percent) and where pedestrian connectivity was poorer it was lower (10 percent). A "Fused Grid" layout, with cul-de-sac or "U"-shaped-street loops made continuous for pedestrians and cyclists via public squares, was calculated to provide a 10 percent increase in relative connectivity for pedestrians. The study estimated that this would raise the odds of walking by almost 10 percent, produce a 23 percent decrease in local VMT, and increase the odds of meeting recommended physical activity levels through local walking by about 25 percent (Victoria Transport Policy Institute, 2011b).

Finally, there is the advantage to transit service of having NMT interconnections that make up for street and sidewalk system discontinuities. Resolving such discontinuities increases transit service effective coverage and thus ridership, and supports choice of walk and bicycle modes for transit access. This role for interconnections of modest scale is discussed below in the "Pedestrian/Bicycle Linkages with Transit" subsection (see "Non-Motorized Access to Transit"—"Pedestrian Access and Egress," especially the 4th and 7th entries in Table 16-26 and associated discussion).

Pedestrian/Bicycle Linkages with Transit

Two primary aspects of NMT access and egress treatments for transit stops and stations are covered here. First addressed are considerations involved in getting to and from transit by walking and bicycling. Of interest are the effects of improved NMT access on both transit ridership and the decision about what travel mode to use for transit access and egress. Modes of transit access include not just walking and bicycling but also motorized options, including driving and parking, getting dropped off in an auto, and connecting to a bus if available. Improved NMT access can come through either pedestrian and bicycle facility improvements, including bicycle storage provisions, or through alternative land development designs that place more residents and businesses within easy walking distance. Thus, the "Non-Motorized Access to Transit" discussion is immediately followed by a review of "Transit Oriented Development" findings.

The other aspect addressed is the on-vehicle accommodation of bicycles to allow transit-riding cyclists to take their bicycles with them for use after alighting. The outcomes of various bicycles-on-transit programs are examined under "Bicycles on Transit Vehicles." Such programs give bicyclists a flexibility of transit use conceptually equal to that afforded walkers, who inherently have full flexibility to walk at both ends of a transit trip. The flexibility to bicycle at both ends of a transit trip expands the effective service area, however, given the longer distances it is reasonable to cover in accessing and egressing transit by bicycle.

Both aspects of NMT access and egress involve and may affect "mode of access" choice or share. It is important to differentiate mode of access share from mode share and sub-mode share. *Mode share* refers to choice of primary travel mode between a trip's origin and its final destination. For example, a trip starting with driving alone to a light rail transit (LRT) station, followed by an LRT ride terminating a quarter-mile from the final destination, and concluding with walking to get there, would be classed as an LRT trip for purposes of mode share calculation. For a trip to be classified as a walk trip in this "mode share" context would require that the entire origin to destination distance be walked, with no other mode involved. A mode share proportion, in most newer studies, is expressed as a percentage of all travel by all modes in the travel category of interest. Mode share is sometimes referred to as "prime-mode share" to clearly distinguish it from sub-mode share or mode of access share.

Less often encountered is *sub-mode share,* the proportion of transit trips using a particular form of transit, such as local bus or heavy rail transit (HRT). A true sub-mode share is expressed as a percentage of all transit travel in the category involved.

Of critical interest in examining NMT linkages with transit, especially in the context of local area traffic, parking, and environmental concerns, is *mode of access share.* This share describes the proportions among means of getting to and from the primary mode. The access and egress modes in the mode share example given above would be, respectively, drive-alone (to the station) and walk (from the station).

As fully detailed in the "Related Information and Impacts" section (see "Extent of Walking and Bicycling"—"Extent of Walking"), the 2001 and 2009 NHTS surveys show 16 percent of all walk trips in the United States to be the access/egress component of transit trips.[30] They compose 1.7 percent of all trips by any mode (Agrawal and Schimek, 2007, Kuzmyak et al., 2011). NMT access and egress to/from transit service is an important contributor to physical activity for transit riders, with an estimated 29 percent of transit users achieving the 30 minutes or more of physical activity a day recommended by the Surgeon General solely by walking to and from transit (Besser and Dannenberg, 2005). Further information on this benefit is provided in the "Related Information and Impacts section" (see "Public Health Issues and Relationships"—"Baseline Walking and Bicycling Activity" and also Table 16-123).

Non-Motorized Access to Transit

The quality of NMT connections to public transit may affect the overall choice to use or not use transit, thus affecting prime mode share, and is an important determinant of the choice of access mode, such as walking versus driving to the station. Even motorists who choose to drive to transit stops must eventually leave their automobiles and walk to the boarding point, and are highly likely to walk to their final destination. A fall 1992 survey of San Francisco BART HRT riders found that walking accounted for more than 75 percent of all BART egress trips (Loutzenheiser, 1997). Similarly, a Chicago intercept survey reported 80 percent of Metra commuter rail riders and 73 percent of Chicago Transit Authority HRT riders walking to their final destination (Wilbur Smith and Associates et al., 1996a). More transit access and egress data are provided or cross-referenced in the discussion which follows.

Walk and bicycle access to transit are examined separately within this NMT access to transit topic. The "Pedestrian Access and Egress" discussion below is immediately followed by discussion of "Bicycle Access and Egress."

Pedestrian Access and Egress. Transit riders are usually thought of as willing to walk about 1/4 mile, or 5 minutes at 3 miles per hour (mph), to a regular bus stop and about 1/2 mile to a rail transit stop. These rules of thumb have been generally confirmed by numerous evaluations, although some transit riders will walk farther (Ewing, 1996). Examples found further on in this subsection suggest that while the 1/4 mile value for bus riders applies to the majority, the 1/2 mile value for rail riders applies more to the median if measured along the walking route.

Of equal importance is the finding of many transit rider surveys that transit mode share and walk to transit share both have a strong inverse relationship to the distance from the stop or station. A classic example addressing likelihood of using local bus transit is a study focused on a typical

[30] The walk access and walk egress components of an individual trip via transit are not counted separately from each other in the NHTS survey, the primary source of U.S. national data on walking to and from transit stops and stations. The walk access and walk egress are counted as one trip.

Hartford, Connecticut, bus route. Riders were surveyed to obtain demographic and travel pattern information. The bus riders and their trips were then classified by car ownership status and walking distance, based upon over 350 usable survey responses. The trips were next compared to the number of dwelling units in each strata, similarly classified. A series of "ridership penetration curves" were developed, relating bus rides per 100 dwelling units to automobile ownership and distance from the nearest bus stop.

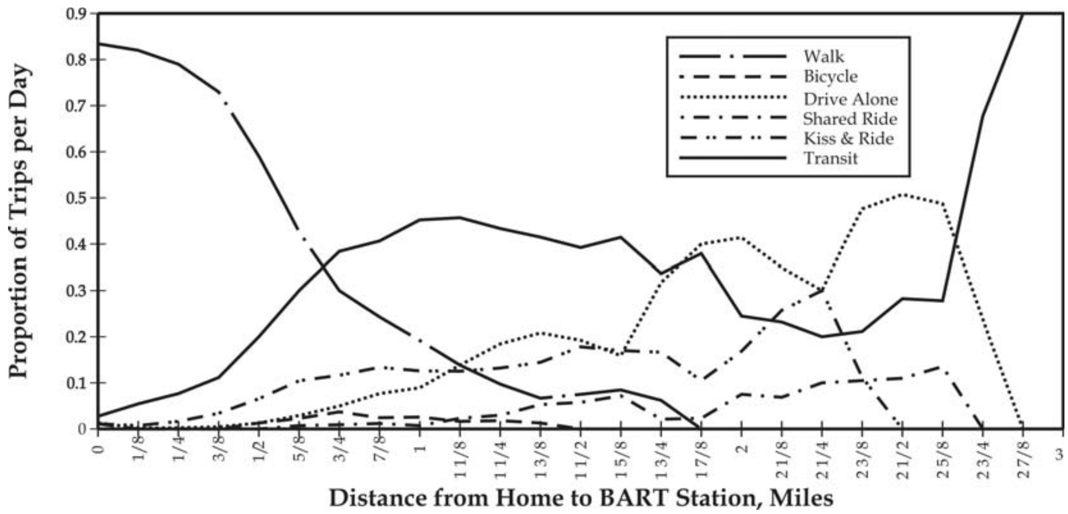
At 200 feet from the nearest bus stop the zero-car ownership penetration ratio was 65 rides per 100 dwelling units, for one car it was 55 rides, and for multiple cars it was 50 rides. A decline in transit use with increasing walking distance to bus stops was found for each level of car ownership. The curves, in a range from 200 to 1,000 feet walking distance, show a drop of about five weekday rides per 100 dwelling units for each 100 feet in added walking distance for households within any one of the three car ownership categories. For example, between 200 and 1,000 feet from a bus stop, the penetration ratio for single-car owners dropped from about 55 rides per 100 dwelling units to 15 rides per 100 dwelling units (Levinson and Brown-West, 1984).

A 1996 Chicago study of HRT (subway/elevated) and commuter rail access provides a rail transit example expressed in terms of likelihood of choosing walk access. It demonstrates the relationship of shorter access distances to larger proportions of walk access and also the longer walks found in rail transit access as compared to local bus access. Overall, 84.1 percent of surveyed rail transit users within about 1/2 mile of the station chose to walk to it, 46.9 percent of users between about 1/2 mile and 1 mile chose to walk, 12.4 percent between 1 mile and 1-1/2 miles, 3.4 percent between 1-1/2 miles and 2 miles, and practically no users from farther than 2 miles (Wilbur Smith and Associates et al., 1996b). After distance, the four most prevalent reasons given by survey respondents for not walking to transit stations were "inadequate sidewalks, weather, not dressed appropriately, and dangerous traffic intersections" (Wilbur Smith and Associates et al., 1996a). Another study cites "danger from auto traffic, no sidewalks, and inadequate lighting" as the chief reasons for not walking by potential walkers (Replogle and Parcells, 1992).

Figures 16-4 and 16-5 provide further background by illustrating the drop-off in walking with distance to BART HRT stations, from home, in the case of work-purpose trips utilizing this Metro-type San Francisco Bay Area system. The graphs show the proportion of work trips by each access mode, during a weekday, for different distances from the stations. Both figures present averages for a group of non-CBD stations, but Figure 16-4 pertains to urban BART stations such as Mission-16th Street (San Francisco), Berkeley, and Lake Merritt (Oakland) while Figure 16-5 pertains to suburban center stations. Note that for urban stations walking takes place for longer distances from the stations, with at least 50 percent walk access for slightly over 1/2 mile. The primary alternative access mode is bus transit. For suburban center stations walking maintains at least a 50 percent walk access mode share for only up to 3/8 mile, and the primary alternative is park-and-ride (Parsons Brinckerhoff et al., 1996b). A survey of Mountain View, CA, Caltrain commuter rail station area resident users showed a walk access from home mode share pattern close to midway between those illustrated in Figures 16-4 and 16-5, but for commuter rail trips of all purposes (Park and Kang, 2008). The illustrations and the Mountain View observations are all based on airline distances (Parsons Brinckerhoff et al., 1996b, Park and Kang, 2008).

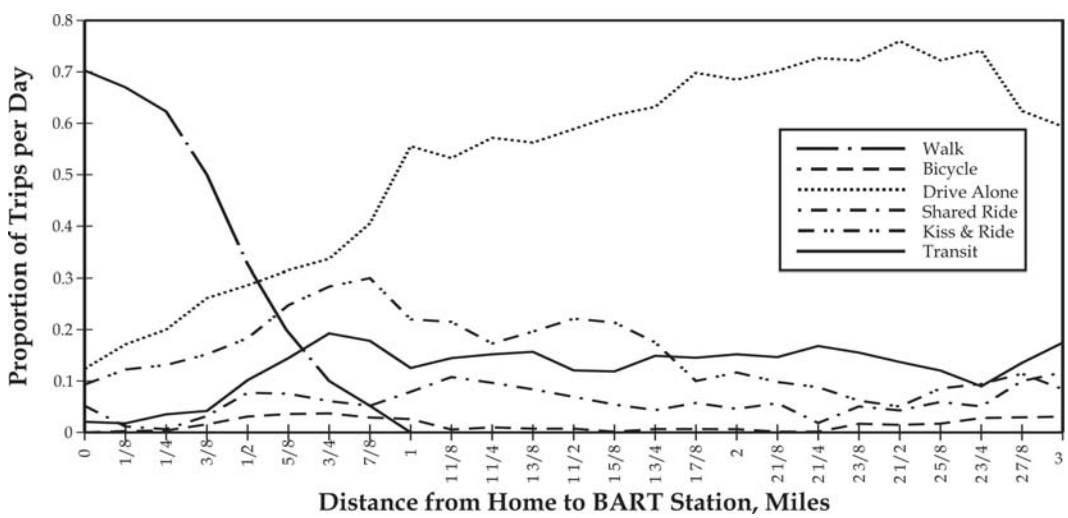
Table 16-26 summarizes a number of studies that, from various points of view, investigated the importance of good transit service to walking activity, or the role of pedestrian access distance or facility availability on transit mode choice, or choice of the walk mode for transit access. The research covered in the 1st and 2nd table entries found, respectively, that quality of transit service is positively associated with choice to walk in general (Committee on Physical Activity, Health, Transportation, and Land Use, 2005) and that transit users are more likely to participate in at least a moderate level of walking than non-transit users (Moudon et al., 2007).

Figure 16-4 Commute trip mode of access from home to urban BART stations.



Source: Parsons Brinckerhoff et al. (1996b).

Figure 16-5 Commute trip mode of access from home to suburban center BART stations.



Source: Parsons Brinckerhoff et al. (1996b).

Table 16-26 Summary of Research Findings and Other Studies on Relationships of Transit Service Levels and NMT Access Quality with Walk and Walk/Transit Activity

Study (Date)	Process (Limitations)	Key Findings
1. Cervero and Gorham – 1987 as summarized per SR 282	Tabulated 1990 Census travel data for 14 income-matched "transit" and "auto" neighborhood pairs in San Francisco Bay Area and 12 in Los Angeles region. (Work trips only.)	Transit neighborhoods in S. F. area had 1.2 to 13.4 percentage points higher walk mode share. In L.A. area, the transit neighborhoods had 1.7 to 24.6 percentage points higher walk share.
2. Moudon et al. (2007) & Moudon et al. (2005) (see "Ped…cycle Friendly Neigh-borhoods" for more information)	Cross-sectional analyses of walking and cycling activity, socio-demographics, attitudes, and objectively measured environmental variables covering 608 adults in King County, WA. (Extent of walk and bike activity self-reported.)	Transit users (at least once a week) were found to be much more likely to walk moderately (odds ratio of 4.4) or to walk sufficiently (Surgeon General's recommendations) (odds ratio of 6.3) relative to their odds of being a nonwalker. Cycling was also positively related to transit use.
3. Besser and Dannenberg (2005) (see also "Under-lying Traveler Res-ponse Factors" – User Factors")	Descriptive statistics were calculated from the 2001 National Household Travel Survey (NHTS) covering the walking activity involved in access-ing U.S. public transit. (Trips with a 2nd access mode such as auto, 5% of the transit trips, were excluded.)	During their survey day, 3.1% of NHTS respondents walked to/from transit, averaging 19 minutes total daily walk time. Highest odds for being transit walkers were found among lower income, less educated, and non-white populations, and in denser urban areas.
4. Investigation by Handbook Authors – 2008 (see Montgomery Co. case study un-der "Results - Path Connection…")	Prior to mid-1980s the Garrett Park, MD, MARC commuter station was separated by private property from Randolph Hills. A park was created and an 800 ft. paved path built, and later illuminated. In 2008 a 1-day count was made of PM alighting riders. (Prior conditions anecdotal.)	Prior to path completion, rail ridership from Randolph Hills was negligible. In the "after" condition, out of 33 alight–ing passengers on 6 outbound trains, 24% walked toward Randolph Hills, 42% walked away into Garrett Park and vicinity, and 33% drove away in cars parked at the station.
5. Project for Public Spaces (1998)	Sidewalk area and curb extensions were added along NW 23rd Avenue in Portland, OR, to help address pedestrian congestion at bus stops. (No investigation of travel effects.)	Despite interference of street furniture with full use, the bus stop improve-ments (including shelters with seating, trash receptacles, newspaper boxes) received high marks in a user survey.
6. Wilbur Smith and Associates et al. (1996a)	Behavioral models describing transit use and transit access mode were developed on the basis of preference and intercept surveys for Chicago's Metra (commuter rail) and CTA (HRT). (Bus not addressed.)	Most pedestrian improvements estima-ted to have positive impact on walk mode access. Significant prior access modes included auto (Metra) and feeder bus (CTA). Estimated up to 7.2% more walk access for Metra.
7. Hsaio et al. (1997) (see this section for more information)	Orange County, CA, 1990 on-board transit rider survey used, in conjunc-tion with GIS evaluation of street pattern and land use effects, and 1990 Census journey-to-work mode shares, in a descriptive analysis of walk distance effects on bus mode share. (Observed static situation.)	Established that 80% of bus riders walk 1/4 mile or less to/from bus stops. Found that as the proportion of an area within 1/4 mile decreases from 80% to 20%, work purpose trip transit mode share declines from 7.9% to 0.5%. From this result the importance of improved pedestrian linkages was inferred.
8. Zhao et al. (2002) (see this section for more information)	Miami Dade County transit onboard survey sample used to improve on use of 1/4 mile buffer to describe walk to transit accessibility for resi-dential population. (Static situation, no accessibility analysis differentia-tion between Metrorail and bus.)	Found a decay function to best repre-sent transit stop accessibility, applied (up to 1/2 mile) to street network distance from the residence, taking walk barriers into account. Relative to transit trips at 300 ft., siting at 1,200 ft. produced 21% as many, at 2,400 ft., 4%.

Table 16-26 (Continued)

Study (Date)	Process (Limitations)	Key Findings
9. Weinstein et al. (2007) (see also "Underlying… Factors" – Trip Factors")	AM surveys of riders walking into 5 U.S. West Coast rail transit stations asked respondents to trace their route from their origin on maps and inquired about route choice factors. (Observed static situation.)	The 25th percentile walking distance was 0.27 miles, the median was 0.47, and the 75th percentile was 0.68 miles. Top ranked route choice factors were distance minimization, followed by safety factors and sidewalk condition.
10. Park and Kang (2008) (see this section both under "Pedestrian Access and Egress" and "Bicycle Access and Egress" for more information)	Self-administered survey was handed to transit users entering Mountain View, CA, Station from 5:30 to 10:30 AM. Origin, route to station, travel, and socio-economic status information was obtained with a 62% response rate. Binomial logit mode of access models were developed. The walk versus auto model covered commuter rail users living within 1.5 airline miles and the bike model covered users within 2.0 miles. (Walk vs. bike vs. bus trade-offs excluded from consideration, only one station area site studied.)	Caltrain user mode of arrival (all distances) was 17% walk, 11% bike, 2% bus, 50% drive alone, and 20% carpool and drop-off. Variables remaining in the final walk model (R^2=0.54) were access distance, work purpose, car availability, race (Asian), auto friendly street close by, and (the only positive) 4-way intersection density. Negative variables in the final bike model (R^2=0.21) were distance, car availability, and auto friendly street. Positives were male gender and white race. Neither model found significance for income, age, or national origin.

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column. The notation "SR 282" is shorthand for Committee on Physical Activity, Health, Transportation, and Land Use (2005) together with Handy (2004).

The 3rd entry in Table 16-26 provides information supportive of the walking sufficiency findings described in the 2nd table entry. It highlights a study, of particular importance to public health practitioners, that found users of transit service in the United States to average 19 minutes total of daily walking time in the course of getting to and from transit stops and stations. As noted already, this same study determined that 29 percent of transit users meet or exceed the recommended 30 minute walk exercise minimum while accessing and egressing their bus or train service (Besser and Dannenberg, 2005).

The 4th Table 16-26 entry presents a small count-based analysis to help demonstrate the obvious yet often overlooked role of NMT connections in facilitating transit ridership by expanding service area. The 5th table entry offers no actual travel demand outcome information, but serves to underscore the contribution made to transit walk and bike accessibility by proper bus stop design (Project for Public Spaces, 1998). Construction of suitable bus stop provisions combined with critical links of sidewalk have been shown in specific cases to be quite cost effective when they allow access to conventional transit service by people with disabilities who otherwise would require expensive-to-provide and often time-constraining Americans with Disabilities Act (ADA) door-to-door paratransit service (Goodwill and Carapella, 2008). (See "Related Information and Impacts"—"Economic and Equity Impacts" for cost recovery calculations.)

Behavioral model research and application, rather than empirical findings, forms the basis of the 6th entry in Table 16-26. Application of mode of access share behavioral models developed for the purpose, in this Chicago area Metra commuter rail and Chicago Transit Authority (CTA) access study, produced estimates that most pedestrian improvements would have a positive impact on choice of walk mode access. The model results for Metra stations indicated that many of new walkers would have previously driven to the station. For rapid transit stations, some of the new walkers would come at the expense of the feeder bus service. Extensive pedestrian improvements tested for the commuter rail stations were estimated to induce up to 7.2 percent more riders to choose walking for access (Wilbur Smith and Associates et al., 1996a).

The 7th entry in Table 16-26 encapsulates an analysis of the Orange County (California) Transportation Authority's 1990 on-board survey along with 1990 U.S. Census journey-to-work mode shares by Census tract. The analysis found that more than 80 percent of bus riders were walking up to, but no more than, 0.25 miles to or from the Authority's bus stops. Using this 0.25 mile threshold as a definition of accessibility, researchers looked at how differences in street patterns or land use characteristics impacted pedestrian accessibility to transit. Two areas with irregular street patterns and lower-density land use were compared with two mature suburban areas with regular grid street patterns and higher-density mixed residential and commercial land uses. Bus stops and residences were pinpointed in a geographic information system and distances were measured along road centerlines. About 56 percent of the population was determined to be "transit accessible" in the two areas of irregular streets compared to 75 and 81 percent in the two gridded-street areas.

Further Orange County analysis found that as the pedestrian accessibility level for an area decreased from 80 to 20 percent, using the 0.25-mile threshold and the street centerline measurement approach, the journey-to-work mode share for transit usage decreased correspondingly from 7.9 to 0.5 percent. This relationship, along with the prime-mode shares for driving alone and carpooling, is illustrated in Table 16-27. The analysis was done at the Census tract level of trip data aggregation. It was concluded that providing additional pedestrian linkages to enable more direct access to transit "would logically result in increased ridership" (Hsiao et al., 1997).

Table 16-27 Walk Access Versus Journey-to-work Mode Share, Orange County, California

Percent of Population within Walking Distance	Total Workers	Bus Riders		Drive Alone		Carpool	
		Number	Percent	Number	Percent	Number	Percent
80 – 100	129,629	10,278	7.9	82,683	63.8	26,958	20.8
60 – 80	213,088	7,013	3.3	160,934	75.5	31,645	14.9
40 – 60	276,417	7,908	2.9	215,343	77.9	38,551	13.9
20 – 40	223,432	3,088	1.4	187,073	83.7	25,154	11.3
10 – 20	166,012	872	0.5	143,160	86.2	16,797	10.1
Total	1,008,578	29,159	2.9	789,193	78.2	139,105	13.8

Source: Hsaio et al. (1997).

The 8th and 9th entries in Table 16-26 provide two more studies along the same vein. The Miami-based analysis, the 8th entry, found walking to drop off sharply with distance from a bus stop or Miami Metrorail station (the transit system and the study are bus-dominant). It was determined that if transit ridership generation at 300 feet from a bus stop or station is indexed at 100 percent, ridership is only 21 percent at 1,200 feet and 4 percent at 2,400 feet (Zhao et al., 2002). The 9th entry illustrates, on the basis of walking patterns to five rail transit stations in the San Francisco Bay Area and Portland, Oregon, that riders tend to be willing to walk farther to access urban rail stations than bus stops. This study found the median walking distance to urban rail to be almost 1/2 mile (Weinstein et al., 2007). Information from both of these two studies is used in a comparative analysis with bicycle access distance within the "Bike-on-Bus Programs" discussion (see Table 16-35).

The 10th entry in Table 16-26 introduces a mode of access modeling research effort that included a review of past mode of access models. The review is summarized in Table 16-28 along with the researchers' own Caltrain commuter rail access model, derived from their survey of Mountain View, California, station arrivals. Except as noted with respect to race, socio-economic variables proved significant in only one modeling effort—the third utilizing San Francisco BART HRT station access data—and then only in one of three formulations reported on. In the Caltrain model, Asian race was a negative for walk access and white race was a positive for bike access. Income, age, and United States versus foreign birth were all specifically found not to be significant in the Caltrain research. Auto availability, however, was a negative factor in three of the models, and station parking supply was a negative in two, indicating that ease of driving dampens non-motorized access choice (Park and Kang, 2008).

Table 16-28 Factors Found in Revealed Preference Modeling to Influence Walking and Bicycling Mode of Access Shares at Rail Stations

	Study/System				
Factors	Korf, Demetsky, and Hoel – 1979 BART	Cervero – 1995 BART	Loutzenheiser – 1997 BART	Cervero – 2001 Wash. Metro	Park and Kang (2008) Caltrain
Socio-economic variables			±W	—	—
Race (Asian, white)			—		±W,B
Gender (male)			+W		+B
Trip purpose (work)					–W
Auto availability	–W		–W		–W,B
Station auto parking supply		–W	–W		*
Station access distance	–W		–W		–W,B
Density/compactness		+W	+W		
Land use mix/retail access		+W	+W		
Intersection density				+W	+W
Sidewalk/street miles ratio				+W	
Auto-friendly street nearby					–W,B

Notes: "+" indicates positive factor, "–" indicates negative factor, "±" indicates sign depends on variable or model.

"W" indicates inclusion in walk model, "B" indicates inclusion in bike model, "—" indicates specifically-reported lack of significance.

Bike model significant factors reported only for Park and Kang (2008).

* Neither station-auto- nor bike-parking supply could be modeled in a single-site study.

Source: Park and Kang (2008), with elaboration by the Handbook authors.

Station access distance once again shows up as important, being so identified in a majority of the mode of access model sets examined in Table 16-28. Also, all but the earliest model—which was limited by data availability—found at least two indicators of pedestrian/bicycle friendly environment to be significant. In the case of the Caltrain model, one of the indicators is a negative, namely, living within 250 feet of an auto-friendly street—defined as having a posted speed of 35 mph or higher. The researchers note that such a street can be either a deterrent to walking or bicycling, or an encouragement to drive, or both. The other significant Caltrain model indicator of pedestrian/bicycle friendly environment is the number of four-way intersections per square mile in the home Census tract (Park and Kang, 2008). This value is a surrogate for good connectivity. Also, in Mountain View, the higher densities of four-way intersections occur where traditional neighborhood design, the historic downtown, and a complete grid system of streets and sidewalks are found.

The relationships between distance to a transit stop or station and the amount or percentage of walk-transit trip making are so strong that it seems reasonable, even without much before-and-after data, to assume at least some relationship transferability to assessment of effects of shortening transit access distance. Shortening pedestrian access distances to transit through introduction of good pedestrian linkages should logically increase walk-transit trip making.[31]

Bicycle Access and Egress. Bicycle trips taken in conjunction with transit use constituted, circa the year 2000, roughly 1/10 of 1 percent of all trips taken in the United States and perhaps 10 percent at most of all bicycle trips. The derivation of this estimate is presented (in conjunction with Tables 16-88 and 16-89) in the "Related Information and Impacts" section under "Extent of Walking and Bicycling"—"Extent of Bicycling." Relatively little empirical study has been done on U.S. bicycle access and egress to/from transit in and of itself. There is additional information, however, on response to allowing bicycles on buses and rail transit vehicles, presented under "Bicycles on Transit Vehicles" following the "Transit Oriented Development" discussion.

Table 16-29 presents a modicum of evaluation findings concerning bike-to-transit activity. In addition to Table 16-29, the 2nd and 10th entries in Table 16-26 included bike-to-transit research in context with walk-to-transit findings. These research efforts are reexamined from a bicycle perspective after review of Table 16-29 entries.

The 1st Table 16-29 entry covers a stated preference experiment aimed at determining the relative effectiveness of bike lanes, lockable covered parking, and bike lockers as means for attracting more usage of bicycling for transit access. Lockable covered parking was estimated to be 40 percent as effective as bike lockers, which were felt by frequent cyclists to be more important than either wide curb lanes or bike lanes on access routes. Infrequent cyclists, however, felt the access improvements were more important than lockers (Taylor and Mahmassani, 1996).

[31] This is essentially the thought process employed by the authors of the Orange County, California, analysis described above in deriving their conclusion about the benefit of pedestrian linkages (Hsiao et al., 1997). The primary limitation in this argument is the extent to which those desirous of using transit may have deliberately "self-selected" their residence location to be close to a stop or station. The phenomenon of self selection is examined in the "Underlying Traveler Response Factors" section under "Choice of Neighborhood/Self-selection."

Table 16-29 Summary of Research Findings and Other Studies on Relationships of Bicycle Access Quality and Bicycle Parking with Bike-Transit Activity

Study (Date)	Process (Limitations)	Key Findings
1. Taylor and Mahmassani (1996) (see "Point-of-Destination Facilities" for more information)	Conducted a stated preference experiment with hypothetical transit access scenarios for commuting to work and developed a nested logit model from the auto-only, auto-park-and-ride, and bike-and-ride preferences expressed. (Convenience sample, mostly avid cyclists.)	Provision of a bike lane slightly *more* important than bike lockers for infrequent cyclists; for frequent cyclists either wide curb or bike lane was 30% as important as lockers. Lockers estimated to encourage bike-and-ride over driving to transit or all the way. Lockable covered parking 40% as effective.
2. Wilbur Smith and Associates et al. (1996a) (see this section for more information)	See Table 16-26 for survey/ forecast process description. (In behavioral model development, the influence of bike paths, lanes, and routes was found not to be statistically significant — possibly reflecting in part baseline bicycle-friendliness of the station areas. Significant effects *were* estimated for "wide curb lanes" but these were undefined in the survey, reducing outcome significance)	Wide curb lanes and most especially secure bike parking were determined to have a positive influence on bike access choice. For access trips from home originating within 2 miles of stations, improvements were predicted to increase bike shares from 2.1% to 3.2% for Metra and from 0.5% to 6.5% for CTA. The overall Metra/CTA bike access share was estimated to increase from less than 1% to nearly 1.5%.
3. Replogle and Parcells (1992) (see this section for additional inventory example)	In July 1979, bicycle racks for 457 bikes were added to 9 commuter rail stations near Chicago to help mitigate Edens Expressway traffic. Bike counts were made at 88 stations in 1990. (No in-depth analyses.)	In August 1979, 222 bicycles were parked in the new racks. In 1990, 88 Metra stations had bike parking. Parked there in designated locations were 564 bicycles, plus 245 more were seen locked to poles, trees, signs, etc.
4. RTC and APBP (1998), Bikestation (2003)	Long Beach, CA, has a Bikestation© on the transit mall at the end of the Blue Line LRT to Los Angeles with free valet parking for 150 bicycles, rentals, repairs, etc., convenient to over 30 miles of bike paths/lanes. (See next column for limitations.)	In its first 18 months of operation, the facility parked about 1,500 bicycles per month, increasing at a rate of about 10% per month. (Proportion of Bikestation use associated with LRT or local bus system usage was not reported.)
5. Replogle (1993) (see this section for more information)	Concurrent with suburbanization, Japan constructed thousands of miles of bicycle paths and lanes and millions of public and private bike parking spaces at rail stations, totaling 2.77 million spaces in 8,735 facilities by 1989. (Few details.)	Despite rising auto ownership, use of bicycles to access rail stations grew from some 300,000 in 1975 to more than 3,000,000 in 1989. Ten percent of rail riders bike to transit stations, with some stations experiencing as much as 50 percent bicycle access.

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column.

Chicago area behavioral modeling of rail transit access choices, based on surveys of existing options, conditions, and choices, is summarized in the 2nd Table 16-29 entry. Again, parking provisions exhibited primary importance, with the estimated opportunity to raise overall Metra commuter rail and CTA subway/elevated bike-to-rail shares by almost 50 percent (Wilbur Smith and Associates et al., 1996a). Bicycle count comparison data presented as a supplement to the 4th entry in Table 16-29 suggest that Chicago's Metra has accomplished more than that in 10 to 15 years.

Additional details of the Chicago area rail transit access behavioral modeling are of interest for the insights provided on primary mode and access mode shift potentials. The separate models for Metra and CTA, when applied for improved bicycle parking and access, predicted Metra bike mode of access choice to increase from 2.1 percent to 3.2 percent for home-based trips originating within 2 miles of the station. For CTA stations, the predicted increase was from 0.5 percent to 6.5 percent. The analysts did not find that the improvements would affect prime mode choice, that is, induce new transit riders. Instead, the changes in access mode share were estimated to accrue from diversions from other modes of access. For Metra, which has extensive drive access (68 percent at the time), about one-half the diversion was from drivers. For CTA, with primarily walk access (44 percent), the majority of the diversion (about 80 percent) was from walkers. The potential for diversion diminished as the origin distance from the station increased. Although for many reasons it is desirable to attract bicyclists from the drive access mode, the study found that bicyclists generally were more likely to be diverted from pedestrian access, there being more in common between these two modes than between bicycling and driving a car (Wilbur Smith and Associates et al., 1996b).

The 3rd and 4th entries in Table 16-29 offer usage-count evidence that moderately-sized bicycle parking facilities will receive worthwhile usage when provided at U.S. rail stations and transit terminals, but the information provided does not lend itself to more expansive conclusions. However, when the report that the Metra system in 1990 parked just over 800 bicycles at stations offering spaces—with 30 percent of the bikes not in designated spots (Replogle and Parcells, 1992)—is contrasted to information that Metra circa 2008 provided 4,257 bicycle spaces (Pucher and Buehler, 2009b), strong continued bike-to-Metra growth is indicated.

With respect to bike stations, the subject of the 4th table entry, 5 of the 10 bike stations in the United States as of 2009 were at San Francisco Bay Area rail transit stations. They provide a total of 433 spaces at three BART stations and 226 spaces at Caltrain commuter rail stations. Reported utilization rates range from over 100 percent at the BART station in Berkeley down to 11 percent at the Caltrain station in Palo Alto. The Berkeley bike station was slated for a tripling of capacity (Pucher and Buehler, 2009b).

Another example of inventory-type information was developed for Miami Metrorail HRT stations and bus park-and-ride lots, in the 2001–2002 period, as a precursor to improvements. At the 21 Metrorail stations, a 3-day average of 122 bicycles system wide was observed in racks or informally parked. In addition, 53 bike lockers were rented, relative to 111 undamaged lockers available out of a total of 246 mostly installed in 1986. It was judged that 170 to 180 patrons used Miami Metrorail bicycle parking daily. A grand total of two parked bicycles were observed at the 10 bus park-and-ride lots.

A survey, offered in three languages, was given to all the Metrorail bicycle parkers who would volunteer and 72 responses were obtained. Racial minorities and persons of Hispanic origin made up 48 percent. Males were over 85 percent of the total, median age was in the 40 to 59 bracket, and almost 60 percent who gave their income earned less than $30,000 per year. Interestingly, the other heavily represented income grouping, at over 20 percent, was persons earning more than $70,000 per year. Bike-transit riding by the Miami Metrorail survey respondents was very regular, with a median frequency of 5 days per week. Some of this usage was bike-on-transit, with 40 percent of respondents sometimes taking their bike on Metrorail (allowed only off-peak) and just over 20 percent reporting use of the Bikes-on-Bus program. Having had a bicycle parked at Metrorail stolen and/or vandalized was reported by over half and the highest level of importance was given to having all bicycle parking in view of staff/security (Hagelin, 2002).

BART 2009 inventory data illustrate the other end of the U.S. HRT spectrum from the early 2000s Miami Metrorail situation. In addition to its 246 bike lockers, not all usable, Miami Metrorail provided racks at a number of its stations: 22 racks in total (Hagelin, 2002). Assuming a rack capacity of a dozen bicycles each, Miami Metrorail would thus have had a theoretical total of about 500 bicycle parking spaces at its 21 stations, an average of 24 per station. BART in 2009 had over 4,300 bicycle parking spaces in total located at most of its 43 stations, an average of 100 per station, 1/4 in secure lockers. Adding in bike-station spaces brings the 2009 BART average to 110 per station (Pucher and Buehler, 2009b). To some extent this is a result, of course, of the much higher BART ridership per station.

The 5th and final Table 16-29 entry illustrates the substantially greater growth and usage (in absolute terms) of transit-related bicycle facilities in Japan, with a 10 percent reported bicycle access mode share for rail stations in 1989, and some stations experiencing as much as 50 percent bicycle access (Replogle, 1993). In the Netherlands, some 35 percent of transit patrons overall use bicycles for access. The typical station with over 5,000 boardings per day might have 2,000 guarded bicycle parking spaces versus only 250 spaces for automobiles (Replogle and Parcells, 1992, Wilbur Smith and Associates et al., 1996a).

Turning back to bicycle access information included in with the "Pedestrian Access and Egress" discussion, the 2nd entry in Table 16-26 provides an example of overall cycling levels found to be related, positively, to higher use of transit, in this instance in the greater Seattle area (Moudon et al., 2005). The 10th entry in Table 16-26 is of special interest as a rare example of a reasonably successful attempt to model bicycle mode of access to transit with revealed preference survey data, notwithstanding the somewhat disappointing explanatory value of the model (R^2=0.21) compared to the companion walk mode of access model (R^2=0.54).

The model development was based on surveyed Caltrain commuter rail rider access to the Mountain View, California, station from surrounding residences. In terms of socio-economic variables, the research found no significance for income, age, or national origin, although male gender and white race were positive factors. Higher car availability was a negative indicator for bike access. The greater the distance of the home from the station, the lower was the probability of bike mode of access choice. One built environment variable was found to be significant. Although residence within 100 feet of a bike lane was one of several built environment variables that had to be discarded, living within 250 feet of a street with fast-moving traffic was a significant negative factor for bike mode of access share. The constraints of the single-site study were such that effects of station automobile parking supply could not be examined (Park and Kang, 2008), and neither would modeling of bike parking supply importance have been possible.

Figures 16-4 and 16-5, presented earlier, illustrate the drop-off in bicycling mode of access shares with distance using BART HRT data for weekday work-purpose trips. Figure 16-4 pertains to non-CBD urban BART stations in San Francisco, Berkeley, and Oakland. The primary market for bicycle access under these conditions can been seen to be between 3/8 and 1-1/2 miles from the station. Figure 16-5 pertains to suburban center stations and shows the primary bicycle access market there to be between 1/4 and 1-1/8 miles from the station. The bicycle access mode share picks up again after 2-1/4 miles, but applies to a diminishing absolute number of rail transit riders that far out from the station (Parsons Brinckerhoff et al., 1996b). The Mountain View Caltrain survey, covering all commuter rail trip purposes, found bicycle mode of access shares to be above 10 percent (considering walk, bike, and auto only) between 1/2 mile and 2 miles of the station. The bike share peaked between 1 and 1-1/4 miles at about 38 percent, and was no less than 5 percent for a distance of 5 miles out from the station (Park and Kang, 2008).

In the 1990s and first decade of the 21st Century, many U.S. transit operators—bus operators in particular—placed more emphasis on allowing patrons to put bicycles onto transit vehicles than on parking them at ordinary transit stops. A return-on-investment analysis and related studies have found that despite considerable bike-on-transit activity, investment in bike parking at bus stops and even many rail stations has been low. Bike parking is receiving renewed interest, however, at agencies where bike-on-transit ridership is exceeding the practical bike capacity on bus bike racks and train cars. Between 2006 and 2008, the number of bike parking spaces at rail stations and bus stops grew by 26 percent in the United States and 67 percent in Canada, with the 2008 U.S. inventory totaling 24,178 at rail stations, 9,005 at bus stops, and 176 at ferry terminals (Hagelin, 2005, Pucher and Buehler, 2009b). Bike-on-transit experiences are presented immediately following the "Transit Oriented Development" discussion. Some of these experiences suggest that opportunities for shifting riders from bike-on-transit to use of station and stop bike parking facilities may have their limits, particularly when both ends of the trip are in spread-out suburban development.

Transit Oriented Development

Perhaps the best way to enhance pedestrian and bicycle access to transit is by placing greater numbers of residences and activities within reasonable walking distance of a transit station or stop, all in a pedestrian-friendly environment. This is the thrust of transit oriented development (TOD), which generally refers to higher density development, with pedestrian priority, located close around a major transit station or stop. TOD should be good for bicycle access as well, although the short access distances offered tend to make walking the dominant TOD transit access mode by far.

TOD is primarily covered within Chapter 17, "Transit Oriented Development," of this *TCRP Report 95: Traveler Response to Transportation System Changes* Handbook. A summary of key comparative observations from Chapter 17 pertaining to impacts of TOD on amount of active transportation is provided in Table 16-30. Prime-mode-share findings are addressed first in discussion of the table, followed by examination of mode-of-access share observations.

Table 16-30 Summary of Primary Comparative Observations from Chapter 17 on Impacts of Transit Oriented Development (TOD) on Non-Motorized Travel Activity

Source (Date)	Process (Limitations)	Key Findings
1. Lund, Cervero, and Willson (2004) and 2000 U.S. Census SF3 data (see Chapter 17, "Response by…" — "…Regional Context" — "Suburban TODs")	Current mode shares and mode of access shares were obtained from self-administered surveys at 4 Pleasant Hill (PH) station area projects. Mode share for Walnut Creek, CA, as a whole was from U.S. Census. (Comparative commute data sources, methods, and definitions not fully consistent.)	Work purpose walk-only prime mode share of 2.3% for PH projects was little different from Walnut Creek overall. However, rail-transit PH-project mode share of 44.3% versus 13.5% for Walnut Creek (bus use nominal), with 96% walk mode of access to rail for PH projects, suggests multiple times as much walking as part of the commute.
2. Derived from data in Evans and Stryker (2005) (see Chapter 17, "Response by…" — "…Regional Context" — "City Center Versus Suburban TOD Comparisons")	Analysis of non-work travel from Portland Metro 1995 regional travel survey. TOD-like traffic analysis zones (TAZs) were identified using professional judgment. Most 1995 TODs were bus-only. (Demographic effects, not isolated out, pertained mostly to household size. Too few central area non-TOD TAZs for direct central area comparisons.)	Home-end walk/bike-only non-work shares of 33% for central area TOD and 14% for outlying TOD vs. 8% for non-TOD (mostly outlying). Non-home-end NMT shares of 18% for both central area and outlying TOD vs. 8% for non-TOD. Non-work transit shares (generally associated with walking) of 7% to 8% for central area TOD and 2% for outlying TOD vs. 1% for non-TOD.
3. Lund, Cervero, and Willson (2004) (see Chapter 17, "Response by…" — "Response to TOD by Land Use Mix" — "Residential")	Self-administered survey responses were obtained from 624 households in 26 station-area projects in CA. For 15 projects throughout the state, commute mode shares were compared with Census data for the surrounding 1/2 to 3 mile "donut." (Survey response rate was 13%.)	Station-area resident transit use for commuting was 20% above that for surrounding "donuts," with a station-area range of 36% above to 8% below the surrounding area. Over 90% of station area residents in the overall survey reached their neighborhood rail station by walking.
4. S.B. Friedman & Company et al. (2000a and 2000b) (see Chapter 17, "Underlying… Factors" — "Land Use…" — "…Supportive Design")	Self-administered passenger surveys were obtained at 6 high-ridership Chicago-area commuter rail stations, with an overall survey response rate of 32%. (Station access trip length was self-reported.)	From 0.0-0.5 miles to station, 82% walked to train; from 0.5-1.0 miles, 41% walked; from 1.0-2.0 miles, 8% walked; from more than 2.0 miles, 1% walked. High ridership apparently related to good pedestrian environment and concentrated station-area development (including stores).
5. Dill (2006a and b) (see Chapter 17, "Related Info…" — "Pre- and Post-TOD Travel Modes" — "Disaggregate Mode Shifts…")	Self-administered survey returns from residents at 8 different TOD and transit-adjacent developments at 4 stations on Portland's LRT Blue line, with individual-development survey response rates ranging from 24 to 43%. (Questions about travel mode at prior residence were dependent on respondent recall.)	Walk-only commute mode shares increased by 38% (2+ percentage points), with no change in bicycling, upon moving to TOD and transit-adjacent developments. Transit commute shares increased by 156% (16 percentage points). Of transit commuters, 69% to 100% walk to the station, depending on the location.

Prime Mode Share Observations. The 1st and 2nd studies listed in Table 16-30 are each comparative in structure. They are divided as to whether NMT-only travel is more prevalent in TODs than other areas, but note that the 1st study addresses work purpose travel only, and the 2nd addresses non-work travel only. The Pleasant Hill, California, transit-adjacent project comparison with nearby conventional suburb Walnut Creek illustrates an instance where, for work-purpose trips, there is little difference between a TOD and conventional suburbs in selection of the walk-only commute mode. In the Pleasant Hill case, a full range of TOD amenities is apparently found only for the specific projects constructed on former park-and-ride lot land areas.

The Portland, Oregon, analysis (the 2nd study listed) examined 1995 non-work travel rather than commute travel, and found major differences in the relative walking/cycling prime mode shares between TOD and non-TOD areas. For example, in outlying Portland TOD areas choice of walk-only and cycle-only modes for non-work travel was roughly twice as likely as in non-TOD areas, taking into account the travel associated with both residences and other land uses. It is important to emphasize that potential socio-demographic effects were not explored in either of these analyses. (See Table 16-30 for sources.)

A different approach to assessing TOD impact on choice of the walk-only and bike-only travel modes, and one that has lesser (or at least largely different) methodological issues, is to find out how TOD dwellers have changed their travel mode choices relative to the choices they made at their prior abode. Chapter 17 summarizes the four such studies known to be available of prime-mode shifts by residents upon moving into TODs. (See "Pre- and Post-TOD Travel Modes" under "Related Information and Impacts" in Chapter 17.) The newest and most comprehensively reported of these is encapsulated as the 5th entry in Table 16-30. In this study of 8 Portland TODs, walk-only mode commute shares increased by 38 percent, from 4.7 to 7.0 percent of work-purpose trips. Bicycling for the commute remained unchanged at 1.4 percent (Dill 2006a and b).

A smaller Portland study reported on mode shifts upon moving into mostly below-market-rate, seniors-oriented housing in the Center Commons TOD. The proportion of bike- and walk-only trips to work actually dropped from 9 percent to 3 percent, apparently reflecting a decrease in the proportion of work trips under 5 miles in length. Bike- and walk-only trips for non-work purposes increased from 5 percent to 6 percent (Switzer, 2002). The other two studies, covering transit adjacent development in California, including but not exclusively reflecting development with full TOD characteristics, appear to suggest that net effects on prime-mode-choice NMT use for commuting are not significant (Cervero, 1993, Lund, Cervero, and Willson, 2004).

This mix of circumstances and findings provides insufficient basis for the drawing of strong conclusions. The effects of TOD projects on enhancing walk-only and bike-only travel mode shares appear to be highly dependent on TOD land uses, design, and stage of development, and on whether or not new residents are attracted from neighborhoods where they had been within walking distance of work and other activities. However, since well executed TODs are pedestrian-friendly by design, the conclusions reached from more extensive research on NMT activity presented in the "Pedestrian/Bicycle Friendly Neighborhoods" subsection below can (with reasonable caution) be taken to apply for prime-mode walking and cycling in TODs as well. Doing so, the possible tendency seen for higher walk-only mode shares in the majority of the individual and collective California and Oregon TODs covered in Table 16-30 entries gains additional support.

Mode of Access Share Observations. Up to this point in discussion of Table 16-30, the focus has been on walk-only and bike-only trips viewed from the perspective of prime mode choice. Focusing exclusively on the prime mode overlooks the crucial walk activity gain and auto use reduction impact of shifts to walking as the transit access mode for most TOD residents using transit. Such shifts are only identifiable if the access mode component of the transit trip is looked at separately. The 1st, 3rd, and 5th studies summarized in Table 16-30 illustrate substantially more transit use in TODs than in nearby non-TOD areas or in the prior-to-TOD residential locations. These same studies also found very high walk access-to-transit shares. The Pleasant Hill station area development projects showed over 3 times the BART rail commute mode share as the comparison area, and a 96 percent walk access share to the station. The average walk access share found within 1/2 mile for 26 California station areas was over 90 percent, and the walk access shares for eight Portland TODs ranged from 69 to 100 percent (Lund, Cervero, and Willson, 2004, Dill, 2006b).[32]

The 4th study in Table 16-30 illustrates, using Chicago commuter railroad passenger survey responses, how the inherent transit adjacency of TOD produces enhanced walk access shares. The walk proportion found at the six stations studied increased from 8 percent for a 1.0 to 2.0 mile distance from the station, to 41 percent for 0.5 to 1.0 miles, and 81 percent for under 0.5 miles (S. B. Friedman & Company et al., 2000a and 2000b). Figures 16-4 and 16-5, presented above, illustrate similar relationships for BART HRT in the San Francisco region. TODs thus have enhanced walking activity and diminished auto use for two reasons in addition to pedestrian friendliness:

1. Shifting from auto to transit use, which in turn comes with substantially higher levels of walking for transit access in the transit-adjacent TOD context.

2. Shifting from motorized means of transit access to walk access for those who would be using transit even if they were not located in a TOD.

The second-listed phenomenon is particularly well illustrated in a previously mentioned comparative study of the BART HRT tributary areas of the pedestrian-friendly Rockridge neighborhood in Oakland, California, and the more auto-oriented nearby city of Walnut Creek. The commute travel share attracted by BART was essentially identical in the two BART station areas (21 versus 20 percent, respectively). The BART-access walk share of 31 percent in Rockridge was, however, well over twice the share in Walnut Creek (13 percent) (Cervero and Radisch, 1995). (For more on this study see Table 16-39, 14th entry, in the "Pedestrian/Bicycle Friendly Neighborhoods" subsection.)

Bicycles on Transit Vehicles

There is no recent assemblage of nationwide U.S. comparative statistics on the transporting of bicycles on urban public transit vehicles (Pucher and Buehler, 2009b). It is, however, informative to examine indications that can be extracted from an advocacy-inspired comparative tabulation based on U.S. data from the 1996–2004 period, roughly halfway along in the development to date of bike-on-transit service. In this data set, bicycle carriage data were seasonally adjusted, and gaps were filled by use of similar-city bike-share analogies (Steve Spindler Cartography, 2010).

The top performer in terms of bike-on-transit share of unlinked trips was Caltrain, the commuter railroad serving the San Francisco Peninsula including Silicon Valley, at 6.2 percent in 1997.[33] (Another source, covered below in examining Caltrain results, puts the 1997 proportion at 7.5 percent.) The 75th percentile bike share performer, at 1.8 percent in FY 2000, was the Chittenden

[32] These are not walk access shares for all users of the HRT, LRT, and commuter rail stations involved. They are the walk access shares for station use by persons living within 1/2 mile (26 California station areas study) or within specific projects or TODs adjoining or surrounding the stations.

[33] An "unlinked trip" is a trip maker's ride (or carriage of a bicycle) on an individual transit vehicle between the boarding point and the alighting point, even if the boarding and/or alighting point represents no more than a transfer from/to another train or bus. Since some bike-on-transit trip makers are using the service to avoid transfers, unlinked-trip bike shares may slightly understate bike-on-transit usage from a "linked trip" perspective, which "links" trips at points of transfer to allow examining whole one-way trips from point of first entry onto the transit system to point of final exit from the system.

County Transportation Authority bus system in Burlington, Vermont—illustrating that location in the sunbelt is not a prerequisite for above-average attraction of bike-on-transit riders. The two operators at the 50th percentile (median) bike share of 0.7 percent, for which there were hard data, were Delaware Transit Corporation's Resort Bus Service (2001 data)—operating 4 months of the year—and King County Metro (no date given), greater Seattle's public bus service provider. The 25th percentile system, at 0.8 percent in May, 2003, was PACE, the Elgin, Illinois, bus operator serving the exurbs of Chicago (Steve Spindler Cartography, 2010). About the only service-area type that has seen no penetration of bike-on-bus is the most dense of cities, where walking is the primary access and egress mode, such as for bus service internal to San Francisco proper and New York City (Pucher and Buehler, 2009b).

Another perspective is offered by looking at the systems with the largest numbers of bike-on-transit trips reported. Table 16-31 lists the top U.S. carrier of bicycles for each primary transit mode in the 1996–2004 data listing described above. The two highest carriers of bike-on-bus trips (with hard data) are both included to provide a bus and LRT comparison within one service area, Santa Clara County, California, served by the Valley Transit Authority (VTA) of San Jose. In this tabulation the dominant bike-on-transit carriers are all found to be in the Sunbelt. This may be as much a reflection of the spread-out nature of the major Sunbelt cities or suburbs as it is a reflection of the warmer climate the Sunbelt is famous for.

Table 16-31 Top U.S. System(s) in Bicycle Boardings per Each Transit Mode, Circa 2000

Agency	Headquarters	Mode	Date	Monthly Boardings	Bike-on-Transit Share
Valley Metro	Phoenix, AZ	Bus	FY 2002	85,000	2.0%
VTA	San Jose, CA	Bus	n/a	77,800	2.0%
VTA	San Jose, CA	LRT	2001	21,200	3.2%
BART	Oakland, CA	HRT (Metro)	n/a	36,800	0.5%
Caltrain	San Carlos, CA	Commuter Rail	1997	45,000	6.2%

Notes: A possible top performer, the Los Angeles Metropolitan Transit Authority bus operation, is omitted because the listed underlying bike share had to be estimated by analogy.

The Valley Transit Authority (VTA), Bay Area Rapid Transit District (BART), and Caltrain data were estimated on the basis of one-day bike-on-transit counts and annual unlinked trip reportings, with applicable conversions.

n/a = Date not given, but presumably from the 1996-2004 period.

Sources: Steve Spindler Cartography (2010), Hagelin (2005).

It is relevant to note that BART, in the San Francisco region, does not allow bicycles on board peak-period, peak-direction trains (Pucher and Buehler, 2009b). More recent statistics for Caltrain of the San Francisco Peninsula, and Valley Metro of Phoenix, are found in the bike-on-bus and bike-on-rail discussions to follow. Table 16-32 summarizes information on these and other bike-on-transit programs selected for their experiences offered and information availability. In reviewing Table 16-32, note that the 1st, 6th, 7th, and 8th table entries, taken together, suggest that where both bike-on-transit and bicycle parking offer viable options, from three out of four to nine out of 10 persons arriving by bicycle apparently prefer bike-on-transit over leaving their bicycles parked at stops and stations (NuStats, 2009, Eisen|Letunic and Fehr & Peers, 2008: Pucher and Buehler, 2009b).

Table 16-32 Summary of Before and After Studies and Research Findings on Relationships of Accommodations for Bicycles on Transit Vehicles with Bicycling Activity

Study (Date)	Process (Limitations)	Key Findings
1. Zehnpfenning et al. (1993), Doolittle and Porter (1994), RTC and APBP (1998), NuStats (2009), Valley Metro (2010) (see this section for more information)	Valley Metro in Phoenix transitioned directly from a 1991 bike-on-bus demonstration, with surveys, to systemwide implementation by mid-1992. Annual boarding counts are readily available from FY 2000-2001 to present. Origin-destination (O-D) survey taken in 2007. (Available bike-on-bus rider analysis largely limited to demonstration period.)	Early full-system usage was some 1,000 bicycles boarded/day, roughly 1% of boarding passengers. Usage increased to 3,200/weekday (2.0%) 10 years later in FY 2002-03, and over 4,600/weekday (2.2%) in FY 2008-09. The O-D survey found 4% bike access among bus riders, with 3 out of 4 bike access trips reporting bike egress (presumably via bike-on-bus with the rest bike-and-park).
2. Newman and Bebendorf (1983), Coverly (2010) (see this section for more information)	A Santa Barbara, CA, bus bicycle-trailer demonstration program with data collection and various surveys was initiated in 1978. Subsequently, bike-on-bus service was off-and-on or partial until 2001. (Late 1970s bus riding increases were attributed mainly to the concurrent gas crisis.)	The college-focused bus bicycle-trailer services carried 42,463 bicycles in FY 1980-81, 60% students. Primary travel effects were access mode shifts from walk to bike access and mode shifts from cycling all the way to bus bicycle-trailer use. FY 2001-02 front-mounted bus rack usage was 52,736 bicycles.
3. Hagelin (2005) (see this section for more information)	An examination of 15 Bikes on Bus (BOB) programs included obtaining performance measures for 3 Florida systems and user surveys for 2 of these plus 1 other. (User survey success rates were 11% to 14%.)	The BOB share of all unlinked transit trips ranged from 0.25% to 1.61% for the 3 systems (Table 16-34). Among BOB users 1 in 4 was new to transit, and for over 80% of these, BOB service availability prompted the switch.
4. American Public Transit Association (1997), SunLine (2003)	SunLine operates a regional transit service ("SunBus") over nearly 1,000 sq. miles in California's Coachella Valley. In 1997, 2-bike racks were in place on the front of all 40 buses. (No formal analysis.)	The system began carrying 6,000 bikes per month. Riders were a combination of both commuters and visitors. In 2002, SunBus operated 46 buses on 13 routes and carried some 3,700,000 riders and 61,300 bikes (1.7% share).
5. Boyle (2002), Hagelin (2005) (see this section for more information)	Denver's Regional Transit District did a study of bicycles-on-bus in the summer of 1999 that included a user survey. Most RTD buses were equipped with front-mounted bike racks by that time. (Summer focus.)	There were some 2,300 bike-on-bus boardings each weekday (about 1.4% of all summer bus boardings). The most popular routes linked to the City of Boulder, home of the University of Colorado. (See text for survey results.)
6. Tannen (2010), Eisen|Letunic and Fehr & Peers (2008) (see this section for more information)	Caltrain commuter rail service from San Jose to San Francisco initiated bike-on-rail with its 1992 demonstration. Stowage was expanded in 1994 with onboard racks. Counts of 1997 and 2007 have been analyzed. (No mode choice effects analysis.)	In September 1997, 1,960 riders (7.5%) boarded bicycles. Mode of access in February 2007 was 7% bike-on-rail and 1% bike-and-park. Prior to ±10:30 AM, 500 NB and 424 SB bikes were boarded. Onboard demand over capacity, but station bike parking 55% of capacity.
7. Doolittle and Porter (1994), TriMet (2009), Pucher and Buehler (2009b). (see this section for more information)	In early 1990s, Portland, Oregon's TriMet equipped buses with bicycle racks systemwide and allowed bikes on its single LRT line. By 2009, with 4 LRT lines, a low-floor car with 4 bike hooks was on each LRT train (not the case at first). Bus and LRT bike use is typically reported in combination but LRT sample counts are taken. (Limited information.)	Early in the program about 80,000 bus and LRT bicycle boardings/year were observed, with bike-on-LRT counts in the range of 70/day in Sept. 1993 and 60/day in Feb. 1994. As of 2009 staff estimated 2,100 daily bicycle boardings on LRT versus 200 parked at stations. A TriMet survey found 76% of cyclists unwilling to park their bikes at transit stops even with security and shelter.

(continued on next page)

Table 16-32 (Continued)

Study (Date)	Process (Limitations)	Key Findings
8. Pucher and Buehler (2009b), Steve Spindler Cartography, (2010)	Bay Area Rapid Transit (BART) focuses heavily on providing bike parking at stations, with 1,010 bike lockers and 3,303 other BART bike spaces at 43 stations in 2009. Bikes may be brought on-board except on peak-direction trains during peak hours. (Limited information.)	Data from 1996-2004 placed BART at the top of U.S. HRT Systems for bike-on-rail riders, with 36,800/day and 1/2 of 1% of passengers bringing a bike on board. Despite the heavy emphasis on bike parking, a 2008 survey indicated that 72% of bike-and-ride passengers bring their bike on the train.
9. Pucher and Buehler (2009b), Handbook authors' comments	The New York MTA in theory allows bikes on its subway trains at all times, but access at 84% of all stations requires carrying the bike on stairs. (No usage data.)	Bike-on-rail use of New York subways is probably on the order of 0.02% of ridership based on comparisons available in the previously cited 1996-2004 data listing utilized for Table 16-31.

Notes: No system charged for bicycle carriage except for pre-1977 experimentation in Santa Barbara.

Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column.

Bike-on-Bus Programs. The Phoenix, Arizona, area bike-on-bus program, overseen by the Valley Metro Regional Public Transportation Authority, is of special interest given both data availability and the consistent offer of bike-on-bus service for almost two decades. In addition, based on circa 2000 national statistics, it has been identified as one of if not the largest carrier of bicycles of any U.S. transit system (Steve Spindler Cartography, 2010). The 1st entry in Table 16-32 addresses the Valley Metro experience.

The predecessor to the Valley Metro Regional Public Transportation Authority in Phoenix began their bikes on buses involvement in 1991 with a demonstration program. This pilot project put front-mounted racks on 40 buses operating on three routes. Over 5,500 bicycles total were carried during the 6-month test. In surveys, some cyclists indicated they would not otherwise have ridden the service. The successful test led to system-wide implementation, complete by mid-1992, and a reported 1,000 bicycle boardings out of a total of 104,000 passenger boardings each day.

Bike on bus was found to be used primarily for commuting to work, but multiple trip purposes were reported. The average origin-to-destination trip length was 7 miles, including a 9 minute bicycle ride to the bus, a 41 minute bus ride, and an 8 minute bicycle ride to the final destination. (The essentially equal bike-ride times at each end of the trip conflict with Florida access versus egress distance findings discussed in connection with Table 16-35 and may be an artifact of analysis in origin-destination trip format). Non-bike-riding passengers were found to be not unduly inconvenienced: 89 percent reported seeing no delays on routes with bicycle racks. Experience from elsewhere suggests that most delays associated with bike-on-bus are caused not by the loading and unloading of bicycles from the racks, but from disputes over how to handle situations when the rack is already full (Zehnpfenning et al., 1993, Doolittle and Porter, 1994, RTC and APBP, 1998). Table 16-33 provides Phoenix bike-on-bus and total ridership data for the initial decade of the 2000s, with abbreviated data for alternate years.

Table 16-33 Passenger and Bike Unlinked Trip Boarding Statistics by 2000–2009 Fiscal Year for Valley Metro, Phoenix

Fiscal Year	Annual Passenger Boardings	Annual Bike Boardings	Percentage Boarding with Bikes	Weekday Bike Boardings	Fiscal Year	Percentage Boarding with Bikes
2008-2009	65,670,807 [a]	1,465,980	2.23%	4,657	2007-2008	2.17%
2006-2007	58,019,812	1,175,935	2.03%	3,800 [b]	2005-2006	1.99%
2004-2005 [c]	56,358,335	1,168,805	2.07%	3,700 [b]	2003-2004 [c]	2.04%
2002-2003 [c]	50,319,003	1,000,050	1.99%	3,200 [b]	2001-2002 [c]	1.94%
2000-2001 [c]	40,011,099	748,124	1.87%	2,400 [b]		

Note: [a] "Metro Rail" LRT was opened in Phoenix during FY-2008-2009. The FY 2008-2009 Annual Ridership Report does not include bike-on-rail counts, therefore rail boardings have been removed from the Annual Boardings statistic for comparability.

[b] Pre-FY-2008-2009 average weekday bike boardings are estimated by the Handbook authors based on the FY-2008-2009 ratio of average weekday to annual bike boardings.

[c] Data from two small operations components lost.

Source: Valley Metro (2010), with elaboration by the Handbook authors.

The data in Table 16-33 is indicative of a plateauing from 2002 to 2006 in growth of the percentage of Phoenix passengers boarding with bikes. This plateauing, at about 2 percent, is in turn suggestive of either full market penetration or capacity constraint effects. The uptick in FY 2007–2008, continuing into the following year, could possibly reflect easing of capacity constraints with introduction of three-bike racks.

Santa Barbara, California's mid-1970s bike-on-bus pilot-then-demonstration project, the 2nd entry in Table 16-32, tested the adding of bicycle trailers to minibuses in a college-town context. The full-scale demonstration involved six trailers deployed on various routes, with emphasis on service to colleges and universities (Coverly, 2010). Not all bus trips on all routes were served. Bicycle trailer scheduling was hourly except for added service toward the end of the demonstration on the route with highest usage. Most successful was an express route serving a residential community, the downtown transit center, and the University of California Santa Barbara with 11 designated bike bus stops in approximately 17 miles. Usage was boosted by high gasoline costs related to the late 1970s fuel crisis (Newman and Bebendorf, 1983).

Overall bus ridership increased from 153 to 487 weekday passengers (up 218 percent) on the bicycle-trailer routes during the time period from November 1978 to November 1979. Bicycle-trailer services increased by 205 percent over the same period and the number of passengers with bicycles increased from 11 to 76 per weekday (up 591 percent). In the next 12 months, between November 1979 and November 1980, the level of bicycle-trailer service was increased by another 23 percent, while the number of passengers with bicycles increased from 76 to 174 per weekday (up 129 percent). Passengers with bikes as a percent of total ridership over the full demonstration period averaged 20 percent except for lower usage between December and March (Newman and Bebendorf, 1983). Annual Santa Barbara bike trailer usage in FY 1980–1981, around the end of the demonstration, was 42,463 bicycles (Coverly, 2010).

The demonstration included placement at stops of bicycle racks and lockers, in addition to the bicycle-trailer service. Regular-rider bicycle mode of access to bus stops on the bicycle-trailer routes increased during the demonstration along with trailer use. The percentage of riders using a bike to access the bus was 1.5 percent in 1978, 12 percent in 1979, and 23 percent in 1980. Walk mode of access decreased, from 80 percent in 1978 to 63 percent in 1979 and 54 percent in 1980. In addition to the shift from walking to cycling access, prime mode shifts occurred, with the majority of diverted users having previously biked all the way. Some 60 percent of transit and/or local bike facility users were students, as compared to 23 percent students in the service area population. At a time when usage of transit for shopping, social, and recreational purposes was increasing, the bicycle-transit service attracted a higher percentage of work and recreational trips than did conventional transit.

It helps in understanding the scale of the Santa Barbara operation to compare the reported level of bus bicycle-trailer usage with metropolitan area bikeway usage. By the beginning of the demonstration, 44 miles of on- and off-road bikeways had been opened, and 600 to 700 bicyclists per weekday used these facilities. That is roughly one bicycle-trailer user at the end of the demonstration per earlier-observed bikeway user (Newman and Bebendorf, 1983).

Bicycle-trailer service had to be terminated in 1982, when larger buses obtained in response to ridership increases could not legally use the trailers. In 1984, two-bike rear-mounted racks were made available on five routes. The rear mounting had poor visibility from the bus, which contributed to crashes and bike theft. Total annual usage never exceeded 1,200 bikes, and rear-rack use was ended in 1987 (Coverly, 2010). Seattle and other properties that tried rear mounting encountered similar operational problems (Federal Highway Administration, 2010).

After nearly a decade, demonstration of two-bike front-mounted racks on three routes was initiated in 1996, producing a 4-year average usage of 18,600 bicycles/year. All 14 routes operating full-size buses (and capable of supporting the racks) were then equipped in 2000–2001, and FY 2001–02 saw 52, 736 bicycles carried. This result was in the context of system ridership that had grown substantially in the 1990s. The modest increase in bicycles carried compared to FY 1980–81 reflects effects of two-bike rack capacity limitations compared to the circa 1980s 14-bike trailers (Coverly, 2010). July 2003 bike-on-bus usage was 1.0 percent of overall ridership, which was then 7,070,700 unlinked trips annually, with 60 percent of all buses equipped with racks (Steve Spindler Cartography, 2010).

A Florida Bikes-on-Bus (BOB) return on investment analysis, the 3rd entry in Table 16-34, examined 11 systems in Florida and four elsewhere in the United States, most of which had been started in the 1994–98 period and had equipped all buses with racks. BOB performance measures were assembled for three Florida systems as set forth in Table 16-32. No BOB user permits were ever required by 11 of the operators surveyed, including all four agencies outside Florida. At the time of the study, the first two systems listed in Table 16-34 plus Jacksonville required user permits, and Miami-Dade Transit had just eliminated their permit requirement (Hagelin, 2005).

Table 16-34 Bikes-on-Bus (BOB) Annual Statistics for Three Florida Transit Agencies

Agency	Annual Statistic	2000	2001	2002	2003
Hillsborough Area Regional Transit (HART)	BOB boardings	54,000	55,200	57,600	68,400
	Unlinked passenger trips	9,219,738	9,761,011	9,390,575	9,185,410
	BOB share	0.59%	0.57%	0.61%	0.74%
Pinellas Suncoast Transit Authority (PSTA)	BOB boardings	45,600	111,480	133,800	152,400
	Unlinked passenger trips	9,360,135	9,372,832	10,118,769	9,487,531
	BOB share	0.49%	1.19%	1.32%	1.61%
Tallahassee Transit (TalTran)	BOB boardings	15,708	12,636	11,568	10,860
	Unlinked passenger trips	3,922,150	3,934,447	4,140,250	4,372,762
	BOB share	0.40%	0.32%	0.28%	0.25%

Source: Hagelin (2005).

The two larger of these systems, HART (Tampa region) and PSTA (St. Petersburg-Clearwater region), together with Miami-Dade Transit, provided permit-holder data bases that allowed random samples for user surveys. The rate of successful telephone calls for the HART and PSTA surveys was 11 percent, and the mail-out survey return rate for Miami-Dade Transit was 14 percent, together yielding 220 completed surveys. The survey found the BOB service to have prompted shifts from other modes to transit use, as quantified in Table 16-32, and self-identified increased frequency of use by 72 percent of the 3/4 of BOB users who were prior transit riders. BOB users were found to be highly regular riders, nearly 70 percent having used the service for 1 year or more, and 65 percent using the service 4 or more days a week on average. Racks often or always full were a problem for 20 to 30 percent of users, yet 1/3 of all BOB users were unwilling to park their bike at a bus stop bike rack whether or not they would otherwise have to wait for another bus.

Nearly 2/3 of BOB user survey respondents were between 25 and 44 years of age, and over 90 percent were male. Work purpose trips accounted for 72 percent of BOB trips taken. Non-whites and Hispanics constituted 52 percent of BOB survey respondents willing to provide their ethnicity, about 4 percentage points higher than for Miami Metrorail bike-to-rail riders. Of respondents willing to give their income, 78 percent made less than $30,000 in self-reported income per year (2004 dollars), and there was no evidence of a significant higher-income ridership component as had been found among Miami Metrorail bike-to-rail riders (discussed above under "Non-Motorized Access to Transit"—"Bicycle Access and Egress"). One-half reported no working vehicles in the household and only 18 percent had more than one working vehicle (Hagelin, 2005).

The BOB survey obtained self-reported bike access and egress distances. A full tabulation is provided in the "Underlying Traveler Response Factors" section under "Trip Factors"—"Bicycle Trip Distance, Time, and Route Characteristics"—"Bicycle Access to Transit" (see Table 16-66). A summary for Miami-Dade transit, contained within Table 16-35, provides a comparison between bike-on-bus access and egress distances (1st versus 2nd rows of mileage entries). These Miami-Dade survey data, either taken independently or combined with HART and PSTA survey data, depict bike egress distances that are substantially shorter than bike access distances.

Table 16-35 Comparisons, by Percentiles, of Florida Bike-on-Bus Access and Egress Distances and Florida and West Coast Walk-to-Transit Access Distances

Systems	Mode	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Miami-Dade [a, b]	Bike access to bike-on-bus	0.50 mile	1 mile	2 miles	3 miles
Miami-Dade [a, c]	Bike egress from bike-on-bus	0.25 mile	0.25 mile	0.50 mile	1 mile
Miami-Dade [d, e]	Walk access to transit	0-0.06 mi.	0.06-0.11 mi.	0.11- 0.17 mi.	0.17-0.23 mi.
West Coast [f, g]	Walk access to urban rail	0.27 mile	0.47 mile	0.68 mile	Not reported

Notes: These comparisons do not have full trip purpose consistency. The Miami-Dade bike access and egress data are for work purpose trips only. The Miami-Dade walk access data are for all purposes of transit travel. The West Coast walk access to rail data are for all purposes of rail transit travel in the morning peak period — presumably work-purpose dominant.

[a] Self-reported distances in 1/4 mile and 1 mile increments gave "lumpy" results.

[b] Same results were obtained for three Florida systems in total (Hillsboro Area Regional Transit, Miami-Dade Transit, and Pinellas Suncoast Transit Authority combined), except 90th percentile fell in 2 mile increment.

[c] Same results were obtained for three Florida systems in total.

[d] Miami-Dade Transit operates both bus and rail, but bus is dominant (Zhao et al., 2002).

[e] Distances measured along the street network with barriers accounted for (Zhao et al., 2002).

[f] One Bay Area Rapid Transit (BART-HRT) station in El Cerrito, CA, one LRT station in San Jose, CA, and three LRT stations in Portland, OR (Weinstein et al., 2007).

[g] Distances per actual routes traced by survey respondents (Weinstein et al., 2007).

Sources: Hagelin (2005) and Zhao et al. (2002), with elaboration by the Handbook authors, and Weinstein et al. (2007).

Table 16-35 also provides a comparison between Miami-Dade bike-on-bus access distances and walk-to-transit access distances (1st versus 3rd rows of mileage entries—rows not shaded). A 4th mileage-entry row pertaining exclusively to walk access to HRT and LRT stations, based on San Francisco Bay Area and Portland, Oregon, data, has been added for comparison with Miami-Dade bike access (to bike-on-bus) and walk access (to both bus and Miami Metrorail, but with bus dominant). These two comparisons illustrate the effective expansion of transit system coverage for those willing and able to use bike access. (Distance differentials are probably exaggerated somewhat by the trip purpose differences documented in the table notes.) This effect of longer bike-on-bus access distances also holds when comparing the bike access distances (1st row of mileage entries) against walk access trips to urban rail (4th row of mileage entries), despite the confirmation that walk access trips to rail tend to be longer than walk access trips to service that is predominantly bus.

PSTA ridership responded in an instructive manner when gasoline prices first exceeded $3.00 per gallon in 2006. Total FY 2006–07 boardings went up by 260,000, or 2.3 percent, from about 11.3 million in FY 2005–06. Within that number, however, BOB boardings grew by 38 percent to over 300,000 annually, representing 2.6 percent of total boardings. Anecdotally, it was reported that ridership stayed firm, at least in the short term, when gasoline prices subsequently declined (Silva, 2007). It would appear that the effective PSTA tributary area expanded with an assist from the BOB program.

The 4th and 5th entries in Table 16-32 serve to give some additional breadth to the coverage of bike-on-bus, illustrating the range operations with examples from California's Coachella Valley (1.7 percent bike-on-bus in 2003) to Denver, Colorado. Denver is of particular interest because of their survey distributed to the users of on-bus bicycle racks in the summer of 1999. Riders were asked what they would have done had the bus not been equipped with a rack, with multiple answers allowed. Many respondents indicated alternatives not involving transit, with 37 percent listing bike all the way; 27 percent, drive all the way; and 6 percent, drive to a park-and-ride. Alternatives involving transit use included walking to the bus at 34 percent and locking the bike at the bus stop at 22 percent. Users gave a variety of reasons for using the bus-on-transit combination including "to cover a greater distance" (65 percent), "to have a bicycle at the destination" (64 percent), "quicker than walking" (61 percent), "avoid transfers" (28 percent), "foul weather/breakdowns" (28 percent), and "avoid parking hassles" (11 percent). A majority (57 percent) stated they used the service 3–5 days a week (Boyle, 2002).

Bicycle on Rail Programs. As with bike-on-bus, bicycle on rail programs expand the number of destinations within quick reach for a public transit user. Perhaps in no environment is this as important as in the service area of North America's leading bike-on-rail provider, the Caltrain commuter rail service on the San Francisco Peninsula. Caltrain and its predecessor, Southern Pacific Railroad's "Peninsula Service," for a century operated a conventional rural-then-suburban rail passenger operation focused predominantly on carrying passengers to and from downtown San Francisco. Indeed, in 1967 it was possible to develop a robust commuter railroad mode share estimating relationship for the Peninsula Service based on nothing more than distance of a suburban station from downtown San Francisco and the Census-based proportion of downtown workers in the suburban workforce residing adjacent to the station (Alan M. Voorhees & Associates, Inc., 1968).

This conventional-commuter dominance began to change with the evolution of today's Silicon Valley, with its high-tech industrial and office parks spread throughout much of the old Peninsula Service tributary area. Suburban residents who work for Silicon Valley employers, and San Francisco residents who reverse-commute—all faced with intensely heavy highway traffic—are desirous of using Caltrain despite the dispersion of Silicon Valley worksites and the limitations of suburban bus connections. The placement of the San Francisco terminus, 1 mile from the city's transit spine on Market Street, has also been a factor (Tannen, 2010). This context is essential to understand when deriving lessons from the extraordinary success of the Caltrain bike-on-rail program.[34]

Caltrain trialed bike-on-rail for 4 months in 1982, but the present operation dates from a larger demonstration in 1992. In 1994 bike stowage capacity was increased by replacing some seats with bike racks (Tannen, 2010). As of 2007 each train had one car or sometimes two cars accommodating 16 or 32 standard bicycles each. In February 2007, from 4:30 AM to about 10:30 AM, 500 northbound (intra-Silicon-Valley and conventional San Francisco commute) and 424 southbound (reverse commute and intra-Silicon-Valley) passengers with bikes were boarded, representing 7 percent of all AM riders prior to midday (Eisen Letunic and Fehr & Peers, 2008). This was essentially the same proportion as 10 years earlier, in 1997, when the bike-on-rail proportion was reported as 7.5 percent (Tannen, 2010).

Caltrain AM mode of access as determined in the February 2007 passenger survey was 7 percent bike-on-rail, 1 percent bike parked at the station, 29 percent walk, 19 percent transit, 8 percent free shuttle, 27 percent drove car, and 9 percent drop-off/pick-up. Caltrain bike-on-rail use had been

[34] The Caltrain experience will be of primary relevance to urban rail planners interested in development of reverse and intra-suburbs ridership in areas of significant suburban employment.

at or above capacity for some time, with just under 2,000 daily trips. A special all-day survey in September 2007 counted 51 bicycles "bumped" (turned away), with 55 percent of the bumps occurring in the morning at the San Francisco terminal and the 22nd Street station in San Francisco, exclusively affecting reverse riders. These two stations attracted 17 percent of AM system total boardings and 26 percent of AM bike-on-rail boardings. Of 10 major stations accounting for 3/4 of both total boardings and total bike-on-rail boardings, all except the San Francisco terminal handled 3 to 9 percent of system bike-on-rail boardings each, with zero to eight bumps at individual suburban stations (Eisen Letunic and Fehr & Peers, 2008). Subsequent Caltrain service changes with introduction of "Baby Bullet" express trains are not reflected in any of these data.

Among "Bike + Caltrain" users taking a 2007 online survey, 1/4 said they ceased using the combined mode of travel because they got tired of being bumped (Caltrain Bicycle Master Plan Technical Advisory Group, 2007). Nevertheless, rack, locker, and other-facility bicycle parking at stations was underutilized. Except for 100 percent utilization at Redwood City, half-way down the Peninsula, utilization ranged from 25 percent (22nd Street) to 75 percent, including 66 percent at the San Francisco terminal with its high bike-on-rail demand. Overall, station bicycle parking capacity was 55 percent utilized (Eisen Letunic and Fehr & Peers, 2008). Clearly bicycle parking at stations did not meet the needs of most Caltrain bike-on-rail commuters, although locker and bike station/shed fees may be a factor compared to the free bicycle carriage onboard.

Although the 2007 online bicycle survey was not statistically controlled, the 13 percent of Bike + Caltrain current users who reported parking at a station, as compared to taking their bike onboard, matched official counts. Bike-on-rail rider responses to "Why do/did you bring your bike on board?" support the importance to them of the service. The top six responses were: "Having my bike with me gives me flexibility" (58 percent), "I need to have my bike with me" (37 percent), "I bike the other way for exercise" (32 percent), "Transit/shuttle connections don't work for me" (31 percent), "Bike parking options are unsatisfactory" (18 percent), and "Saves money over connecting transit or renting a bike locker" (15 percent). Another question of both current and former users found that 80 percent of Bike + Caltrain riders rode Caltrain *without* their bike on board only 0 to 10 percent the time (Caltrain Bicycle Master Plan Technical Advisory Group, 2007).

The final three entries in Table 16-32 present perspectives gained from additional bike-on-rail experiences and current operations. The Portland TriMet entry provides an LRT example. The Portland and San Francisco BART entries make clear the preference of a majority of bike-using riders for bike-on-rail over bike-and-park. Although "Portland does not provide much parking at train and bus stops," with 670 spaces total at transit centers and LRT stops, BART places strong emphasis on bike parking as indicated in Table 16-32.

The BART and New York Metropolitan Transportation Authority (MTA) entries span the spectrum from late 20th Century (and newer) Metro-type HRT to subway/elevated HRT systems whose core elements reflect the bicycle-unfriendly station access standards of the early- and mid-20th Century and also tend to serve dense and highly walkable urban development (Pucher and Buehler, 2009b). The BART and New York City systems also span the range of crowding encountered, with BART normally having a low proportion of standees and New York typically experiencing packed rush hour subway trains.

As noted in the Portland TriMet entry, bike-on-transit statistics are often presented with LRT and bus information combined. This adds interest to the VTA San Jose data, presented earlier in Table 16-31, separately covering the Santa Clara County, California, bike-on-bus and bike-on-rail programs. As seen there, VTA LRT attracted a bike-on-transit share of boarding passengers about 50 percent higher than did bus, at 3.2 percent versus 2.0 percent circa 2001, although the LRT system's absolute numbers were smaller (Steve Spindler Cartography, 2010). VTA serves essentially the same suburban environment as Caltrain, although more focused on the southern sector of Silicon Valley.

Bicycle on Ferry Programs. In addition to bike-on-bus and bike-on-rail programs, there are programs to prioritize the accommodation of bicycles on ferries. (The actual carriage of bicycles on ferries has been commonplace from the widespread introduction of bicycles in the late 19th Century.) Particularly notable is the approach developed by the Washington State Ferries for their Seattle area commute period runs. Loading-area bicycle lanes, auto deck arrangements, and loading and unloading procedures afford on-time bicyclists first-loading and first-off priorities in addition to lower fares than autos. The bicycle surcharge on the passenger fare is waived entirely for $20 annual permit holders (Washington State Department of Transportation, 2011).

Washington State Ferries were delivering 295 bicycles to the downtown Seattle terminal in the 2007 AM 3-hour peak period. This was 13 percent of the bicycle volume at the 29 count stations along the downtown cordon, and reflected a growth since 1992 of just slightly less than the 106 percent for the cordon as a whole. For context, the four highest AM 3-hour counts out of the 29 cordon stations were the Dexter Avenue bike lanes (connecting with multiple shared use trail approaches to the north) at 318 bicycles, the ferry terminal at 295, and the Elliott Bay Trail from the northwest at 218 and from the south at 220 bicycles (City of Seattle, 2008). Given the limited numbers of urban ferry routes in the United States, the traveler response to specific actions has not been investigated for *TCRP Report 95;* however the bicycle priority and pedestrian-handling strategies used with ferries are important to NMT encouragement where they are relevant.

Point-of-Destination Facilities

Point-of-destination facilities are provided at a workplace, school, shopping area, or other attraction to make it more feasible or easier to use non-motorized transportation. The obvious example is bicycle parking. Other point-of-destination facilities, conditions, and services examined here are showers and changing facilities, overall destination ambiance, walkable accessibility to multiple stores and services, and bikesharing. The quantitative evidence of effect on active transportation choice is limited and not in consistent measures. Nevertheless, an overall importance of destination facilities for encouraging more utilitarian bicycling—and also walking—comes through. Although bicycle parking and bikesharing are facilities unique to the bicycle mode of active transportation, other destination features bear as much or more on the choice to walk.

Bicycle Parking and Changing Facilities

The few research efforts pertaining to bicycle parking and changing facilities, including showers and lockers, have tended to focus on the commute to work and on bicycling. Although some pedestrians may avail themselves of changing facilities, especially if they run or jog to work, the primary market for such facilities is bicyclists. One researcher noted, “arriving at work sweaty from exertion with nowhere to shower and change discourages all but the most die-hard cyclists” (David Evans and Associates, 1992). A Bicycling Magazine Harris Poll in April 1991 found that “showers and storage” would encourage 17 percent of all adults and about 44 percent of “active riders” to ride a bicycle to work (Goldsmith, 1992). Such surveys identify intent, not actual response, but they are suggestive of the role of point-of-destination facilities.

Bicycle parking and changing facilities are considered by most NMT planning practitioners to be basic necessary conditions for bicycle commuting. They may be provided separately or together and on-site or nearby. The facilities may be exclusive to the purpose or may have dual use. For example, many developments provide access to changing facilities through an on-site health club. Buildings may have a bicycle room or the developer may set aside space in a parking garage for bicycle parking (C.R.O.W., 1993). A survey of employers participating in Southern California's trip reduction program found that 45 percent provided bicycle parking and 26 percent provided changing facilities (Litman, 1994). A September 1993 survey of trail use in the Baltimore-Washington area found that among bicycle commuters, 75 percent reported availability of bike racks or showers at their destination (Guttenplan and Patten, 1995).

In terms of impact on NMT travel choice, the consensus on the need for good bicycle parking and associated facilities is stronger than the research on the question, perhaps because the need seems so obvious. It is not clear whether bicycle parking tends to be provided in response to increasing demand for it, or comes first and encourages more cycling (Pucher, Dill, and Handy, 2010).

Table 16-36 identifies the findings of a few studies that have actually attempted to assess the effects of parking provisions and showers/lockers on bicycling, or bicycling and walking, along with what is available on outcomes of specific parking and shower/change facility actions. Key findings are expressed in a number of different metrics, making quantitative synthesis unfeasible. All programs were found, however, to have had a positive impact or to have shown indications of popularity. Together they lend support to the importance of bicycle parking and related amenities.

The 1st and 2nd entries in Table 16-36 report research that isolated positive effects on bicycling or cycling and walking levels of bicycle parking or shower provisions. The 2nd of these studies obtained its bicycling and walking measurements in the context of employers subject to a Southern California vehicle trip reduction ordinance (Pucher, Dill, and Handy, 2010, Comsis, 1993). The 3rd Table 16-36 entry focuses on a specific Southern California suburban employer faced with trip reduction ordinance requirements. In this example, the employer chose to combine bicycle storage and changing facility provisions with both a financial incentive and bike maintenance assistance. A 10 percent bicycle commute mode share was achieved, 10 times the regional average (RTC and APBP, 1998).

Table 16-36 Summary of Studies on the Travel Effects of Providing Bicycle Parking and Shower/Change Facilities

Study (Date)	Action	Key Findings
1. Noland and Kunruether – 1995 as summarized in Pucher, Dill and Handy (2010)	The researchers estimated the effect, on commuter choice to bicycle, of having safe bike parking available at the workplace.	A significant rise in perception of cycling convenience and an increased likelihood of cycling to work was identified in connection with safe bicycle parking provisions.
2. Comsis (1993)	A 1990s survey of employers participating in Southern California's trip reduction program was utilized in California Air Resources Board TDM impact modeling to assess effectiveness of individual strategies.	Provision of either bicycle racks or showers in the workplace was found to be associated with discernibly higher levels of bicycling and walking to and from work.
3. RTC and APBP (1998)	Fleetwood Enterprises in suburban Riverside, California, installed bike lockers, provided changing facilities, and offered access to tools for cycle repairs. Financial incentives were offered to bicycle commuters in the form of a point/reward program worth about $2.00 per day cycled.	This builder of recreational vehicles and manufactured homes, with about 650 employees, ran its bicycle commuter program between the late 1980s and early 1990s as part of a trip reduction ordinance compliance effort. The 10% bicycle commute mode share achieved was 10 times the regional average.
4. Hunt and Abraham (2007)	Utilized a stated preference experiment based in Edmonton, Canada, to estimate effects of providing secure bicycle parking and showers at the trip destination. (Convenience sample: survey attached/handed to parked/passing bikes/cyclists.)	Found statistically significant effects on bicycling, large for parking provisions (equivalent to a reduction of en route cycling time in mixed traffic of 26.5 minutes) and small for showers (equiv. to 3.6 minutes). Parking effect more for younger cyclists, less for older groups.
5. Wardman, Tight, and Page – 2007 as summarized in Pucher, Dill, and Handy (2010)	Used the U.K. National Travel Survey and stated preference data, in a multivariate analysis, to examine effects on bike commute shares of different degrees of workplace bike parking and facilities provision.	With a base work trip bicycle mode share of 5.8% given no special provisions, estimated that bike share would increase to 6.3% with outdoor parking, 6.6% with indoor secure parking, and 7.1% with that plus showers.
6. RTC and APBP (1998) and Herman (1993) (see this section for more information)	The City of Chicago embarked in 1992 on a large-scale effort to install bicycle parking throughout the city. The first 1,100 racks were located per suggestions from cycling advocates and city planners.	The racks, first located at public places, neighborhood retail, and the CBD, proved popular with cyclists and — after initial objections — businesses started to request them. By the end of 1997, 4,250 racks had been installed.
7. Taylor and Mahmassani (1996) (see "Pedestrian/ Bicycle System Linkages with Transit" for more information)	Utilized a stated preference experiment with hypothetical work trip transit access scenarios to estimate auto-only, auto-park-and-ride, and bike-and-ride preferences. (Convenience sample, mostly avid cyclists; no reported investigation of bicycle locker space pricing.)	Bike lockers identified as a significant incentive to bike-and-ride instead of driving to transit or all the way. Lockable covered parking 40% as effective. Bike lane more important than lockers for infrequent cyclists; lockers more important for frequent cyclists. Results for showers at work were illogical.
8. Urban Transportation Monitor (2009)	Bike stations in 8 U. S. and British Commonwealth cities ranging in size from Boulder, CO, to Chicago, IL, responded to a survey on bike station characteristics. Usage data was given for 7 stations in 6 cities.	Consolidated parking was offered in 8 stations (7 cities) ranging in capacity from 40 (Aukland) to 300 (Chicago). Average percent occupancy, where known, ranged from 28% (Seattle) to 88% (San Francisco, Caltrain terminal).

(continued on next page)

Table 16-36 (Continued)

Study (Date)	Action	Key Findings
9. RTC and APBP (1998) and City of Portland (2001)	In the context of an aggressive program of providing bicycle parking while gradually restraining CBD auto parking, Portland created "Bike Central" — four locations offering showers, changing facilities, and bicycle storage. Monthly or daily passes allowed use at a modest fee.	A before-and-after study found users of the service increased their frequency of commuting by bicycle from 3.1 days/ month before to 15.5 after; driving or taking transit less. First year estimates were 14,600 bicycle trips generated and 46,400 VMT, 23 tons of CO, and 360 pounds of hydrocarbons eliminated.

Note: Study methodology, where available, is summarized in the "Actions" column. Analysis limitations were not reported except as provided (in parentheses).

Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column.

Canadian and U.K. research on importance of bicycle parking and showers is covered in the 4th and 5th table entries. A stated preference study in Edmonton, Alberta, slanted toward more frequent cyclists, found significant but small importance for showers and a large importance for parking. Secure parking was, in the research model, equivalent in benefit to avoiding 26.5 minutes of en route mixed-traffic cycling time (Hunt and Abraham, 2007). The research in the United Kingdom estimated that, starting with a 5.8 percent bicycle mode share, outdoor bike parking was associated with 0.5 additional percentage points of bicycle share (9 percent more cycling), secure indoor parking with 0.8 additional percentage points (14 percent more cycling), and secure indoor parking plus showers with 1.3 additional percentage points of bicycle mode share (22 percent more cycling compared to the starting share) (Pucher, Dill, and Handy, 2010).

The 6th Table 16-36 entry offers circumstantial evidence of bicycle rack installation effectiveness in Chicago (RTC and APBP, 1998, Herman, 1993). A separate analysis of concurrent Chicago bicycle lane impacts found a bicycling commute mode share increase from 0.28 percent in 1990 to 0.50 percent in 2000 in the bike lane corridors, a 78.6 percent increase in a small starting bicycle share of journeys to work. Three major forces are likely to have affected this gain: implementation of bicycle lanes on at least five radial arterials, extensive promotion of cycling, and the bicycle rack program (Cleaveland and Douma, 2009). The 7th table entry reports on stated preference work that found bike lockers to be over twice as well regarded as ordinary lockable covered parking for transit station use. Frequent cyclists ranked the bike lockers higher in importance than infrequent cyclists, who identified bicycle lanes as being more important to bike-and-ride mode choice selection (Taylor and Mahmassani, 1996).

The 8th and 9th entries in Table 16-36 address bike hubs, stations, or the equivalent. The survey forming the basis for the first of these two entries employed a voluntary convenience sample of bike hubs/stations to identify bicycle parking occupancy rates. They were found to range, under widely varying circumstances, from 28 to 88 percent occupancy (Urban Transportation Monitor, 2009). It is difficult to conclude much from the bike hub/station usage statistics other than that some locations/operations are more successful than others, illustrating the importance of location, approach, and execution. The last (9th) table entry provides results from the earlier development of four bike storage and changing/shower facilities in downtown Portland, Oregon, along the lines of what is now termed "bike hubs" or "bike stations." Users were charged a modest fee. Rates of initiation of bicycle commuting were not given, but for Bike Central users who already commuted from time to time by bicycle, a fivefold increase in days per month of bicycle commuting was seen (RTC and APBP, 1998, City of Portland, 2001). The overall context of auto parking restraint in the downtown is described in the "CBD Parking Supply Management in Portland, Oregon" case study of Chapter 18, "Parking Management and Supply."

Other Destination Amenities

There is more at trip destinations than just bicycle parking and showers, or lack thereof, that may be of importance to the choice of travel via walk, bicycle, or transit/walk. Destination amenities include the variety of shopping and services available close by, allowing more daily needs to be met at the workplace or other destination, and friendliness of the destination walk environment. Both land use variety and walk environment friendliness are factors that spread over into other topics, most particularly "Pedestrian/Bicycle Friendly Neighborhoods" in the subsection to follow. Nevertheless, there are some findings of traveler response studies that may be productively considered by taking a trip destination perspective. A sampling of these "destination amenities" findings is presented here.

A study of workplace destination amenity effects on combined walk and bike work trip mode shares was carried out in the early 1990s using a sample of 330 employment sites in Los Angeles County subject to vehicle trip reduction requirements. Observed NMT mode share averages for the various worksite-environment groupings examined were within or close to the range of 2 to 4 percent. All five amenity measures examined were associated, when indicative of conditions postulated to be favorable to walk and bike commutes, with higher NMT mode shares.

For example, high walking accessibility to convenience services around the workplace was associated with NMT work trip shares that were higher by 0.7 percentage points (employers without TDM financial incentives) and 1.1 percentage points (employers with TDM financial incentives) compared to sites with low workplace walking accessibility. High appearance of safety around the workplace was associated with NMT shares higher by 1.5 percentage points (without or with incentives) compared to sites with a low appearance of safety. High workplace and vicinity aesthetic appeal was associated with NMT work trip shares that were higher by 0.7 percentage points (without TDM financial incentives) to 1.3 percentage points (with incentives) compared to sites with low aesthetic appeal. (These examples are derived from Table 19-28 in the "Land Use and Site Design" subsection within the "Underlying Traveler Response Factors" section of Chapter 19, "Employer and Institutional TDM Strategies." A fuller description of the study may be found there.) Oddly, the only characteristic that achieved statistical significance in the final explanatory model was aesthetic appeal, leading the researchers to speculate that it was acting as a surrogate for other unidentified factors (Cambridge Systematics with Deakin, Harvey, Skabardonis, 1994).

City and county of San Francisco travel demand modeling results covered in Chapter 15, "Land Use and Site Design," extend the Los Angeles findings into a fuller array of trip purposes and destination types. Besides topography, which in San Francisco tends toward the dramatic, the most influential destination pedestrian environment characteristic among those scaled for model use by a Delphi panel proved to be urban vitality. The urban vitality characteristic, both in the case of work and in the case of other trip purposes, was an indicator of higher mode shares for walking, walk-transit, and also ("other" trip purposes only) bicycling. Only destination (non-home) pedestrian environment factors proved useful in estimating choice of mode in the San Francisco context (Cambridge Systematics et al., 2002). (In Chapter 15, see "Response by Type of Strategy"—"Site Design"—"Transit Supportive Design and Travel Behavior"—"Pedestrian/Transit-Friendliness," including Table 15-44, for further detail.)

Finally, it is appropriate that attention be drawn back to the Austin, Texas, research reported on in this "Response by Type of NMT Strategy" section under "Sidewalks and Along-Street Walking"—

"Sidewalk Coverage and Traffic Conditions" (see 1st entry in Table 16-2 and related discussion). The Austin findings strongly suggest that completeness and quality of commercial area sidewalks and sidewalk connections to stores is of major importance for attracting more persons to the walk mode for shopping trips (Cao, Handy, and Mokhtarian, 2006). Indeed, these factors appear—under light residential traffic conditions—to likely be more critical for utilitarian walking than completeness of the residential area sidewalk system.

Bikesharing

Bikesharing, involving the shared use of a publicly available bicycle fleet, may be considered both an origin and a destination facility and service. A subscriber obtains a standardized bicycle at a bikeshare docking "station" close to his or her trip origin or mode change point and after using it turns it in, taking care of parking in the process, at a bikesharing station close to the destination. The intended use is short-term, and pricing is often set to strongly discourage longer-term use.

Bikesharing Development. Bikesharing is in the developmental stage of being scaled up into major programs from the predecessor small-scale applications that had been gradually evolving since 1965. Evolution has taken place in three stages. In the first generation distinctly-painted bikes were made available in selected local areas, typically tourist areas and downtowns, for free use. Some attempts failed because of theft, but others survived and evolved. The second generation involved a shift to coin-deposit systems requiring deposits averaging roughly US $4.00 to unlock a bike, with the deposit being remitted with return of the bicycle. Theft remained a major problem. The earlier programs tended to be too small or unreliable for citywide impact.

The third and present generation, greatly facilitated by the arrival of information technology (IT), includes the bicycles (still distinctive), docking stations, a user interface for check-in and check-out (kiosk or technology), and IT with GPS to facilitate reservations, pick-up and drop-off management, and location tracking. Modest single-use, day/week-pass, and/or annual subscriber fees are typically assessed. Some systems offer a brief initial or quick-trip period of use at no rental cost. The Paris Vélib day pass in 2009 was just under US $1.50, and the Washington, DC SmartBike and Paris annual passes were US $40.00 or thereabouts (Shaheen, Guzman, and Zhang, 2010). Theft and vandalism have been reported as growing problems in Paris. Some 80 percent of the initial fleet was stolen or damaged in the initial 1 to 2 years, and satisfaction with condition of the bikes declined from 55 percent in 2008 to 46 percent in 2009 (Erlanger and De La Baume, 2009). On the other hand, only one or two bikes out of 700 were lost in the initial year of Nice Ride Minnesota's operation in Minneapolis, and only three had vandalism damage costs of over $100 (DeMaio and Meddin, 2010, Dossett, 2011).

Nice Ride Minnesota requires a $50.00 deposit when taking out a one-day subscription to the service. Subscription fees themselves are $5.00 for 24 hours, $30.00 for 30 days, and $60.00 for 1 year ($50.00 for students). There is no trip fee for using a bike for 30 minutes or less. Beyond that, trip fees are $1.50 for up to 60 minutes, $4.50 for up to 90 minutes, and $6.00 for each additional 30 minutes, up to $65.00 maximum per day. The fee system is clearly set to encourage short-term use, and the Nice Ride website links prospective users to local bike rental services for longer-term uses (Nice Ride MN, 2011).

When tabulated circa 2009, a number of area-wide systems were already in operation, as shown in Table 16-37. They were predominantly in Europe, although the most bikes deployed were in China. Not included in this table, or this discussion, are "closed" systems on university and workplace campuses and the like. As of 2009 there were over 65 such closed systems in the United States alone, and 10 more were expected in 2010. Also not included are more traditional bicycle rentals such as are typically arranged by bicycle shops (Shaheen, Guzman, and Zhang, 2010).

Table 16-37 Public Bikesharing Programs Listed by Country in Decreasing Order of Numbers of Bicycles Deployed, Circa 2009

Country	Number of Programs [a]	Number of Bicycles	Number of Stations
China	3	65,000	2,522
France	21	34,898	2,797
Spain	21	11,080	842
Germany	3	6,069	128 [b]
Canada	1	5,000	400
Italy	16	3,392	361
Denmark	3	2,513	277
Sweden	3	2,125	171
Taiwan	2	2,000	31
Norway	1	1,660	154
Austria	3	1,500	82
United Kingdom	2	1,410	809
Belgium	1	1,000	100
Ireland	1	450	40
South Korea	1	430	20
Luxembourg	2	370	40
Finland	1	300	26
Brazil	2	232	26
New Zealand	1	175	11
Switzerland	1	120	11
United States	1	120	10
7 Other Countries [c]	9	311 [d]	263
Total	99	140,155 [d]	9,121 [b]

Notes: [a] Within each country, each system is counted as one program even though it may serve multiple cities. "Closed" systems, such as a number of campuses have, are not included.

[b] Number of stations does not include "flex station" drop-off points used in 5 German cities.

[c] Countries reporting 100 or fewer bicycles or for which bicycle totals could not be confirmed.

[d] Does not include the bicycle totals for Mexico (1 program, 12 stations) or The Netherlands (1 program, 200 stations) because the researchers could not confirm bicycle numbers.

Source: Shaheen, Guzman, and Zhang (2010).

The market penetration of public bikesharing systems is rapidly evolving, making tabulations such as that presented in Table 16-37 only a snapshot in time. Technology adoption lifecycle research by Everett Rogers and colleagues in the last half of the 20th Century identified a course of innovation adoption that follows a "bell curve" or normal distribution. Innovators and early adopters "buy in" on the upswing, which in isolation, takes on the appearance of an exponential curve. Early-majority adopters take the curve up to its apogee, with late-majority and laggard adopters on the mirror-image downswing (Wikipedia, 2011).

A rough tally of bike-sharing services worldwide (quite likely not using the same criteria as Table 16-37) identified 11 in 2004, 60 in 2007, 92 in 2008, 160 in 2009, and 238 in 2010 (DeMaio and Meddin, 2010). These data points approximate an exponential curve, particularly if one accounts for fleet growth of services already established, placing the third generation of bikesharing in the innovator or early adopter phases of technology adoption. Compared to the one U.S. system of Table 16-37 in

2009, three large-scale U.S. services were implemented in 2010 (DeMaio and Meddin, 2010), and at least 10 U.S. metropolitan areas had major systems in the process of implementation or actually operating in mid-2011 (DeMaio, Simmons, and Meddin, 2011).

Bikesharing Operational and Impact Statistics. Given the relative newness of third generation bikesharing programs, statistics—especially relevant travel demand statistics—are sparse. Among available operating statistics, Table 16-37 indicates an average per-docking-station deployment of 15 bicycles. The range of per-country-averages is 9 to 26 bicycles per station, excluding one outlier (Taiwan).

With 20,600 bicycles and 78,000 trips on an average day, Vélib in Paris achieved a daily turnover rate of 3.8 uses per bike. Hangzhou, China, reported a turnover rate of 6 daily uses per bike for their 40,000-bicycle system (circa 2009), the world's largest (Shaheen, Guzman, and Zhang, 2010). There are also reports of Velo'v bicycles in Lyon, France, being used 6.5 times per day (DeMaio, 2009) and a small Dublin, Ireland, Dublinbikes service reaching 10 trips per day (DeMaio and Meddin, 2010). Other statistics offered in parallel are actually subscribers per bike; not the same thing as actual turnover. Viewed in the context of typical U.S. short-term parking turnover rates, the Paris bicycle turnover rate of 3.8 seems a more conservative representation of likely citywide bikesharing usage patterns in western countries.

Indeed, Capital Bikeshare January through July 2011 statistics for Washington, DC, and Arlington County, Virginia, indicate a 3.3 rentals-per-bike winter-into-summer average. Turnover increased from 1.3 in January to just under 5.0 in June, with nearly identical turnover in July, at which time there was a 3 percent bike availability constriction relative to June. June 2011 saw 140,400 rentals, an average of 4,680 per day, with 943 bicycles in service. January 2011 was only the fifth month of operation (Capital Bikeshare Dashboard, 2011). The relative effects of season, numbers of tourists, and system newness are unknown. First-year (2010–2011) Capital Bikeshare statistics include an average trip length of "around 1.79 miles per trip" (David C., 2011).

Internationally published mode shift data, while not documented or defined in detail, seems to indicate notable increases in cycling in response to the major citywide programs. Bicycling in Lyon, France, is reported to have increased 44 percent in the first year of their Velo'v program. All but 4 percent were "new users who had not previously bicycled in the Lyon city center." Reports of bicycle riding increases in Paris in response to deployment of their Vélib system range from 70 percent (Shaheen, Guzman, and Zhang, 2010) to 250 percent, the latter measured as a 1.5 percentage point shift starting from about a 1 percent share in 2001 and increasing to 2.5 percent in 2007, the year of system implementation.[35] The bicycle share in Barcelona, Spain, increased from 0.75 percent in 2005 to 1.76 percent in 2007, again the year of implementation, representing a 235 percent increase and a 1.0 percentage point shift (DeMaio, 2009). The starting shares were low in Paris and Barcelona, and in both cities bicycle facility improvements were made during the years in question.

In Lyon, user survey respondents reported replacing about 1/2 of their transit trips with Velo'v bicycle trips. The trade-off is the advantage for accessing transit, possibly compensating to some degree for loss in transit riding. In Paris, 21 percent of 2008 survey respondents reported use of Vélib for transit access and 25 percent reported Vélib use for transit egress, with 28 percent overall reporting reduced use of their private vehicle during the day. The 2009 survey found 28 per-

[35] Some of these bicycle mode share increases possibly pertain to the city center rather than the city as a whole and/or seem likely to incorporate overall trends.

cent of respondents indicating use of Vélib "to begin and to end their multi-leg transit trip," with 48 percent overall reporting reduced private vehicle use (DeMaio, 2009).

In 2010, the first season of the Nice Ride Minnesota operation (it shuts down for the winter), most subscribers were for 24-hours only. This pattern is shifting. The 1,300 annual-subscriber base of December 2010 grew to 3,200 in June 2011, with the system poised for expansion from Minneapolis into St. Paul (DeMaio and Meddin, 2010, Dossett, 2011). A 2010 Nice Ride subscriber survey obtained 685 responses, a return of 53 percent compared to the December subscriber base. Respondents came from a fairly broad range of ages, but with only eight younger than age 18 or older than 64, and with the most in the 25 to 34 age range (39 percent). Aside from only 6 percent reporting household annual incomes below $20,000, the income spread was remarkably even. On the other hand, only 15 percent reported less education than a full four-year college degree. Students accounted for 19 percent of subscribers. The gender split was typical of U.S. bicycling, 63 percent male after correction for non-responses to the question. Before Nice Ride, 1/3 rode a bike less than once a month, while almost 1/2 rode at least once a week (Nice Ride MN, 2010). These and other responses, given the newness of the system, may be judged representative of innovative and early-adopter subscribers more than would be seen with a more mature operation.

The survey results provide further insight into usage patterns and the relationships between bikesharing and transit use. However, all but one of the relevant survey questions were couched in terms of primary use rather than a specific trip. Primary use by purpose category was 37 percent commuting to work or school, 30 percent errands and meetings—transportation around downtown, 5 percent each for social riding and exercise, 3 percent shopping, 13 percent going to events and eating/drinking establishments, and 6 percent other. Self-reported changes in use of transit (bus, LRT, and commuter rail) identified 10 percent who increased use, 17 percent who decreased use, 58 percent whose use stayed the same, and 14 percent who were not transit users. Some 32 percent primarily used Nice Ride to connect with bus or rail transit. The trip-specific question elicited responses that if Nice Ride Minnesota had not been available for the respondent's most recent trip, it would have been made by walking (38 percent), personal bicycle (8 percent), public transit (20 percent), driving (19 percent), getting a ride (1 percent), taxi (3 percent), other (2 percent), or would not have been made at all (9 percent) (Nice Ride MN, 2010).

Pedestrian/Bicycle Friendly Neighborhoods

Some of the more notable travel impacts of urban land use structure and design relate to their effect on "active transportation"—the decision to walk, to cycle, or to do one or both in conjunction with taking public transportation. The travel demand, land use, and urban design interrelationships involved have attracted a significant proportion of research on effects of the physical environment on walking and cycling. This circumstance leads to a modified approach for presentation of available findings. The presentation approach is also shaped by the fact that this "Pedestrian/Bicycle Friendly Neighborhoods" subsection supplements the full presentation and interpretation of the travel behavior effects of urban form in Chapter 15, "Land Use and Site Design." It is also augmented by the "Transit Oriented Development" discussion within the "Pedestrian/Bicycle Linkages with Transit" subsection above, which is drawn from Chapter 17, "Transit Oriented Development." Both Chapters 15 and 17 serve as primary cross-references and should be referred back to for additional context and insights, particularly on the broader topic of urban form's influence on all modes of travel as well as the underlying role of socio-demographic factors.

Accordingly, the following discussions are oriented to findings of five major NMT syntheses (including a meta-analysis) that are newly available since Chapter 15 was prepared, taken together with an NMT-specific extraction from the Chapter 15 material itself. The five syntheses primarily address land use, transportation, and public health. Information from these sources is leavened with additional or confirmatory insights from selected individual studies, but without any attempt at completeness in terms of individual study inclusion. The numerous findings in Chapter 15 concerning land use effects on transit use per se are not repeated here, but elasticities for transit use are reported alongside walk elasticities in the "Walk Elasticities for Land Use and Site Design Parameters" discussion at the end of this subsection. As emphasized elsewhere, significant walking is involved in most transit trips.

The presentation uses four summary tabulations of findings, Tables 16-38, 16-39, 16-40, and 16-41. Table 16-38 draws from the five NMT syntheses. Table 16-39 extracts from Chapter 15 material specifically pertaining to walking and bicycling, Table 16-40 is a selection of individual studies with information about impacts on primarily adult active transportation, and Table 16-41 is a selection focused on child walking and bicycling activity. In addition, meta-analysis built-environment elasticity results are provided in Table 16-42.

Some summaries in these tables are allowed to speak for themselves without much if any further elaboration. Studies addressing choice of mode for access to transit stops and stations are, however, all discussed further in the text. The same is done for studies focusing on bicycling relationships with land use and site design. This approach is to compensate for the general lack of coverage of transit access mode choice effects and bicycling-specific effects in the five major NMT syntheses.

Table 16-38 Relationships between Pedestrian- and Bicycle-Friendly Neighborhood (NBH) Characteristics and Walking/ Bicycling, Summarized from Key Syntheses

Study (Date)	Process	Key Findings
1. Ewing and Cervero (2010)	This research used meta-analysis of over 50 quantitative studies to derive and interpret new elasticities for an array of land use and site design parameters. Many additional studies were used in the overall synthesis. VMT, walking, and transit use elasticities were derived.	Built environment descriptors found most closely related to walking were intersection/street density, diversity (all measures), and local access to jobs. Land use mix, the neighborhood design measures, and distance to a stop were important to transit use. All elasticities were in the lower inelastic range.
2. Saelens and Handy (2008)	This synthesis was designed as a broad update to both SR 282 (see below) and the child-focused work by Davison and Lawson (2006) (see below). It covers 9 reviews published 2002-2006 and also individual adult- and child-focused papers published 2005-May 2006, almost all on cross-sectional studies.	Found greater density, higher mix of land use, aesthetics, street connectivity, enhanced accessibility or proximity, traditional NBH design, and related infrastructure and conditions such as sidewalks and safety to be positively correlated with walking or walk+bike activity. For children the list was shorter, with distance to school critical.
3. Committee on Physical Activity, Health, Transportation, and Land Use (2005), Handy (2004)	*TRB Special Report 282* (SR 282) examined the connection between U.S. physical activity levels and the built environment, employing synthesis of both transportation and physical activity research results, along with 7 specially commissioned papers including Handy (2004).	Similar to other contemporary reviews, found the basic density, diversity, and proximity measures positively related to NMT travel, as were traditional, transit-served, and walkable NBHs. Relationships with total physical activity were mostly limited to NBH pleasant-environment measures.
4. Davison and Lawson (2006)	Researchers at the University at Albany – SUNY, in New York State, prepared a synthesis on the same questions as SR 282 but focused on school access commute modes and physical activity of children.	Of 3 studies of school access distance, all found use of active modes for access to be correlated positively with shorter distances. Less consistent research, on balance, found street connectivity and good access to destinations positively related with student physical activity.
5. Moudon, Stewart, and Lin (2010)	This Washington State Department of Transportation (WSDOT) assessment undertook a comprehensive international literature review with interpretation of Safe Routes to School (SRTS) programs and outcomes and related information.	All 19 studies that examined distance to school found it inversely related to use of active transportation to school (ATS). Increased distances from 1969 to 2001 explained 47% of the drop in ATS. NBH characteristics were mostly logically or insignificantly related.

Note: Findings of each of these syntheses are discussed further within this "Pedestrian/Bicycle Friendly Neighborhoods" subsection.

Sources: As indicated in the first column.

The organization of this subsection revolves around the various "D's" describing the built environment. First come the "original" 3D's of density, diversity, and design. Those are followed by effects of destination accessibility and distance to transit, and then all built environment factors operating in conjunction. Two other "D's" sometimes included in land use and transportation discussions are demographics and demand management (Ewing and Cervero, 2010). Demographics receive limited attention in the "Response by Type of . . ." subsections of this "Traveler Response to Transportation System Changes" Handbook because they are treated as a given. Socio-economic effects on walking and bicycling are primarily examined in the "Underlying Traveler Response Factors" section under "User Factors." The positive effect on bicycling of one example of workplace travel demand management (TDM) was covered in the "Point-of-Destination Facilities" subsection under "Bicycle Parking and Changing Facilities."

Density

Density is a measure of concentration of population, dwelling units, employment, or other variables of interest per unit area. Historically, this measure has often been used in aggregate, simple relationships that cause higher densities to act as a stand-in for many other closely linked characteristics—such as closeness to the CBD, better transit service levels, lower auto ownership, and higher parking costs—and to thus exhibit very strong associations with NMT and transit use and lower VMT (e.g., Dunphy and Fisher, 1996, Table 16-39, 1st entry). Newer research typically examines density independent of such influences. Findings concerning magnitudes of density effects thus cover a broad spectrum.

In interpreting research that addresses density in isolation, it is important to take into account that certain associated factors are directly affected by density. Population and employment densities are intermediate variables often expressed through other variables with effects stronger than density itself. Included among other variables positively affected by higher densities are not only transit service intensity (more people available to support good service) and auto ownership (lower auto ownership where auto availability need is less and parking is more difficult and costly) but also NMT accessibility (more activities within a given walking or cycling distance) (Ewing and Cervero, 2010, Schneider, 2010). On the other hand, other influences that often historically accompany density such as orientation to the CBD, greater land use mix, grid street patterns, and lower incomes are not caused by density. They should properly be considered exogenous influences whose effects ought not to be attributed to density in and of itself.

A weak association was found between density and vehicle miles of travel (VMT), walking, and transit use in meta-analysis derivation (Table 16-38, 1st entry) of built environment elasticities. (See also Table 16-42 under "Walk Elasticities for Land Use and Site Design Parameters.") This may be taken to infer that when other factors are controlled for the direct effect of more residents or jobs per unit area only slightly increases walk and transit use activity or mode shares (Ewing and Cervero, 2010).

As already noted, however, there are other positive influences on active transportation that draw support from higher densities. To elaborate on the example of transit service, where higher densities move the number of transit riders upward beyond basic-service-level bus transit capacity thresholds or rail transit investment thresholds, more intensive transit service is the result, providing service frequency and speed benefits. These benefits attract more transit riders on their own, in line with service and ridership relationships not much built into independently derived density elasticities such as those in Table 16-42.[36] However, an important "take-home" lesson from the low

[36] There are several parts of Chapter 15, "Land Use and Site Design," that address these important relationships, including "Density"—"Density Related to Transit Use"—"Density and Transit Choice" within the "Response by Type of Strategy" section, "Transportation Service Levels" in the "Underlying Traveler Response Factors" section, and "Transit Service Feasibility Guidelines"—"Density Thresholds for Transit Service" under "Related Information and Impacts."

elasticities for density per se is that density not well integrated into the urban fabric—such as apartments in the middle of auto-oriented suburban sprawl—will not offer a full measure of beneficial effects on VMT, transit use, or walking and bicycling for transportation.

Three of nine reviews published between 2002 and 2006 (Table 16-38, 2nd entry) identified density as being linked to added walking. The researchers conducting the overall synthesis suggest that this outcome reflects the fact that higher density tends to make destinations more proximate. Indeed, five of the nine reviews—representing "the most consistent set of conclusions"—found accessibility based on closeness to destinations to be associated with additional walking. Individual studies reviewed, mostly newer, supported these conclusions but only for utilitarian walking. Little or no evidence was found for relationships between recreational walking and density or non-residential destination proximity (Saelens and Handy, 2008). The term "recreational walking" generally includes walking for exercise.

TRB Special Report 282: Does the Built Environment Influence Physical Activity? Examining the Evidence (SR 282) (Table 16-38, 3rd entry), in general anticipates the results of the Saelens and Handy synthesis, particularly as they pertain to travel undifferentiated by utilitarian versus recreational purposes. Unlike the Saelens and Handy 2002–2006 synthesis and the Ewing and Cervero meta-analysis, SR 282 includes consideration of bicycling. Bicycling is included, however, only in combination with walking and not independently.

SR 282 specifically offers the observation that in those studies which examined *both* density and accessibility, only accessibility was found to be significant as a predictor of walking and bicycling. A likely explanation offered is that "density may serve as a proxy for accessibility, which provides a more direct explanation for travel behavior" (Committee on Physical Activity, Health, Transportation, and Land Use, 2005, Handy, 2004). Along the same vein, a review of infrastructure, programs, and policies to increase bicycling notes that one of many probable reasons for higher cycling rates in northern Europe is the general restriction of low-density, auto-oriented land uses. The resulting compact, mixed-use development supports shorter trip distances more readily covered by bicycle (Pucher, Dill, and Handy, 2010).

Individual research efforts covered in Chapter 15, extracted in Table 16-39, and the additional individual studies assembled in Table 16-40, add more texture to the synthesis study findings. However, the individual studies that address density also address diversity, design, and/or accessibility, typically with more notable results. Thus Table 16-40, covering additional individual studies, is introduced later on.

Table 16-39 Summary of Primary Comparative Observations from Chapter 15 on Impacts of Density, Diversity (Mix), and Design on Walking/Bicycling

Study (Date)	Key Observations
1. **Density**: Dunphy and Fisher (1996) (within Chapter 15, "Land Use and Site Design," under "Response by Type of Strategy," see "Density" — "Density as Prime Indicator at the Behavioral Level" — "Density Inclusive of Related Phenomena")	Active transportation becomes more significant at higher densities. Nationwide, at population densities of 2,000 to 5,000 persons/sq. mi., 7% of daily trips are made by walking or biking, versus 28% at 10,000 to 49,000 persons/sq. mi., and 46% at over 50,000 persons/sq. mi. These percentages are in response not only to density but also to all the urban characteristics that usually accompany it, including greater land use mixing, shorter distances between attractions, and better pedestrian accommodations.
2. **Density**: Kockelman (1996) (in Chapter 15 see "Diversity (Land Use Mix)" — "Accessibility, Entropy and Other Measures" — "Accessibility and Land Use Mix")	Evaluation of NMT choice relative to density in its purest form found no significant direct density effect on the basis of detailed San Francisco area data. There was a small positive effect channeled through reduced auto ownership.
3. **Density**: Frank (1994) (in Chapter 15 see "Density" — "Density related to Transit Use" — "Density and Transit Choice")	Seattle area research estimated that higher population density of 10 persons *more* per acre at origin and destination was associated with ~8% higher NMT share, with 10 more employees per acre adding another 1% to 2% of NMT share.
4. **Density**: Parsons Brinckerhoff et al. (1996b) (in Chapter 15 see "Density" — "Density related to Transit Use" — "Density and Means of Transit Access")	For access to rail transit service, walking normally predominates for only up to 1/2 to 3/4 of a mile, though a peripherally located downtown commuter rail terminal can push the envelope up to 1-1/2 miles. Population density higher by 1% is associated with 1 to 2 *percentage points* higher choice of walking to rail transit in Chicago and to the Bay Area Rapid Transit (BART) system in the San Francisco area. Associated auto use is lower by about 2 percentage points for more-suburban systems, and bus use for rail access drops by about 1 percentage point on the urban rail systems.
5. **Diversity**: Kockelman (1996) (in Chapter 15 see "Diversity (Land Use Mix)" — "Accessibility, Entropy and Other Measures" — "Accessibility and Land Use Mix")	The research on San Francisco area data that did not turn up a direct density effect on NMT choice estimated walk/bike elasticities of +0.23 and +0.22 relative to land use balance and accessibility, respectively.
6. **Diversity**: Frank (1994) (in Chapter 15 see "Density" — "Density related to Transit Use" — "Density and Transit Choice")	In the Seattle area evaluations, choice of walking for the work trip was the only instance where land use mix proved to be statistically significant as a research model variable.
7. **Diversity**: Steiner (1998) (in Chapter 15 see "Diversity (Land Use Mix)" — "Land Use Mix and Transit Use" — "Mix and Pedestrian Access")	Some 20% to 38% of weekday shoppers at highly walk-accessible San Francisco East Bay shopping centers were observed walking to shop (more on Saturday), though the result at the more popular centers was not less parking demand, but rather more shopping activity.
8. **Diversity**: Parsons Brinckerhoff et al. (1996a) (in Chapter 15 see "Diversity (Land Use Mix)" — "Land Use Mix and Transit Use" — "Mix and Mode Choice")	An 11-city study found proximity of retail to housing most important for NMT choice, with — depending on density — a 15 to 17 *percentage point* gain in walking and cycling for trips 1 mile long.

Table 16-39 (Continued)

Study (Date)	Key Observations
9. **Diversity**: Parsons Brinckerhoff et al. (1996b) (in Chapter 15 see "Diversity (Land Use Mix)" — "Land Use Mix and Transit Use" — "Mix and Means of Transit Access")	Estimated elasticities for mode of access/egress to Bay Area Rapid Transit (BART) stations, quantifying response to an index of mix, were +1.1 for walk and -1.3 for auto, both reflecting elastic (very sensitive) travel demand behavior.
10. **Diversity**: Cervero (1988) (in Chapter 15 see "Site Design" — "Suburban Centers" — "Suburban Employment Centers")	Study of suburban employment centers (SECs) identified mix of uses within SECs as having a small but positive effect on the incidence of walking trips. Houston's SECs had 20% of all trips being made by walking despite long blocks, limited crossings, and disconnected sidewalks. The non-work walk share was 22%. Of all walk trips 1/3 were between 11 AM and 2 PM.
11. **Diversity**: Rutherford, McCormack, and Wilkinson (1997) (in Chapter 15 see "Site Design" — "Community Design and Travel Behavior" — "Paired TND and CSD Communities")	Higher walk mode shares were found in mixed use locales with gridded streets in Seattle (18% walk versus 9% for the whole of North Seattle), and in the Seattle suburbs (8% for a town with mixed land use and partially gridded streets versus 3% for the inner ring overall).
12. **Design**: Parsons Brinckerhoff (1996) (in Chapter 15 see "Site Design" — "Suburban Centers" — "Worksites with Travel Demand Management")	Worksites with an "aesthetic" setting obtained employee commute NMT shares 25% higher than other worksites, except this relationship held only in the presence of TDM programs with financial incentives.
13. **Design**: McNally and Kulkarni (1997) (in Chapter 15 see "Site Design" — "Traditional Neighborhoods versus Hierarchical Planned Unit Developments" — "Community Design and Travel Behavior")	Southern California comparisons found pedestrian shares in traditional neighborhood design (TND) communities ranging from 17% less to 53% more than in conventional planned unit developments (PUDs).
14. **Design**: Cervero and Radisch (1995) (in Chapter 15 see "Site Design" — "Community Design and Travel Behavior" — "Mixed Use Communities versus Surrounding Areas" and "Paired TND and CSD Communities" for more information, and see also "Case Studies" — "San Francisco East Bay Area Pedestrian versus Auto Oriented Neighborhoods" in Chapter 15 for an expanded description with additional travel data)	A paired community analysis in the San Francisco East Bay showed the TND neighborhood with fine-grained land use mix and integrated sidewalks and paths to engender a 31% walk share for rapid transit station access, compared to 13% for the community with a conventional suburban design (CSD) environment and a coarser land use mix, mostly stand-alone auto-oriented retail, large blocks, and a substantial commuter parking lot. (The rail transit stations are centrally located in both communities and had 21% and 20% rail mode shares, respectively, for work trips.) Also found was a large difference in walk/bike choice for non-work travel: 10% NMT share in the TND neighborhood versus 2% in the CSD area. The corresponding walk-only shares for work purpose trips were 7% (TND) versus 1% (CSD).
15. **Design**: Kitamura, Mokhtarian, and Laidet (1994) (in Chapter 15 see "Site Design" — "Community Design and Travel Behavior" — "Traditional Urban Neighborhoods versus Newer Suburbs")	A 5-neighborhood San Francisco Bay Area study concluded that attitudes are more important in NMT choice (though not exclusively so) than either household or urban form characteristics. Urban location and presence of sidewalks were isolated as significant built environment factors.

(continued on next page)

Table 16-39 (Continued)

Study (Date)	Key Observations
16. **Design**: Cambridge Systematics, Putman Associates, and Calthorpe Associates (1992), Cambridge Systematics et al. (2002) (see "Site Design" — "Transit Supportive Design and Travel Behavior" — "Pedestrian/ Transit-Friendliness," still within Chapter 15)	Good pedestrian environment was found to be positively related to higher NMT shares in Portland, OR, and City/County of San Francisco travel demand modeling applied research. In San Francisco, where gridded streets with sidewalks predominate, urban vitality and amenable topography were the strongest indicators.

Note: The location in *TCRP Report 95*, Chapter 15, "Land Use and Site Design," where the full discussion is provided (in all cases within the "Response by Type of Strategy" section) is noted in the first column.

Sources: As indicated in the first column.

The 1st entry in Table 16-39 sets the stage by illustrating how much NMT activity varies in accordance with residential density when density is allowed to act as a surrogate for all the urban and socio-demographic characteristics that historically accompany it. The 2nd and 3rd entries are illustrative of the range of results obtained when density effects have been estimated on the basis of research constructed using individual-study disaggregate data sets and modeling.

The 4th entry in Table 16-39 is one of a handful of studies that address the effect of the built environment on the choice of whether to access transit service via walking or bicycling or some motorized mode. Differentiation between access mode choice, involved in the NMT versus motorized-mode choice of how to get to and from transit stops and stations, and prime mode choice, such as the choice to walk or bicycle all the way instead of using transit or driving, was explained earlier within the lead-in to the "Pedestrian/Bicycle Linkages with Transit" subsection.

The mode of access analysis identified a substantial positive effect of density on the overall choice of whether to access transit service via walking or some motorized mode, a finding bolstered by TOD research reported in Chapter 17, "Transit Oriented Development." Choice of mode for accessing transit service presents a situation akin to choice of mode for short distance local area travel, and is very sensitive to urban form. Higher densities place more riders within the walking radius. For rail transit service, walking predominates for up to 1/2 to 3/4 of a mile, but no farther under normal circumstances. Population density higher by *1* percent was found to be linked with 1 to 2 *percentage points* higher choice of walking to rail transit in Chicago and to the Bay Area Rapid Transit (BART) system in the San Francisco area. The associated auto use was lower by about 2 percentage points for the more suburban systems, while bus use for rail access dropped by about 1 percentage point on the rail rapid transit systems, with more people walking. Higher residential area employment density—actually a measure of land use mix—was shown to also enhance walking to the urban systems, by the same order of magnitude (Parsons Brinckerhoff et al., 1996b).

Diversity

Diversity, or land use mix, is a measure of the variety of land uses in a specified area. Entropy is a formulation—when used in land use applications—designed to quantify land use mix in a manner that the lowest values represent single-use development and progressively higher values indicate increasing land use mix at a scale determined by the analyst. Other descriptors used include jobs/housing balance (a ratio) and distance to stores.

Diversity and design are, in the meta-analysis elasticities derivations (Table 16-38, 1st entry), both more strongly related to prevalence and mode choice of walk trips than density. For walking, the relationship holds for all three measures examined: land use mix, jobs-housing balance, and distance to a store, with walk elasticities in the 0.15 to 0.25 range. Basically these elasticities indicate that where there are more local opportunities to meet daily needs there will be more walking.[37] Only one diversity measure was covered by enough applicable studies to allow weighted average elasticity calculation for transit use, and at 0.12 the elasticity shows a modest positive relationship. The reason for the positive relationship with transit use does not immediately stand out, but one possibility is that ready availability of local shopping and services—especially if along the walk to and from transit—makes not having one's auto at hand for errand running during the commute and at work more feasible (Ewing and Cervero, 2010).

As with density, three of nine 2002–2006 reviews (Table 16-38, 2nd entry) pointed to mixed land use as important for more walking. Again the synthesis researchers posit that this is a manifestation of the demonstrated association of walking with proximity of destinations, which land use mix serves to intensify. Individual studies reviewed supported these conclusions (for the most part) for both utilitarian and recreational walking, although there were a number of inconsistent or insignificant results for recreational walking in particular. The generally positive relationship between land use mix and recreational walking was probably not directly caused by proximity of primary non-residential destinations, given the lack of consistent evidence that destination proximity is associated with recreational walking (Saelens and Handy, 2008).

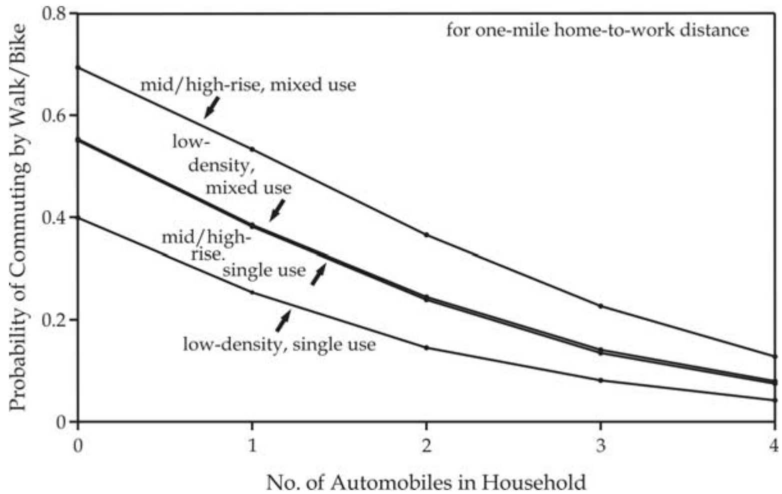
The 5th and 6th entries in Table 16-39 from Chapter 15 address diversity and are the counterpart to the 2nd and 3rd entries. The first-listed of the study pairs together found minimal direct density effect on NMT mode choice but elasticities on the order of +0.2 for land use balance and accessibility (Kockelman, 1996). The second-listed of the pairs, in contrast, found broader impact for density than diversity (Frank, 1994).

The 7th and 8th studies entered in Table 16-39 address the importance of retail proximity to housing and mixed land use in general for engendering walk activity. Figure 16-6 graphs relationships developed in the 11-city study (8th entry) for commute trips. Both density and land use mix have comparable importance for the work commute in this illustration (Parsons Brinckerhoff et al., 1996a).

The 9th entry in Table 16-39 again highlights the particular sensitivity of choice of walk versus auto for access to transit. Not only is choice of transit access mode an aspect of travel behavior sensitive to land use characteristics in general, it is shown to be highly sensitive to mix in particular. The walk elasticity for access/egress to BART stations relative to an index of mix was, at 1.1, estimated to lie in the elastic range: very sensitive (Parsons Brinckerhoff et al., 1996b). The 10th and 11th entries provide additional examples of apparently positive influence of mix on walking, the former involving Houston observations within suburban employment centers in the presence of detrimental design features, and the latter, Seattle area observations with land use mix in the presence of supportive street layouts (Cervero, 1988, Rutherford, McCormack and Wilkinson, 1997).

[37] The meta-analysis researchers conclude that the positive elasticity between walking and jobs-housing balance demonstrates the importance of linking where people live and work (Ewing and Cervero, 2010). This certainly has some validity, but it must also be remembered that jobs in with housing may also be indicative of the presence of stores and services.

Figure 16-6 Probability of commuting by walking or bicycling as a function of density, land use mix, and auto ownership.



Note: Based on modeling of survey results from the 11 metropolitan areas (MSAs or CMSAs) of Boston-Lawrence-Lowell, Dallas, Detroit, Los Angeles-Long Beach, Fort Worth-Arlington, Minneapolis-St. Paul, Philadelphia, Phoenix, San Francisco-Oakland, Tampa-St. Petersburg, and Washington, DC-MD-VA.

Source: Parsons Brinckerhoff et al. (1996a).

Additional findings concerning land use diversity (and density) impacts in selected individual studies are shown at the outset of Table 16-40. The 1st and 2nd entries are of particular interest because the one research effort sought to quantify land use and physical environment effects on walking, while the other did the same for bicycling, with much commonality of data and procedures. These two public-health-oriented studies examined the incidence of walking in terms of nonwalkers, walkers not meeting 150-minutes-per-week walking exercise recommendations, and walkers meeting the recommendations. Utilitarian walking, specifically including walking for transit access, and recreational/exercise walking were both included. Incidence of bicycling was identified as cycling at least once a week (Moudon, et al., 2007, Moudon, et al., 2005). The pairing of these two research studies allows exploring differences and types of impacts as they pertain to these two primary NMT modes.

Table 16-40 Selection of Additional Findings from Transportation and Physical Activity Research on Relationships between Pedestrian- and Bicycle-Friendly Neighborhood (NBH) Characteristics and Adult Walking/Bicycling

Study (Date)	Process (Limitations)	Key Findings
1. Moudon et al. (2007) (see this section for more information)	Cross-sectional analysis of walking activity, socio-demographics, attitudes, and objectively measured environmental variables covering 608 adults in King County, WA. (Extent of walking self-reported.)	Among neighborhood environmental measures found to be most related to walking were closeness to grocery stores, restaurants, and retail; lack of office building dominance; and density of the respondent's home parcel.
2. Moudon et al. (2005) (see this section for more information)	Similar to Moudon et al. (2007) but focused on cycling (at least once a week versus less), with inclusion of perceived environmental variables. (Some evidence in 1/3 of cyclists of neighborhood "self-selection" for recreational facility accessibility.)	Cycling appears to be an individual choice that "is only moderately associated with the neighborhood environment," at least in the Puget Sound/U.S. context. Trail proximity and certain commercial use groupings had significant positive relationships.
3. Cervero and Duncan (2003), and SR 282	Cross-sectional S.F. Bay Area survey and discrete-choice modeling controlling for disability, race, gender, and auto ownership and examining walking and bicycling separately. (Street-scale design elements not examined.)	Deterrents found were distance (walk and bike), slope (walk), rain (walk), and darkness (bike). Supportive factors included origin land use mix (walk), recreational/social purpose (both), or eating/shopping purpose (walk). Weaker factors included small blocks.
4. Krizek and Johnson (2006)	Objectively measured Minneapolis-St. Paul household proximity to nearest neighborhood retail employment site was related to home-based walk trip activity. (Unfactored samples from year 2000 regional survey; 205 exhibited walk trips.)	Walk trip activity more than twice as likely for individuals in households less than 200 meters (1/8 mile) from nearest retail as compared to those greater than 600 meters (3/8 mile) from retail. Very close proximity (<1/8 mile) was found to be most important.
5. Handy et al. – 1998 and Handy and Clifton – 2001 as summarized in Heath et al. (2006) and per SR 282	Linear regression analysis of cross-sectional 1994 recall mail survey with responses from 1,368 residents in 6 NBHs of Austin, TX; 2 traditional, 2 early modern, 2 late modern. Closeness of stores measured using GIS; other environmental variables were perceived measures. (15% and 29% of variation explained.)	Perceived safety, shade, and presence of people positive for strolling frequency; perceived presence of stores, walking incentive, walking comfort, plus closeness of stores positive for walk-to-store frequency; residence in Old West Austin NBH positive for both types. Living in traditional NBH associated with 163% more walking to store than modern NBHs.
6. Ball et al. – 2001 as summarized per SR 282	Logistic regression relating neighborhood aesthetics, congeniality, and access to facilities/paths to incidence of walking in Australia. (Measures based on perceptions.)	High aesthetics (5-point scale) linked with 41% more likelihood of walking than low; high convenience to facilities including paths linked with 36% more likelihood of walking than low.
7. Handy – 1996 as summarized in Heath et al. (2006) and per SR 282	Cross-sectional ANOVA analysis of 4 San Francisco Bay Area traditional NBHs with small, close-by shopping centers, vs. suburban NBHs and shopping, controlling for type of household. (Recall phone survey.)	NBH type not significant for strolling (1% to 5% more in traditional NBHs). Respondents reported walking to stores during the month almost 50% more in traditional NBHs; walk to store frequency was 182% greater.

(continued on next page)

Table 16-40 (Continued)

Study (Date)	Process (Limitations)	Key Findings
8. Berrigan and Troiano (2002), and SR 282	Used logistic regression to relate physical activity in U.S. to year home built. (Year home built a proxy for multiple urban form factors from core area accessibility to NBH layout and transit availability.)	Controlling for socio-demographic factors, persons living in a pre-1946 home walk 43% more and persons living in a 1946-1973 home walk 36% more relative to those living in a post-1973 home. (Non-rural homes only).
9. Doyle et al. – 2006 as summarized in Saelens and Handy (2008)	Related incidence of walking 1 uninterrupted mile in previous month to a composite walkability measure (block size, percentage of blocks <0.01 square miles in area, and intersections per road mile). (Sidewalk availability not considered.)	Among 35 large U.S. counties, found higher walking likelihood, even after controlling for individual demographics, for residents of counties having higher walkability scores, especially lifelong residents. Walkability had a stronger effect on walking than crime.
10. Hanson and Schwab – 1987 as summarized per SR 282	Analyzed 35-day travel diary survey covering 278 Swedish households. Calculated accessibility using number of establishments and Euclidean distance. (Evaluation based on correlation coefficients.)	Percent of all stops by NMT modes positively related to home-based accessibility; percent of all work-based stops by NMT modes positively related to both home-based and work-based accessibility.
11. Krizek – 2003 as summarized per SR 282	Tested, with socio-demographic controls and same data set as Krizek – 2000 (see 16th entry), both NBH and regional accessibility variables. (Composite NBH accessibility measure.)	Built environment accessibility variables showed no significant relationship to percent of trips by walking in this study of Puget Sound Area travel survey panel data.
12. Greenwald and Boarnet (2001), and SR 282	Probit model cross-sectional analysis of 1995 Portland, OR, regional travel survey and Pedestrian Environmental Factors (PEFs), small- and larger-area residential and retail densities, and survey respondent median walk trip characteristics reflecting trip cost. (Correlations reduced clarity.)	Walk trip frequency positively and significantly related to TAZ (or block group) PEFs, NBH population and retail density, percent area within 1/4 mile in grid plan, and median walk distance and speed. Positive but lesser and not significant relationship with larger area (non-localized) densities.
13. Craig et al. – 2002 as summarized per SR 282	Evaluated 28 NBHs in Canada on a 10-point ecologic scale and related the results to walk-to-work rates. (No non-work trip data.)	Controlling for socio-demographic factors, a 1-unit increase in the ecologic score was associated with a 25 percentage point increase in walking.
14. Clifton and Dill – 2005 as summarized in Saelens and Handy (2008)	Using a composite sample drawing from NHTS national, Portland, OR, and Baltimore data, and controlling for demographics, modeled number of walk trips relative to various objective and perceived measures. (Conflicting transit access and density results for different walking measures.)	Higher walk trip incidence related to high housing densities and land use mix, good transit access and pedestrian environment, greater park access, and perception that lack of sidewalk is not a problem. Walk trips *on survey travel day* negatively related to street connectivity, transit access, and for men only, density and percent vacant.
15. Berke et al., (2007b)	Cross-sectional analysis of fine-grained walkability scores for King County, WA, in conjunction with Adult Changes in Thought (ACT) cohort study data, including measures of activity. (Extent of walking self-reported.)	Found, after controlling for various socio-economic and health status variables, a significant positive association between NBH walkability and a report of any walking session over 15 minutes long during the week.

Table 16-40 (Continued)

Study (Date)	Process (Limitations)	Key Findings
16. Krizek (2000), and SR 282	An "LADUF rating" (land use, density, and urban form score based on housing density, employment presence/mix, and block size) related to percent of trips by alternative mode (NMT and transit) as obtained in longitudinal Puget Sound panel survey, and to shifts with change in LADUF rating. (Small LADUF-change sample sizes of 19 to 84 persons moving.)	Raw 1997 alternative mode shares were, for high LADUF, 29%; medium, LADUF, 14%; low LADUF, 6%. Drop in alternative mode share for 1989-1997 panel members moving from high to medium LADUF (before- and after-move time-series data) was 9.9 percentage points. Other mode shifts with LADUF change were logical in sign but not statistically significant.

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column. The notation "SR 282" is shorthand for Committee on Physical Activity, Health, Transportation, and Land Use (2005) together with Handy (2004).

The walking-focused King County, Washington, study (Table 16-40, 1st entry), using highly disaggregated data on trip origin and destination characteristics along with information on conditions en route, is notable for isolating impacts largely consistent with the larger body of research on land use effects. Higher net residential density, measured on the basis of each survey respondent's home parcel of land, was strongly and significantly related to more walking.[38] Living closer to a grocery-shopping or eating/drinking opportunity, along with typically associated retail and banking, was fairly consistently associated positively with walking. Directness of walking to the closest grocery store and the nearest school, measured in terms of airline distance versus network distance, was positively associated. Living closer to office-oriented development, particularly large sites, was negatively associated. Not significant to walking were recreational, institutional, or auto-oriented-retail land uses. Traveling through areas with more complete sidewalks along major streets (the only streets for which sidewalk data were available) was positively associated with additional walking (Moudon, et al., 2007).

The companion cycling-focused study (Table 16-40, 2nd entry) did not find any of the objective distance-based fine-grained accessibility/diversity measures to be significant to prevalence of bicycling. Perceived presence of grocery stores and schools showed negative associations to cycling. A handful of disparate land use diversity measures such as number of convenience store parcels in the neighborhood and parcels within the nearest office/hospital complex were positively related to cycling. A possible unifying factor was that land use descriptors positively related for cyclists were not for walkers, and vice versa (Moudon, et al., 2005). This disparity was not necessarily an illogical outcome considering the package-carrying limitations associated with bicycling and the substantively different trip length distributions that normally characterize bicycle trips as compared to pedestrian trips.

[38] This finding of significant density effects is not necessarily inconsistent with disaggregate analysis findings (presented above under "Density") of little density impact. Research efforts such as those by Ewing and Cervero, and Kockelman, focused on walk-only trips, whereas the walk activity research by Moudon et al. explicitly included transit-access walking in the dependent variable (Ewing and Cervero, 2010; Kockelman, 1996; Moudon, et al., 2007). As stressed in the "Density" discussion, more intensive (and thus better) transit service is normally provided where residential densities are higher. The transit-access component of walking activity would therefore logically be positively associated with density.

No objectively-measured infrastructure or route-related characteristics showed significant associations with cycling except for closeness to an off-road trail, which was a positive. Indeed, it was found that 33 percent of cyclists—as compared to 17 percent of non-cyclists—had considered recreational amenities when choosing their current residence. Also related significantly and positively to more cycling was *perceived* closeness of trails and bike lanes. Perceived traffic problems and presence of auto-oriented facilities were negatively related to cycling at the two ends of the spectrum—major traffic issues/many facilities and also insignificant traffic issues/few facilities.

The researchers conclude "that the decision to bicycle seems to rest largely on personal, and not environmental, factors" although "improving the built and transportation environment for cycling may still help promote general increases . . ." An unexpectedly high 21 percent of research survey respondents proved to be cyclists, according to the "at least once a week" definition, but most bicycle trips were for recreation. Limited infrastructure for cycling in the study area may have hindered ferreting out significant relationships with land use and route-related characteristics (Moudon, et al., 2005).

The 3rd entry in Table 16-40 also pertains to research examining both walking and bicycling. In this San Francisco Bay Area study, trip origin-area land use mix was found positively associated with walking, but not significantly with cycling. The only other strongly significant physical environment factors, excluding rain and darkness, were slope (negatively associated with walking) and trip distance (negatively associated with both walking and bicycling). The 4th entry presents, on the basis of research from Minneapolis-St. Paul, a commonly encountered overall positive relationship between closeness of retail and walking. As noted, very close proximity was determined to be especially important, a finding of particular relevance to the upcoming "Design" and destination accessibility discussions. In the more fully specified of three research models, the odds of walking at greater than 600 meters (3/8 mile) from the nearest retail establishment were 2/5ths the odds at less than 200 meters (1/8 mile), while the odds of walking at intermediate distances were still only 1/2 to 3/5ths the odds at less than 200 meters. While only the odds for shortest versus longest distances from closest retail were statistically significant, the odds for all four studied distance categories exhibited logical interrelationships (Krizek and Johnson, 2006).

Design

Design, as a land use descriptor, covers small-to-intermediate-scale transportation network and streetscape characteristics. Measures may indicate sidewalk extent, streetscape features such as building setbacks and parking front or rear, and NMT network continuity. Continuity in particular is often represented by surrogates such as average block size, intersections per unit area, or prevalence of four-way intersections.

The relatively substantial 0.39 elasticity obtained in the meta-analysis derivations (Table 16-38, 1st entry) for the effect of intersection/street density on walking presumably results from the importance of a fine-grained infrastructure for walk trip efficiency (Ewing and Cervero, 2010). The same importance pertains to transit use as well (see Table 16-42 below for elasticities), given the desirability of being able to walk directly to the nearest bus stop. The substantial positive relationship between transit use and prevalence of four-way intersections may relate to the efficiency of bus services possible in a grid system of streets as well as to efficiency of walk access to transit. The slightly negative relationship (based on five studies) between the walk-only mode and prevalence of four-way intersections may suggest that other measures do a better job of representing pedestrian interconnectivity or it may simply be an artifact of analysis based on small numbers of available studies within individual categories.

Six of nine reviews published in the 2002–2006 period (Table 16-38, 2nd entry) pointed to aesthetics, or attractiveness of the environment, as being associated positively with walking. Sidewalks and network connectivity were similarly found to be positively correlated. The researchers note that connectivity affects proximity, separately identified as being important, by virtue of providing more direct and thus shorter routes. Nevertheless, in both these matters of design, there was substantial variability across studies and an indication that different attributes of the built environment are important for recreational as compared to utilitarian walking. In the individual studies reviewed, little or no evidence was found for correlation between utilitarian walking and either aesthetics or conditions of pedestrian infrastructure and traffic. Relationships with route/network connectivity and presence of parks or open space were equivocal. Recreational walking findings were more limited, but appeared to support associations with aesthetics and quality of pedestrian infrastructure. Positive recreational walking relationships with connectivity measures were identified in just two more individual studies than the number showing insignificant or negative findings. No recreational walking associations were established in these studies with parks, open space, or traffic conditions (Saelens and Handy, 2008).

The SR 282 review (Table 16-38, 3rd entry) highlighted traditional, transit-served, and walkable neighborhoods—typically characterized by grid street systems—as being positively associated with greater use of active transportation (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). Caveats presented in the "Analytical Considerations" section of Chapter 15, "Land Use and Site Design," may pertain. There it was noted that weak attention to socio-economic variables such as income and family size, or other study limitations in some earlier investigations, results in a need for careful interpretation of certain neighborhood-type study conclusions. Full transferability of traditional neighborhood travel characteristics findings to newer land-use constructs such as neo-traditional communities cannot be taken for granted and must be viewed in appropriate socio-demographic and regional accessibility contexts.

The 12th and 13th extractions from Chapter 15 in Table 16-39 provide various individual research perspectives on design impacts, as do the 5th through 9th individual studies in Table 16-40. Design aspects addressed range from aesthetics to neighborhood type to system connectivity. Three of the seven research efforts explicitly or implicitly tested measures of aesthetics and produced findings ranging from qualitative identification of positive effect to 25 and even 41 percent positive differentials in NMT or walk shares in prescribed circumstances and comparisons (Parsons Brinckerhoff, 1996a, Heath et al., 2006, Committee on Physical Activity, Health, Transportation, and Land Use, 2005). Three of the research efforts explore comparisons of traditional neighborhood design (TND) with more typical suburban designs.[39]

One of the seven design-oriented research efforts, the 9th study in Table 16-40, focused exclusively—other than taking demographics into account—on street and block layout. It used a composite walkability score, encompassing three different measures of street system connectivity, and related it to walking activity. Street interconnectivity served as a surrogate for the extent to which the pedestrian system was tightly interconnected. The study found higher incidence of walking among counties with higher scores (Saelens and Handy, 2008).

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[39] Further insights into the Austin, Texas, findings (5th entry in Table 16-40) are afforded by additional evaluations involving a reexamination of the research data. See the "Sidewalks and Along-Street Walking" subsection under "Sidewalk Coverage and Traffic Conditions," starting with the 1st entry in Table 16-2 (Cao, Handy, and Mokhtarian, 2006). Also, further exploration of factors related to aesthetics is found in the "Underlying Traveler Response Factors" section (see "Environmental Factors"—"Surroundings Environment"—"Ambiance").

Other "D's"

The two additional "D's" covered here are destination accessibility and distance to transit. Destination accessibility is a measure of ease of access to jobs, shopping, and other non-home destinations—"attractions" in demand modeling parlance. Common regional destination accessibility measures include attractions reachable within a given mode-specific travel time and attraction accessibility as calculated using a gravity-model-type of formulation. Also used is the simpler measure of distance to the CBD (Ewing and Cervero, 2010). Local accessibility measures, often more apropos for NMT analysis, can range from jobs within a given walkable/bikeable distance to distance to the nearest store. Distance to transit, often treated as a transit service parameter rather than a land use descriptor, is typically measured as distance to the nearest bus stop or rail station. Alternatively, stop, station, or route coverage measures may be used.

The elasticities meta-analysis (Table 16-38, 1st entry) finds all investigated forms of regional accessibility measures, including simple closeness to downtown, to be negatively related to VMT. Data was insufficient, however, for computation of average elasticities of walking and transit use to these regional measures. Accessibility measures, most particularly closeness to downtown, probably act as a surrogate for lack of auto dependency and presence of impediments to auto use such as congestion and parking costs. Walking was found positively related to jobs within 1 mile, with an elasticity of 0.15, this being the only walking-scale average accessibility elasticity derivation allowable given numbers of studies available. Distance to the nearest transit stop produced elasticities with the expected signs. The most straightforward explanation pertains to the transit use elasticity: that closeness of transit service supports transit use (Ewing and Cervero, 2010).

Five of nine reviews published between 2002 and 2006 (Table 16-38, 2nd entry), as previously noted, consistently found accessibility to be significantly associated with additional walking. The accessibility measures used effectively described closeness to destinations. Individual studies examined also found consistent positive associations between walking and closeness to non-residential destinations, except in the case of research focused on recreation walking, where little or no identifiable relationship was demonstrable (Saelens and Handy, 2008).

SR 282 (Table 16-38, 3rd entry) used a slightly different approach to trip purpose differentiation, noting that studies from the transportation literature tended to focus on utilitarian travel, while physical activity research in the preceding years was primarily concerned with walking and perhaps cycling for recreation and exercise. (The physical activity research also made more use of accessibility measures constructed on the basis of survey respondent perceptions.) In the transportation literature significant associations with walking and cycling tended to involve destinations such as stores, bus stops, and parks, particularly in the case of shopping and schoolchild trips. In the physical activity literature, the more significant destinations for active transportation were partially the same (parks, local shopping, and transit stops) but also specifically included bicycle paths/trails (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). However, there were no reported overall conclusions as to whether the importance of transit stops in both categories of studies was a reflection of transit access activity or some secondary effect of transit availability on choice of walking or cycling as the primary mode.

Several of the individual studies in Table 16-40 used local-accessibility measures to examine effects of land use mix, but the 10th and 11th entries explicitly investigated accessibility to multiple potential destinations. The Swedish research found both home-based and work-based accessibilities to have a positive relationship with NMT mode use. The study utilizing Washington State Puget Sound Area data found no significance for regional accessibility or for a composite neighborhood accessibility measure (Committee on Physical Activity, Health, Transportation, and Land Use, 2005).

Overall Neighborhood Environment

The meta-analysis derivation of built environment elasticities (see Table 16-38, 1st entry, and Table 16-42) found them all to be inelastic—the impact always proportionally less than the stimulus provided by changing any one particular land use or urban design characteristic. In fact, most of the elasticities are much smaller than the 0.39 value for the walking response to greater intersection or street density. Nevertheless, "the combined effect of several built environment variables on travel could be quite large" (Ewing and Cervero, 2010). It is of interest to note that the elasticities for walking and transit use are almost all larger, some substantially so (especially for walking), than corresponding elasticities for VMT reduction. This outcome may reflect complex factors such as differential shifting from carpooling versus driving, or short versus long vehicle trips, to active transportation modes. Alternatively there may be a degree of elevated trip-making (trip generation) where walking and transit use are easy.

Transit Oriented Development (TOD) is a particular application of "smart growth" land use and design precepts that should by definition cover enhancement of most of the "D's" within the overall neighborhood environment. Properly implemented TODs focus on provision of higher densities within walking distance of the transit station or stop, follow guidelines suggesting land use diversity, design for quality NMT connections to the stop, offer good regional transit accessibility and transit stop accessibility, and obviously incorporate many housing locations in close proximity to transit. TOD is addressed within this chapter in the "Pedestrian/Bicycle Linkages with Transit" subsection under "Transit Oriented Development" as well as being the topic of Chapter 17.

There it can be seen that researched TOD outcomes are quite consistent with those identified for pedestrian/bicycle friendly neighborhoods in general. The TOD objective of enhancing transit ridership as a primary travel mode has been very successfully met in many TODs, and less successfully in others, but with only one small-scale partially negative outcome reported. Whatever the degree of transit mode share increase a particular TOD achieves, logic and substantial experience indicate that the walk mode of access share for users of the primary transit stop or station is very high even in suburban locations. Typically TOD studies report walk access shares between about 70 and 100 percent walk. Finally, comparative and prior-circumstance information indicates that trips made exclusively by walk or bicycle are more prevalent in the typical TOD than conventional development. The observed differences range from roughly double in the case of non-work trips to and from TODs outside the central area of Portland, Oregon, to no significant difference for work trips in the Pleasant Hill TOD in the East Bay Hills of the San Francisco region.

The 14th entry in Table 16-39 (from Chapter 15), the paired-communities analysis of the Rockridge and Walnut Creek communities in the San Francisco East Bay, provides texture for the TOD findings even though neither community was formally planned as one. Rockridge, a TND neighborhood, grew up as a "streetcar suburb," with retail and other development oriented toward surface transit. Walnut Creek is of conventional suburban design (CSD). Today each has a centrally located Bay Area Rapid Transit (BART) station. They are on the same BART line, albeit separated by the first range of East Bay Hills. As indicated in Table 16-39 the walk/bike-only mode choice for non-work travel was found to be 10 percent in the TND neighborhood versus 2 percent in the CSD area. The comparable NMT shares for work purpose trips were 7 percent (TND) versus 1 percent (CSD). For non-work trips under 2 miles in length, a 52 percent NMT share was encountered in the TND environment versus 17 percent for the CSD community. Also highly significant for local area walk versus driving activity is the previously introduced finding of 31 percent TND neighborhood walk share for BART station access, compared to 13 percent walk access for the station in a CSD environment. This differential is particularly noteworthy considering the similarity of the work commute rail transit shares at 21 percent for the Rockridge TND neighborhood and 20 percent for the Walnut Creek CSD community (Cervero and Radisch, 1995).

Three of nine reviews published in the 2002–2006 period (Table 16-38, 2nd entry) concluded that neighborhood-based composite walkability measures were positively correlated with walking (Saelens and Handy, 2008). The 15th and 16th entries in Table 16-39 from Chapter 15 present two additional perspectives on overall neighborhood environment effects. One suggests that attitudes are most important in NMT choice (Kitamura, Mokhtarian, and Laidet, 1994). The other reports on two travel demand modeling efforts that successfully used multi-faceted neighborhood environment measures in estimating NMT mode shares. The environment measures involved are generally known as Pedestrian Environmental Factors (PEFs) (Cambridge Systematics, Putman Associates, and Calthorpe Associates, 1992, Cambridge Systematics et al., 2002).

The last five individual studies summarized in Table 16-40, the 12th through 16th entries, also show relationships between better NMT environment scores—sometimes in combination with other measures—and higher walk, or walk and bike, mode shares (or walking activity in one case). The 16th table entry is of special interest because of its use of Puget Sound panel time series travel data rather than cross-sectional data. The vast majority of land use and transportation research relies on cross-sectional studies. In such studies, although which caused what may often seem fairly obvious, causality cannot be absolutely demonstrated. With panel survey data over time, however, the effects reported involve the same respondents before and after moving from one neighborhood type to another. All respondent moves from one rating category to another resulted in logical shifts in walking, bicycling, and transit shares. Even though the numbers of movers were small and shifts reached statistical significance for only one category of change, the commonality of logical outcomes gives fairly strong evidence that change from less to more favorable neighborhood environments is linked to increases in alternative travel mode use, and vice versa (Krizek, 2000).

The Built Environment and Child Walking and Bicycling

Research on choice of mode for children and adolescents traveling to school demonstrates clearly that distance between home and school is a dominant factor in the choice to walk or not. The SUNY synthesis of environmental influences on children's physical activity (Table 16-38, 4th entry) found that three out of three studies which directly or indirectly examined the role of distance found walking to be inversely related to distance or walking time (Davison and Lawson, 2006). Less than a half-decade later, the WSDOT review of SRTS-related research (Table 16-38, 5th entry) located 19 studies that examined distance between home and school. All 19 found a significant negative relationship between this distance and active transportation to school (ATS).

The WSDOT reviewers concluded: "Distance from a child's home to school is the strongest predictor of ATS." They report that 47 percent of the decline in ATS between 1969 and 2001 is explainable on the basis of greater home and school separation (Moudon, Stewart, and Lin, 2010).[40] The synthesis of nine reviews and other studies (Table 16-38, 2nd entry) reported that the relationship has not been "universally found," but agreed that the preponderance of evidence shows proximity to exhibit a consistently positive relationship (Saelens and Handy, 2008). ATS is primarily comprised of walking and cycling, but may include other NMT modes such as scooters where allowed by schools and parents.

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[40] Walking and bicycling to school by children up to age 18 declined from just under 41 percent in 1969 to 13 percent in 2001 (Moudon, Stewart, and Lin, 2010) and 10 percent in 2009 (Kuzmyak et al., 2011). (See Table 16-88 in "Extent of Bicycling" under "Related Information and Impacts"—"Extent of Walking and Bicycling.")

Two studies examined in the SUNY synthesis examined possible links between population density and ATS. One found no significant association when considering densities in the immediate area around children's homes. The other found walking and cycling to school to be more prevalent where densities were higher (Davison and Lawson, 2006). It is logical that there should be a positive relationship, in that higher densities put more students close to their schools (U.S. Environmental Protection Agency, 2003). In that regard, it is of note that a national study reviewed for the WSDOT synthesis (Moudon, Stewart, and Lin, 2010) found high negative sensitivity to walk time to school (a marker for distance) and also determined higher density to have a significant positive relationship to more walking (McDonald, 2008).

Other findings on land use and design relationships to walking and cycling by children are equivocal, aside from attractiveness of a good pedestrian infrastructure and associated traffic safety, for which there is strong evidence (Saelens and Handy, 2008). Three of four studies in the SUNY synthesis (Table 16-38, 4th entry) did find a significant positive relationship between children's physical activity, including active transportation, and destination proximity. Destination measures ranged from retail to transit stops. Only two of four studies found a significant effect for street connectivity in the expected direction (Davison and Lawson, 2006). The WSDOT review (Table 16-38, 5th entry) reached the conclusion that a "majority" of neighborhood characteristics researched have shown either a relationship to ATS in the expected direction or no significant association. Characteristics tested include urbanization level, population density, land use mix, and street layout (Moudon, Stewart, and Lin, 2010). Obviously a number of the same few studies have been assessed more than once.

Table 16-41 encapsulates six of the available studies on interrelationships between patterns of childhood travel and the extent of neighborhood pedestrian and bicycle friendliness.[41]

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[41] Additional gleanings from the limited knowledge base available on active transportation by children are primarily concentrated in specific child-related discussions within this chapter. One, later in this "Response by Type of NMT Strategy" section, is under "NMT Policies and Programs"—"Schoolchild-Focused Programs." Others are in the "Underlying Traveler Response Factors" section (see "Behavioral Paradigms"—"The Travel Choice Making of and for Children," and "Trip Factors"—"Schoolchild Trip Factors," plus brief entries in the "User Factors" subsection under "Age" and "Ethnicity"). The final key child travel discussion is in the "Related Information and Impacts" section under "Public Health Issues and Relationships"—"Health Benefits for Children of Enhanced NMT Systems and Policies."

Table 16-41 Selection of Additional Findings from Transportation and Physical Activity Research on Relationships between Pedestrian- and Bicycle-Friendly Neighborhood (NBH) Characteristics and Child Walking/Bicycling

Study (Date)	Process (Limitations)	Key Findings
1. Braza et al. – 2004 as summarized by Davison and Lawson (2006)	Employed bivariate modeling of objective measures of California school area characteristics and surveyed rates of walking/biking to school.	Walking and biking rates to school were found to be associated with higher population and intersection densities, but not school size.
2. Carver et al. – 2005 as summarized by Davison and Lawson (2006)	Cross-sectional analysis of parent and child perceptions of various facilities and environmental conditions. (Used self-reported physical activity measures as well as perceived environment measures.)	Australian adolescents were found to walk/bike more where there were more physical activity opportunities and where convenience stores were *farther* from home (among other not immediately intuitive findings).
3. McMillan – 2007 as summarized in Saelens and Handy (2008)	Surveyed caregivers of California children in 16 schools and tested neighborhood relationships against NMT access. (Self-reported walking/biking and perceived environment measures except as noted.)	Higher probability of walking/biking to school with school within 1 mile, greater perception of neighborhood and traffic safety, and more land use mix and houses with windows facing the street (both objectively measured).
4. Kerr – 2006 as summarized in Saelens and Handy (2008)	Developed an objective walkability composite of density, connectivity, land use mix, and retail presence, and tested using survey data from caregivers in King County, WA, on perceptions and walking/biking to school at least once a week. (Sidewalks not included in measure.)	High walkability neighborhoods were associated with increased probability of walking/biking to school, particularly for parents with low traffic/crime concerns, high income areas, and areas with high perceived aesthetics. Perceived walkability measures, when included, overrode objective measure.
5. U.S. Environmental Protection Agency (2003) (see this section for more information)	Used 2 regional travel diary surveys and regional model, GIS, and other data to develop a logit mode choice model of student travel to/from K-12 public and private schools in Gainsville, FL. (Detail limited by surveys' trip sample rates and TAZ-level aggregation of descriptors.)	Lower income and auto ownership, shorter walk times, and better sidewalk coverage were all associated with higher probability of walking to school. For bicycling, only shorter bike times were significant. School size and land use density/mix were not significant factors after accounting for travel time.
6. McDonald (2008) (see also "Behavioral Paradigms" in "Underlying… Response Factors")	Used 2001 NHTS data to investigate mode choice for child travel to elementary and middle schools with a multinomial logit choice model. (Limited data on environment, times estimated with aggregate speeds.)	Associated with higher walk-to-school mode shares were shorter walk time (elasticity -0.75), longer auto time, population density, years of age (elasticity +0.82), number of siblings, lower income, and fewer vehicles/driver.

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

Sources: As indicated in the first column.

The research published by U.S. Environmental Protection Agency (EPA), covered in the 5th entry of Table 16-41, went beyond research model development and interpretation to test sensitivities of key parameters and examine benefits of neighborhood schools. Although the model derivations proved not to be independently sensitive to neighborhood density, they did show walking and bicycling to be sensitive to travel times, and thus closeness of homes to school. Higher residential densities place more students within short walking and biking distance, other things being equal.

Having local schools—drawing students from smaller areas—likewise helps provide shorter walk and bike travel times, leading to increased use of active transportation for school access (U.S. Environmental Protection Agency, 2003).

The estimated elasticities for probability of walking to school were –0.84 with respect to income, –1.16 with respect to per capita auto ownership, and +0.42 with respect to sidewalk coverage ratio. For reasons not clear, the elasticity for walking with respect to walk travel time was inelastic, yet the elasticity for biking with respect to bike travel time was elastic. In any case, a 25 percent reduction in either walk or bike travel time was estimated to produce a 1.0 percentage point gain in use of the mode. In the Gainesville context, this represented a 4.5 to 5.5 percent walk share shift and a 3.4 to 4.4 percent bike share shift.

A neighborhood schools simulation was made, also in the Gainesville context, by assuming all students to live within 1/2 mile. Walk share changed from 4.5 to 10.3 percent, bike share from 3.4 to 11.1 percent, school bus share from 15 to 13 percent, and auto share from 77 to 66 percent. Clearly a key neighborhood design issue from the perspective of child active transportation use and promotion is school placement relative to school populations along with the provision of safe and direct access routes (U.S. Environmental Protection Agency, 2003).

The national study listed as the 6th entry of Table 16-41 estimated a substantial walk mode choice sensitivity to walk travel time to school, similar to that estimated by Ewing and Greene in 2003 (the research incorporated into the EPA study reviewed above). Nonetheless, it *also* isolated a significant positive relationship to population density, as noted already. The elasticity calculated for income was, however, substantially lower. Since the national data used did not allow consideration of fine-grained physical environment factors such as sidewalks or connectivity (McDonald, 2008), the possibility must be entertained that density stood in as a surrogate for such design factors. More on this national study, including elasticities, is found in the "Behavioral Paradigms" school travel choice discussion previously cross-referenced.

Walk Elasticities for Land Use and Site Design Parameters

Researchers Ewing and Cervero, at the end of the 1990s, synthesized results from a large number of land use and site design studies and developed a consolidated set of elasticities of travel with respect to built environment parameters. The results are presented in Table 15-56 of Chapter 15, "Land Use and Site Design" (see "Related Information and Impacts"—"Trip Making and VMT"—"Consolidated Vehicle Trip and VMT Elasticities"). Vehicle trips (VT) and vehicle miles of travel (VMT) elasticities were provided with respect to differences in the original 3D's—local density, local diversity, and local design—plus regional accessibility (Ewing and Cervero, 2001).

Their work, some 10 years later, was completely updated with additional data sources and a full meta-analysis approach (Table 16-38, 1st entry). In the update, in addition to VMT, elasticities were developed for walking and transit use. Two or three separate measures were utilized for each of the original 3D's, and distance to transit was added to destination accessibility as a second urban form characteristic beyond the basic 3D's. As before, elasticity development involved going back to original sources and, in selected cases, re-analyzing the data. After inspecting over 200 studies, the researchers selected 59 investigations as the meta-analysis sample. The common metric sought was the elasticity of the travel outcome of interest with respect to one of the urban form characteristics variables. Different elasticity formulae were used depending on the form of the original equations, but the results may be interpreted as point elasticities (Ewing and Cervero, 2010). The results are reproduced in Table 16-42.

Table 16-42 Meta-Analysis Elasticities of Travel with Respect to Urban Form Parameters

Urban Form Characteristic	Nature of Measure	Vehicle Miles of Travel (VMT)	Walking (Only)	Transit Use
Local Density	household/population density	-0.04	0.07	0.07
	job density	0.00	0.04	0.01
	commercial floor area ratio	—	0.07	—
Local Diversity	land use mix (entropy index)	-0.09	0.15	0.12
	jobs-housing balance	-0.02	0.19	—
	distance to a store	—	0.25 [a]	—
Local Design	intersection/street density	-0.12	0.39	0.23
	percent 4-way intersections	-0.12	-0.06	0.29
Destination Accessibility	job accessibility by auto	-0.20	—	—
	job accessibility by transit	-0.05	—	—
	jobs within 1 mile	—	0.15	—
	distance to downtown	-0.22 [a]	—	—
Distance to Transit	distance to nearest transit stop	-0.05 [a]	0.15 [a]	0.29 [a]

Notes: Meta-analysis sample sizes for the elasticities shown range from 3 to 10 studies each.

[a] Sign reversed to provide consistency of interpretation, i.e., negative for trip reduction and positive for higher walking activity and transit use. (The reversed signs in effect apply to "closeness" rather than "distance.") For use in an elasticity application formula employing the nature of measure indicated, these signs should be restored back to the opposite of what is shown.

Sources: Ewing and Cervero (2010).

The researchers averaged elasticities within each category, such as the elasticity of walking to job density, using averaging weighted by study sample size. The number of suitable studies available for each included category ranged from three to 10. To maximize sample sizes, the relatively few studies having controlled for self-selection effects were mixed in with the larger number of studies that did not. The approach used, which involved combining both "significant and insignificant individual effect sizes," did not provide the data necessary for testing the statistical significance of the averaged elasticities. The researchers outline these and other limitations of the study, and urge due caution when making use of the results (Ewing and Cervero, 2010). It appears likely that these elasticities encompass certain second order effects, such as the impact of density on mode choice that is channeled via auto ownership, but probably not others, such as the impacts of enhanced transit service made feasible by higher densities (except as measured by distance to nearest transit stop).

The individual and collective elasticity results provided in Table 16-42 have been interpreted in the preceding "Pedestrian/Bicycle Friendly Neighborhoods" discussion. Note that the transit use elasticities have been included not just as general information, but also in recognition of the importance of transit riding to active transportation and vice versa. Of all U.S. walk trips, as previously noted, 16 percent are made for the purpose of accessing transit (Agrawal and Schimek, 2007, Kuzmyak et al., 2011), and the associated physical activity contribution to chronic disease prevention is of consequence (Besser and Dannenberg, 2005). The transit-access component of walking, and the transit usage linked with it, is thus of substantial interest from both NMT analysis and public health perspectives.

NMT Policies and Programs

Instances of city-wide policy in support of NMT are found throughout the world. The results from Europe tend to be the most dramatic, but questions about transferability of findings to New World auto-oriented environments persist. This examination of policy and program effects starts with four examples from the United States and Australia. Then European examples and the lessons they offer are highlighted. There is no attempt to present a random or representative sample. Instead, results obtained in exemplary programs are examined. Finally, Safe Routes to School (SRTS) and related programs focused on children are covered. Here data limitations also make a random sample impossible, although the 10 California programs examined under "Schoolchild-Focused Programs"—"Infrastructure and Traffic Engineering Improvements" are thought to be reasonably representative of California's early state-sponsored program achievements.

New World Program Examples

Major examples of translating policy into city-wide bicycle or NMT programs in the United States are provided by Portland, Oregon, Davis, California, and Boulder, Colorado. These three cities were, as of 2008, the only U.S. cities awarded the platinum bicycle-friendly rating of the League of American Bicyclists (LAB). The LAB rankings are based not only on presence of exemplary facilities but also on education and enforcement programs (League of American Bicyclists, 2009). Davis and Boulder may be characterized as university towns, which makes transfer of their experiences to other types of urban areas somewhat problematical, but the shifts in travel mode experienced still help scale what may be possible in terms of relative change. (See "Underlying Traveler Response Factors"—"Other Factors and Factor Combinations"—"University Affiliation" for further discussion of university effects.)

Results of these three programs are examined here along with a summary for the Brisbane, Australia, active transportation policy application example previously examined under "Pedestrian/Bicycle Systems and Interconnections," a closely aligned topic. Indeed, that subsection (located earlier in this "Response by Type of NMT Strategy" section) should be referred to for policy/program thrusts such as the series of pedestrian and bicycle improvements in Minneapolis which together form the equivalent of an overall program extending—at least in the downtown—over half a century.

Portland, Oregon. The NMT policies and program in Portland, Oregon, have been heavily focused on bicycles. Pedestrians and recreational walkers have benefited, but documentation and the available longitudinal descriptive analyses have bicycling as the primary focus.

In viewing the results of Portland's bicycle program, it is important to keep in mind that the City of Portland has since the mid-1970s pursued policies designed to reduce auto use, particularly in the central area. The 1975 "Downtown Circulation and Parking Policy" placed constraints on downtown parking which, though since modified, continue to effectively dampen parking supply. Transit service enhancements started with more than a doubling of bus service, followed by free downtown transit, a downtown bus mall, a light rail transit (LRT) system that has grown to include multiple lines, and a central area streetcar circulator. (More background, along with sources, is found in the case study, "CBD Parking Supply Management in Portland, Oregon," in Chapter 18, "Parking Management and Supply.")

Portland's attention to bicycling also dates back to the 1970s. Oregon's "Bicycle Bill" shaped city NMT policy, requiring inclusion of pedestrian and bicycle facilities in transportation projects, and specifying that local jurisdictions should spend a minimum of 1 percent of transportation funding on bicycling (Alliance for Biking & Walking, 2010).

Implementation of a Portland Bicycle Master Plan did not move full steam ahead, however, until the 1990s. Bicycle programs in the 1970s and early 1980s were heavily event-based, and focused on promotions, maps, and the like, although concrete work was accomplished on bicycle parking requirements and provisions. In the mid-1980s, Portland began to emphasize corridor bicycle facility improvements, but these were slowed by neighborhood opposition. In 1988 the corridor projects approach was modified into a more flexible district improvements program, and implementation moved sharply ahead (City of Portland, 2004). Portland has also renewed its commitment to education, encouragement, and outreach, resulting in such promotional successes as the highest number of schools participating in National Walk and Bike to School day among major cities in 2006–2008 (Alliance for Biking & Walking, 2010).

The Willamette River bisects Portland along eastern boundary of the original central business district (CBD). In the 1992–2004 period, major bicycle provision improvements were made to the four key central area bridges, as described previously (with bicycle counts) in the “Pedestrian/Bicycle Systems and Interconnections” subsection under “River Bridges and Other Linkages.” Pursuant to a “build it and they will come” approach, the total overall miles of bikeways was increased from 78 miles in 1991 to 256 miles in 2004, a 228 percent increase. Bikeways consist of bicycle boulevards, bike lanes, and shared-use paths, supported by short signed connections. These improvements were accompanied by an estimated 210 percent increase in bicycle trips, as extrapolated from Willamette River crossing counts in context with U.S. Census travel data (Birk and Geller, 2006).

Interestingly, bridge bicycle traffic further increased—and sharply so—in the years following 2003, even though expansion of system extent slowed. Bikeway extent grew from 262 miles in 2004 to 274 miles in 2008 (Gotschi, 2011), a 5 percent increase. Bridge bicycle volumes, however, increased by 90 percent over this period, to about 16,700. A small bicycle traffic drop-off occurred in 2009, despite introduction of additional facility mileage (Raisman, 2010), likely related to the “Great Recession.” A number of driving forces may be behind the strong post-2004 cycling increase, some 18 times the bikeway mileage increase. They include:

- A lag effect, whereby the pre-2004 bikeway system expansions were only gradually taken advantage of by potential cyclists (see “Time to Establish Facility Use” within the “Related Information and Impacts” section).

- A mid-2004 to mid-2008 doubling of gasoline prices (Energy Information Administration, 2008), occurring in the context of an already-extensive bikeway system offering good travel options.

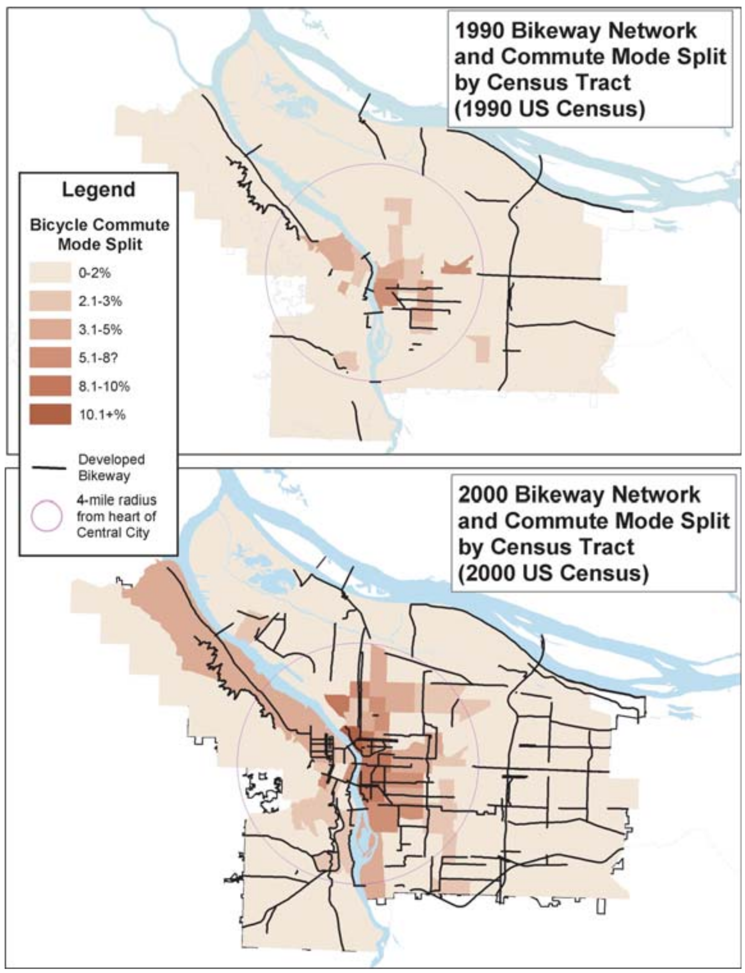
- A response to annual sector-by-sector implementation (following a 2003 pilot application) of individualized marketing in support of active transportation (see “Individualized Marketing” in the following “Walking/Bicycling Promotion and Information” subsection, and also the final case study, “Variations on Individualized Marketing in the North West United States”).

- Concurrently increased cycling education, encouragement, and community outreach (Alliance for Biking & Walking, 2010).

- Flowering of a “virtuous circle,” wherein the increasing numbers of bicyclists have made cycling more visible and generally accepted (Alliance for Biking & Walking, 2010).

Corroborating the increases seen in the 1990s bicycle counts, U.S. Census data for 1990 and 2000 show overall Portland bicycle commute shares growing from approximately 1 percent to 3 percent, with more dramatic increases in the dense, flat, neighborhoods of the inner city. Figure 16-7 shows the increases in commute mode shares obtained over the decade, as measured at the home end of the work trip, and also illustrates the growth of the bikeway network (Birk and Geller, 2006). Beyond the year 2000, substantiation is provided by the American Community Survey, which found commute mode shares for bicycling of 1.8 percent in 1996 and 6.4 percent in 2008 (Gotschi, 2011).

Figure 16-7 Bicycle commute mode share by home residence census tract, Portland, Oregon, 1990 and 2000.



Source: Birk and Geller (2006).

Davis, California. Also focused on bicycling have been the NMT policies and overall program in Davis, California, long known as the bicycle capital of the United States. Davis created the first post-World-War-II bicycle lanes in America, growing out of 2 years of citizen lobbying and 1 year of engineering effort. The city today has bicycle lanes on 95 percent of arterial streets, totaling almost 50 miles in an area of 10 square miles. It also has nearly 50 miles of separated shared use paths. A number of crossings of major roads feature path grade separations or signalization.

Anecdotally, it is understood that Davis is a city where "ordinary Americans" can and will ride a bike for their daily travel needs.

Davis provides a unique sequence of lessons, in that the bicycle program reached its zenith in the latter half of the 20th Century, and now the effects of program maturity and even decline may be observed. Constraints on drawing transferable lessens include the fact that Davis is very much a college town, and the lack not only of overall pedestrian data and any non-commute mode shares, but also of any comprehensive bicycling statistics up through the zenith of the program. Overall bicycle commute statistics may, however, be closely inferred for the peak years and are available for 1977 through 2007. Table 16-43 summarizes the epochs of the Davis bicycle program, the actions and status during each epoch, and available bicycle mode share statistics (Buehler and Handy, 2008).

Highly effective advocacy starting in the 1960s that translated into civic action and institutions resulted in transportation being "oriented toward the bicycle" in Davis. Cycling has declined since the 1970s (Buehler and Handy, 2008), but still exceeded the journey-to-work bicycling rates found in other U.S. cities as of the 2000 Census (Xing and Handy, 2010). Some 41 percent of the Davis population reportedly considered bicycling their primary mode of transportation as of the 1990s (Environmental Working Group et al., 1997).

Reasons offered by university officials for the post 1970s bicycling decline include the fare-free transit instituted in 1992, increasing student affluence, and increased intercity student and worker commuting. An alternative perspective is that a major problem is loss of personalized programs that formerly ranged from elementary school cycling education to subsidized helmets, university student orientation, support of U-fix services at a university "Bike Barn," removal from racks of abandoned bicycles, and strict enforcement of bicycle-friendly traffic laws (Buehler and Handy, 2008). Davis does have a good foundation, in four decades of controlled growth planning policy, to maintain and strengthen its active transportation modes. The 1990 versus 2000 Census comparisons show a modest growth in walking and transit commute shares. That trend has so far been insufficient to counter the loss of bicycling, however, such that post-1980 auto commute shares have continued to rise. Davis auto commute shares reached about 67 percent in 1990 and 70 percent in 2000 (Garrick, 2005, Buehler and Handy, 2008).

Table 16-43 Five Decades of Bicycle Policy and Outcomes in Davis, California

Epochs	Status and Actions	Active Transportation Outcomes
Pre-1964 (Pre-City-program) 1960 Davis pop. 8,900	Davis bicycling received a boost from a cycle-riding university chancellor with a cycle-friendly campus design for growth from 2,000 to 10,000 students. City enforcement policies grew unfriendly to bicyclists as auto use rose.	Anecdotal reports indicate that cycling in Davis, always a bicycle-friendly city with a temperate climate and gentle terrain, exceeded the levels observed in nearby communities.
1964-1973 (Policy development and application) 1970 Davis pop. 23,500	Heady years of pro-bike citizen action and lobbying, continued university support, city policy development, engineering problem solving, bike lane implementation (15 miles in 1976), and numerous supportive actions. City planning process favored compactness.	Davis bicycle mode share to work neared or may have exceeded 30%, while student share to campus approached or reached 80% (Handbook authors' extrapolations from Buehler and Handy, 2008, Tables 4 and 6).
1974-1993 (Program maturation) 1980 and 1990 City of Davis pop. 36,600 and 46,300	The bicycle program was fully institutionalized, with facilities required by city code, as Davis grew. Nascent greenway links (7 miles in 1976) were expanded into a comprehensive shared use path system (27 miles in 1993). Yolo County agreement of 1978 supported containment of growth within Davis.	Census data interpolation suggests a 1980 bicycle work commute share of approximately 28%, compared to 4-6% in the university towns of Eugene, Oregon, and Boulder, Colorado. Student shares to campus were about 78% in 1977 and 72% in 1987.
1994-2007 (Bicycling in flux) 2000 Davis pop. 60,300	Bike lanes totaled 37 miles in 1993, 47 in 1998, 49 in 2000. Path system grew to 41 miles in 1998 and 49 in 2000. Mileages were static 2000-2007. City staff from the bicycle policy development period retired, university spent $60 million on new parking garages without renewing old bike parking, numerous support programs withered and disappeared. General plan of 2001 emphasized downtown and neighborhood centers to keep trips short, benefiting walking/biking.	Davis-specific Census data show a drop in bicycle work-trip share from 22% in 1990 to 14% in 2000, while Eugene and Boulder held at 5-7%. Student bicycling shares to campus dropped to 43% in the late 1990s, rebounding a bit to 48% in 2007. Davis walk and transit 1980-2000 work-trip shares each stayed within a range of 4-7%, presumably helped by the controlled growth planning focus. Student transit access to campus, fare-free, reached 25-30%; from 3% in 1977.

Note: Eugene, Oregon, Boulder, Colorado, and University of California (UC) Davis bicycle shares, and 1980-1990 Davis non-bicycle commute shares, scaled approximately from Tables 4, 5, and 6 in Buehler and Handy (2008).

Source: Assembled and interpreted from Buehler and Handy (2008) and Garrick (2005).

Small-sample 2006 surveys in Davis (N=354, 18.8 percent response rate) and Boulder (N=129, 12.2 percent response) found only 13 percent agreement in Davis that "Bicyclists spend a lot of money on their bikes" (compared to 60 percent agreement in Boulder). This outcome could be interpreted as updated support for the perception that Davis residents react to utilitarian bicycling as an ordinary choice. In the same surveys, 50 percent of Davis residents reported that their bike trips were all or mostly for transportation purposes, relative to only 29 percent for Boulder respondents. The surveys found 2 to 3 times more journey-to-work cycling in the two cities than did the 2000 Census, with the Davis survey showing a slight but inconsequential and statistically insignificant bias compared to a control survey administered by telephone (N=400, 100 percent response). These 2006 surveys found slightly higher cycling rates in Davis than in Boulder by most measures, but no differences reaching statistical significance except in the "transportation" versus "recreation" split (Xing and Handy, 2010).

Boulder, Colorado. The policy and program focus in the City of Boulder, Colorado, differs from Portland and Davis in that it effectively addresses in one Transportation Master Plan (TMP) goal the enhancement of all active transportation modes—pedestrian, bicycle, and transit. The explicit travel demand objectives are expressed in terms of reducing single-occupant vehicle (SOV) mode shares and holding VMT constant. Boulder uses travel demand management (TDM) techniques in conjunction with improvements to alternative modes to help meet goals. The 1996 TMP called for reduction in SOV travel to 25 percent of trips by 2025 (City of Boulder, 2003, Roskowski et al., 2010), as compared to 44.2 percent by residents in 1990 and 38.4 percent surveyed in 2006 (National Research Center, 2007).

Boulder has both built-in and self-generated advantages and support for encouragement of active transportation. About 20 percent of residents during the school year are University of Colorado (CU) students (National Research Center, 2007). Presence of the university brings a population that is often more progressive, more educated, and less inclined to drive. Among proactive efforts by the City of Boulder has been its buying of open space since the late 1960s in the form of a buffer, which combined with county comprehensive-plan coordination, has effectively provided a growth boundary. This growth boundary, in turn, has fostered in-fill development and redevelopment, enhancing density and multimodal-friendly urban design. Most city destinations are within 5 miles. Boulder priorities led to its spending, in 2007–2008, of 49 percent of its transportation budget on pedestrian, bicycle, transit, and TDM projects. The city monitors its progress over time using a variety of measurement tools (Roskowski et al., 2010).

Table 16-44 presents the results of mode share monitoring from 1990 through 2006. The mode shifts illustrated are in the context of continuing NMT facility, transit, and TDM enhancement programs. Each year during a period roughly coincident with the 1990 through 2006 time span, Boulder was adding—on average—about two shared use NMT underpasses of roads and highways (Roskowski et al., 2010), 1/2 to 1 mile of off-street shared use path, and 1/2 to 1 mile of on-street bicycle lanes (Ferguson, 2009, Roskowski et al., 2010). As of mid-2008 there were 72 underpasses and two overpasses; 111 miles of shared use, off-road paths; and 74 miles of bike lanes (Ratzel, 2009). The city estimates its pedestrian and bicycle system is 85 percent complete (Roskowski et al., 2010).

Utilizing this information and accompanying path and bike lane annual construction tallies, the Handbook authors have estimated the following percentage-growth-in-supply values:

- Grade-separated underpasses in number, 1990–2006—84 percent increase.
- Shared use, off-street paths in miles, 1990–2006—15 percent increase.
- On-street bike lanes in miles, 1990–2006—25 percent increase.

Table 16-44 Modal Shift Summaries for Various Boulder Travel Categories, ca. 1990–2006

Travel Category	Walk	Bike	Transit	Total Active	School Bus	SOV	MOV	Total Auto
	Travel Mode							
All Trips by Residents								
1990 mode share	18.2%	9.1%	1.6%	28.9%	0.6%	44.2%	26.3%	70.5%
2006 mode share	18.9%	13.6%	4.0%	36.5%	0.1%	38.4%	25.0%	63.4%
Percentage point change	+0.7%	+4.5%	+2.4%	+7.6%	-0.5%	-5.8%	-1.3%	-7.1%
Percent gain/loss	+4%	+49%	+150%	+26%	-83%	-13%	-5%	-10%
Travel Miles by Residents								
1990 mode share	3.0%	4.9%	4.1%	12.0%	0.2%	50.0%	37.7%	87.7%
2006 mode share	3.7%	7.2%	5.7%	16.6%	0.1%	46.9%	36.3%	83.2%
Percentage point change	+0.7%	+2.3%	+1.6%	+4.6%	-0.1%	-3.1%	-1.4%	-4.5%
Percent gain/loss	+23%	+47%	+39%	+38%	-50%	-6%	-4%	-5%
Work Trips by Residents								
1990 mode share	8.9%	10.6%	4.0%	23.5%	0.0%	66.6%	9.9%	76.5%
2006 mode share	11.0%	20.5%	5.1%	36.6%	0.0%	52.7%	10.7%	63.4%
Percentage point change	+2.1%	+9.9%	+1.1%	+13.1%	0.0%	-13.9%	+0.8%	-13.1%
Percent gain/loss	+24%	+93%	+28%	+56%	0.0%	-21%	+8%	-17%
Work Trips by Employees					**Other**			
1991 mode share	3.5%	8.4%	1.7%	13.6%	1.6% [a]	73.0%	11.8%	84.8%
2005 mode share	2.8%	3.5%	9.5%	15.8%	6.9% [b]	69.0%	8.3%	77.3%
Percentage point change	-0.7%	-4.9%	+7.8%	+2.2%	+2.3% [a]	-4.0%	-3.5%	-7.5%
Percent gain/loss	-20%	-58%	+459%	+16%	+144% [a]	-5%	-30%	-9%
Employee Midday Trips								
1991 mode share	6.6%	5.3%	1.2%	13.1%	n/a	68.2%	18.8%	87.0%
2005 mode share	10.1%	3.6%	3.4%	17.1%	0.9%	68.9%	13.1%	82.0%
Percentage point change	+3.5%	-1.7%	+2.2%	+4.0%	n/a	+0.7%	-5.7%	-5.0%
Percent gain/loss	+53%	-32%	+183%	+30%	n/a	+1%	-30%	-6%

Notes: [a] Work at home.

[b] Includes 3.9% work at home, 2.2% multi-mode (car/bus, bike/bus, 2 buses), 0.8% other.

Sources: National Research Center (2006a and 2007) with elaboration.

These NMT facility supply growth increases may be compared with the 1990–2006 mode share change percentages in Table 16-44. In doing so, however, it is critical to take into account the concurrent transit improvements and TDM efforts. Local bus routes have been expanded to provide full interconnection with regional routes. The city spends about $1.5 million annually for higher-frequency services by Denver's Regional Transit District, resulting in 10-minute frequencies on core Boulder routes. Support to TDM programs includes approximately $175,000 million annually in subsidies to employers in the start-up phase of offering Eco Pass transit passes to employees (Roskowski et al., 2010).

The 1990 through 2006 shifts in active transportation mode use for trips by residents, for all travel purposes, total a 7.6 percentage point gain in the proportion of trips by active modes (from 28.9 percent to

36.5 percent), equating to a 26 percent increase. This breaks down into a 0.7 percentage point gain in walk trips (from 18.2 percent to 18.9 percent), equating to a 4 percent increase; a 4.5 percentage point gain in bicycle trips (from 9.1 percent to 13.6 percent), a 49 percent increase; and a 2.4 percentage point gain in transit trips (from 1.6 percent to 4.0 percent), a 150 percent increase. At the same time, SOV trips have declined by 5.8 percentage points (from 44.2 percent to 38.4 percent), a 13 percent decrease, while multi-occupant vehicle (MOV) trips have declined by 1.3 percentage points (from 26.3 percent to 25.0 percent), a 5 percent decrease (National Research Center, 2007). These data and corresponding summary statistics for other travel categories are displayed in Table 16-44.

Boulder is moving toward its objective of reducing SOV trips to 25 percent of all trips by 2025, but as of 2006 was falling behind in terms of rate of progress (National Research Center, 2007). The city updated its VMT calculations at about the same time, and determined it was "close to keeping VMT growth flat, in contrast to most of the Denver region" (Roskowski et al., 2010). Along the way, the total active transportation mode share has increased markedly in each travel category covered in Table 16-44.

In some categories the overall active transportation increases have been primarily thanks to growth in bicycling. In other cases they are mainly attributable to transit service and ridership growth (even countering bicycling declines for persons working in Boulder), and in still other cases to major bicycling and transit use increases together. Walking increases have not been universal across categories, and tend to be smaller, though the 53 percent increase in walk mode share for employee midday trips suggests that NMT system improvements are positively affecting employment areas as well as resident-based travel. Of particular interest is to compare the 5 percent growth in walk share for all trips by residents with the corresponding 23 percent walk share growth for all travel miles by residents. This suggests that residents are electing to make longer walk trips—a 17 percent growth in walk trip distance would explain the differential.

Difficulties in the 2006 survey with surveying CU students in group quarters reduced the usual student sample by about 40 percent (National Research Center, 2007). This circumstance casts uncertainty on the shift to bicycling from walking observed for 2006 relative to prior years. Using two different survey question approaches, a one-time 2005 UC survey obtained school commute shares for students of 24 to 27 percent walk, 18 to 21 percent bike, 26 percent bus, 7 to 15 percent multimodal, 10 to 11 percent SOV, and 2 to 3 percent MOV, with the remainder working at home, other, or unreported. These shares offer what seems to be a logical progression from prior findings. Together the data suggest perhaps a tripling in bus commuting since 1990, a halving of walking, and a slight decline in bicycling (National Research Center, 2006b and 2007). These shifts presumably reflect, in the main, expansion of bus service and the bus pass program along with changes in student residence patterns. The net proportion of student commuting via active transportation modes (taking multimodal trips into account) appears to be roughly the same in 2005, or slightly less, as compared to 1990.

The roles of Boulder's pedestrian and bicycle system growth and improvement, transit service expansion, TDM actions, land use and design strategies, and interactions among these program elements in effecting the mode shifts achieved are worthy of in-depth travel-model-based research. Lacking that, it is instructive to compute and examine—with due caution—some simple elasticity relationships based on supply (separations, paths, lanes) and observed demand (NMT mode shares). The data and calculations presented here pertain to all trip purposes combined, not solely work purpose trips.

Supply information for bicycle facilities is the more complete. Using a simple average growth for separations, paths, and lanes of 41 percent over 16 years, the 1990–2006 shift in resident bicycle mode shares from 9.1 to 13.6 percent produces a log arc elasticity of +1.17, a value that is both elastic (very sensitive) and substantially higher than other bicycle facility-extent elasticities available. If only shared use paths and bike lanes are considered, the simple average growth is 20 percent, and the associated elasticity is even higher at +2.2. Even the elasticity of +1.17 must be regarded as expressing the effect of bicycle facility expansion in a highly supportive programmatic context, which in Boulder's case includes the city's overall palette of actions in support of active transportation and vehicular travel minimization.

Pedestrian facility supply information for Boulder is less comprehensive, lacking sidewalk-extent growth quantification. Relying on a simple average 16-year growth for separations and paths (50 percent) as the supply measure, the 1990–2006 shift in resident walk mode shares from 18.2 to 18.9 percent produces a log arc elasticity of +0.09, positive but small. Considering only the growth in path extent (15 percent) changes the pedestrian share elasticity to +0.27, still inelastic but more substantial. Factors external to pedestrian system extent confound the analysis further. The expanding transit system has likely drawn ridership especially from the walk mode, making it notable that positive elasticities for walk mode shares are seen at all. Not in the travel data of Table 16-44 at all are the walk trips added by increased access and egress to the growing transit service, with its 1990–2006 increase in resident transit mode share from 1.6 percent to 4.0 percent.

Brisbane, Australia. In Australia, the "Brisbane Active Transportation Strategy" has addressed both walking and bicycling and tracked each over time. Australia shares with North America a historical reliance on the automobile that makes for less uncertainty in learning from their experiences than pertains with the transportation and land use differences encountered in most other overseas countries.

Development of Brisbane's system of off-road shared use paths and on-road bicycle facilities began in the mid-1980s. From 1995 to 2005, facility development—particularly local government components—was guided and supported by the "Bicycle Brisbane Plan." This was folded into the "Walking and Cycling Plan 2005–2010," to be updated every 5 years, and forms a part of the "Brisbane Active Transportation Strategy." The policy context of these plans includes the "Australia Pedestrian Charter," an outcome of a 1999 National Pedestrian Summit, and "Australia Cycling—The National Strategy," a product of visioning by the Australian Bicycle Council (Brisbane City Council, 2009b).

As a practical matter, the state government components (at least from the 1980s through the early 2000s) were the result of Main Roads internal agency initiatives which provided long lengths of cycle network along rivers and motorways without, and mostly in advance of, master-plan guidance. This state-level investment enabled local governments to direct resources into important missing links and connections (Davies, 2010).

The Brisbane shared use path system, from its mid-1980s start, had reached out roughly 12 km. (7-1/2 miles) from the CBD in one corridor by ca. 1995 and three corridors by ca. 2000. By the time the "Walking and Cycling Plan 2005–2010" was written, the total on-and-off-road bikeway network totaled over 550 km. (342 miles), serving in partnership with the city's more than 3,950 km. (2,454 miles) of sidewalks and other pedestrian infrastructure. By 2008–09, the bikeway network had passed the 760 km. (472 mile) mark, comprising 412 km. (256 miles) of off-road shared use paths and 348 km. (216 miles) of on-road bicycle facilities (Queensland Transport, 2007, Brisbane City Council, 2009a and b). In the earlier "Pedestrian/Bicycle Systems and Interconnections" subsection, under "Overall Systems and System Expansions," Figures 16-2 and 16-3 provide graphic illustration of 1986, 1996, and 2006 walk and bike mode shares from individual analysis districts to the CBD. Figure 16-3 also illustrates the growth of the off-road shared use path network infrastructure.

The mode share results for work purpose commuting to the Brisbane CBD and CBD fringe, from Figures 16-2 and 16-3, are summarized below in Table 16-45 with intervening years included. Further information on effects of opening the Goodwill Bridge component of the overall system is provided in the earlier systems and interconnections discussion under "River Bridges and Other Linkages."

Table 16-45 Work Purpose Trip Walk and Bicycle Mode Shares to the Brisbane CBD and CBD Fringe 1986–2006

		Bicycle Mode Share		
Year	**Walk Mode Share Overall**	**North**	**South & West**	**Overall**
1986	5.9%	0.5%	0.5%	0.5%
1991	7.1	0.9	1.2	1.1
1996	7.6	1.0	1.8	1.5
2001	10.5	1.9	3.1	2.5
2006	17.4	2.2	3.7	3.0

Notes: Data is for census journey-to-work trips to the Brisbane, Australia, CBD and CBD fringe from city and suburbs within roughly 6 km. (3-3/4 mile) of the CBD for walk trips and 12 km. (7-1/2 miles) of the CBD for bike trips.

The development of residential land uses within the CBD is thought to be a factor in walk mode share growth.

As of 2006 the north corridor, in contrast to the south and west corridors, still lacked complete, good quality, off-road, shared use path links the full distance to the CBD.

Sources: Queensland Transport, Transport Research and Analysis Centre (2007), Davies (2008).

European Programs and Comparisons

The countries of north-central Europe are often held up as examples of what can be achieved—in terms of walking and cycling prevalence—with well developed, long-running, supportive policies and programs. National-level mode share comparisons such as those in Table 16-46, together with information on policies and programs that go well beyond those normally encountered in the United States, provide the circumstantial evidence. All north-central European countries included in Table 16-46, for example, had reported ca. 1995 walk and bike mode shares that—combined—are 5 to 6 times higher than those found in the United States, including walk shares 3 to 5 times higher and bicycle shares 10 to over 25 times higher (Pucher and Dijkstra, 2003).[42]

[42] These comparisons are for ca. 1995, including use of the U.S. 1995 NPTS. Comparisons on the basis of the U.S. 2001 NHTS or 2009 NHTS, with their enhanced procedures for eliciting more complete reporting of walk trips, would show somewhat reduced differences for walk trip shares and combined walk and bike shares.

Table 16-46 Urban Area Walking and Bicycling Trip Shares in Various Countries, ca. 1995

Country	Walk Share	Bike Share	Total NMT	Bike Share ca. 2000
United States	6%	1%	7%	1%
Canada	10	2	12	2
England and Wales	12	4	16	1
France	24	4	28	3
Italy	24	4	28	n/a
Switzerland	24	10	34	6
Germany	22	12	34	10
Austria	28	9	37	5
Sweden	29	10	39	10
Denmark	21	20	41	18
The Netherlands	18	28	46	27

Note: Bicycle shares shown shaded and labeled "ca. 2000" are 1998-2005 except France and Austria, which are 1994-1995 (Pucher and Buehler, 2008b).

All data shown here are for purposes of illustrating approximate differences and "should not be used for exact comparisons" (Pucher and Dijkstra, 2003). The bicycle share discrepancy for Austria, originating from two different sources but both for 1995, illustrates the difficulty of working with travel demand data from different parts of the world.

Source: Data "ca. 1995," Pucher and Dijkstra (2003); data "ca. 2000," Pucher and Buehler (2008b).

A concern often expressed with such U.S.-European comparisons is that the dense urban conditions in many European cities simply cannot be found or reasonably anticipated in most American urban areas. Such issues lessen the utility of aggregate level cross-county comparisons. Stratification by demographic or trip characteristics provide, however, additional perspective. Table 16-47, for example, examines the proportion of female bicyclists in the United States and other countries. Cycling is clearly a gender-neutral activity in Denmark, Germany, and the Netherlands, relative to the United States and other countries with less emphasis on bicycling and bicyclist support policies. The inference here, although other explanations could theoretically be postulated, is that the comfort level of bicycling in the north-central European countries has been raised to the point that women are as attracted to bicycling as men (Pucher and Buehler, 2008b).

Table 16-47 Percentage of Bicycle Trips by Females, ca. 2000–2005

Country	Pct. Female Cyclists	Country	Pct. Female Cyclists
Australia	21%	Denmark	45%
United States	25	Germany	49
United Kingdom	29	Netherlands	55
Canada	30		

Source: Pucher and Buehler (2008b).

Examination of NMT mode shares for different age levels of walkers and bicyclists paints a comparable picture. Table 16-48, using older data that include the walk mode, illustrates that walking steadily increases with age in Germany and the Netherlands, while cycling holds more or less steady. This is in contrast to the United states, where walking dips with increasing age until it barely climbs back up at over age 65, while cycling drops precipitously. Again, the inference is that pedestrian and bicycle system quality and supportive enforcement policy, as provided by Germany and the Netherlands, make older persons as comfortable engaging in active transportation as those more youthful (Pucher and Dijkstra, 2003).

Table 16-48 Walk and Bicycle Trip Mode Shares by Age in Three Countries, ca. 1995

<table>
<tr><th colspan="4">United States</th><th colspan="4">Germany</th><th colspan="4">The Netherlands</th></tr>
<tr><th></th><th colspan="3">NMT Mode Share</th><th></th><th colspan="3">NMT Mode Share</th><th></th><th colspan="3">NMT Mode Share</th></tr>
<tr><th>Age</th><th>Walk</th><th>Bike</th><th>Total</th><th>Age</th><th>Walk</th><th>Bike</th><th>Total</th><th>Age</th><th>Walk</th><th>Bike</th><th>Total</th></tr>
<tr><td>16-24</td><td>7%</td><td>1%</td><td>8%</td><td rowspan="2">18-44</td><td rowspan="2">17%</td><td rowspan="2">10%</td><td rowspan="2">27%</td><td>18-24</td><td>12%</td><td>30%</td><td>42%</td></tr>
<tr><td>25-39</td><td>5%</td><td>0.5%</td><td>6%</td><td>25-39</td><td>13%</td><td>19%</td><td>32%</td></tr>
<tr><td>40-64</td><td>4%</td><td>0.3%</td><td>4%</td><td>45-64</td><td>23%</td><td>9%</td><td>32%</td><td>40-64</td><td>14%</td><td>22%</td><td>36%</td></tr>
<tr><td>≥65</td><td>6%</td><td>0.2%</td><td>6%</td><td>65-74</td><td>39%</td><td>11%</td><td>50%</td><td>65-74</td><td>19%</td><td>25%</td><td>44%</td></tr>
<tr><td></td><td></td><td></td><td></td><td>≥75</td><td>48%</td><td>7%</td><td>55%</td><td>≥75</td><td>24%</td><td>24%</td><td>48%</td></tr>
</table>

Source: Pucher and Dijkstra (2003) with totals added.

Perhaps the most direct countering that has been offered for arguments that higher bicycling shares in north-central Europe relative to the United States are primarily attributable to higher urban densities and correspondingly shorter trips is based on comparison of mode shares stratified by trip length. Table 16-49 presents bicycle share percentages for three categories of short to medium trip length. Within all three individual categories, bike shares are an order of magnitude higher or more in Germany, Denmark, and the Netherlands than in the United States (Pucher and Buehler, 2008b).

Table 16-49 Bicycle Mode Shares by Trip Length Category in Five Countries, 2000–2005

Country	Bike Shares for Trips of 0-2.4 Km. (0-1.5 Mi.)	Bike Shares for Trips of 2.5-4.4 Km. (1.6-2.7 Mi.)	Bike Shares for Trips of 4.5-6.4 Km. (2.8-4.0 Mi.)
United States	2%	1%	0.4%
United Kingdom	2	1	1
Germany	14	11	7
Denmark	27	24	15
The Netherlands	37	37	24

Source: Pucher and Buehler (2008b).

There is, however, a key limitation to comparisons made on the basis of trip length across differing urban development patterns that will require further research to resolve. In many cases short trips, and thus seemingly obvious active-transportation candidates, are in fact components of much longer tours. An auto may be needed for the full tour even if individual links within the chain of trips are seemingly short enough for walking or bicycling (Schneider, 2010). In research on San Francisco Bay Area tours involving a pharmacy-shopping stop, high average walk mode shares (80 and 76 percent) were found to be sustained only up to tour lengths of 1.0 mile. Walk share then declined sharply with tour length, until beyond 3.0 miles the walk share was down to 4 percent (Schneider, 2011). A brief exposition is provided in the "Underlying Traveler Response Factors" section (see "Trip Factors"—"Walk Trip Distance, Time, and Route Characteristics"—"Walk Trip Speeds and Lengths").

NMT policies and programs seen in countries such as the Netherlands, Denmark, and Germany were implemented following an extended period, roughly from 1950 to 1975, when bicycling shares plummeted. Approaches used in response, to make walking and cycling as attractive as it is today, include the following (Pucher and Dijkstra, 2003, Pucher and Buehler, 2008a and b).

- Pedestrian system enhancements (such as pedestrian zones, often encompassing much of the city center in larger cities, and well-lit sidewalks on both sides of streets).
- People-oriented urban design (with mixed land uses and a fine mesh of local streets—often traffic calmed—with non-vehicular shortcuts, providing NMT connectivity without use of busy arterials).
- Bike paths and lanes (mileage in the Netherlands and Germany doubled between the mid-1970s and the mid-1990s).
- Ample and secure bicycle parking (by ordinance in private buildings, plus extensive public and train station bicycle racks and parking, often guarded: 24,600 bike and ride parking spots in the Berlin region in 2005, for example, at metro, suburban, and regional rail stations).
- Integration with public transit (copious bike parking as described above, plus amenities such as bike rentals at major stations—taking bikes on board is generally limited to trains, off-peak, for a fee).
- Promotion (including route/path numbering, color coding, signage, and maps; bicycling websites with trip planning options; neighborhood ambassador programs; and festivals, competitions, and awards).
- Discouragements to private vehicle use (access restrictions, city speed limitations, parking management, allocation of capacity to NMT and public transit, and high auto and fuel fees and taxes).
- Safety and confidence-building measures including pedestrian crossing and intersection improvements, traffic calming, education, training, and favorable traffic regulations with strong enforcement (for more see "Related Information and Impacts"—"Safety Information and Comparisons"—"Foreign Versus U.S. Safety Comparisons").

Schoolchild-Focused Programs

The first national-scale SRTS program was established in Denmark in 1976 (Zhou et al., 2009). U.S. SRTS Program activity began in the late 1990s and was initially, aside from California and Florida state-level programs (and some unofficial grass-roots efforts), a local or pilot study endeavor in maybe three or four locales. The initial California statewide program (which used the acronym SR2S, not employed here) is of particular importance because of its reporting of effects on school travel choices of NMT infrastructure improvements including sidewalks and street crossing enhancements. The Florida studies dealt with safety but did not examine travel choice impacts (Moudon, Stewart, and Lin, 2010).

U.S. schoolchild travel data from the 2009 NHTS indicate continuation since 2001 of a long-established downward trend in school access via NMT. In 1969, 40.7 percent of U.S. children traveled to school by walking or bicycling. In 2009, only 10.2 percent of children reached school independent of vehicle use, a quartering of NMT school access in 40 years (Kuzmyak et al., 2011).

The primary school-focused active transportation program effort in the United States is now the national SRTS program. Nation-wide federal involvement and funding was legislated in August, 2005, following two SRTS pilot applications. Funding distribution is by the Federal Highway Administration (FHWA), to individual state departments of transportation (DOTs), for purposes of improving pedestrian and bicycle infrastructure in the vicinity of schools, providing safety education, and encouraging walking and cycling for school access. State DOTs in turn award program funds to localities, over 4,000 of them as of December, 2008. In late 2009, 6,500 schools were participating (ITE, 2008, Marchetti, 2010).

SRTS federal program goals include making walk and bike access to schools safer and more appealing, enabling and encouraging children to use walk and bicycle travel modes, and facilitation of projects to improve safety and reduce school-vicinity traffic and associated fuel consumption and air pollution. Typical infrastructure projects have included improvement of sidewalks, crosswalks, and signage. Program involvement has benefited from topical concerns about childhood inactivity, traffic safety, pollution, and desire for community involvement, all of which are addressed by the program (ITE, 2008).

The U.S. federal SRTS program is not—as of this writing—at a stage where results can be gauged at a broad-based national level (Moudon, Stewart, and Lin, 2010), although an evaluation plan has been published (National Center for Safe Routes to School, 2011). Various "case studies" covering programs at individual schools have been made available. These briefs mostly focus on programmatic aspects, providing "success stories" for encouragement and guidance by example, without pretense of scientific sampling or complete technical analysis. A few provide outcome data sufficient to gauge, with caution, basic travel behavior shifts obtained. These primarily U.S. snapshots are discussed here in conjunction with foreign experience that lends more depth to cohesive review of "soft measure" encouragement program SRTS experience, especially experience with walk-trip or mileage-tracking incentive programs, "walking school buses" (WSBs),[43] and "cycle trains" (CTs).[44] Results for individual U.S. and foreign SRTS programs illustrative of school travel choice outcomes are summarized in Table 16-50.

[43] A walking school bus (WSB) is an adult-accompanied group of children who walk to/from school along a pre-arranged route with set departure times, picking up or dropping off other children at "bus stops" along the way. The route may start from within a neighborhood or at a parking lot that can be used as a drop-off point by parents coming from longer distances. The WSB, which may be formal or informal in its arrangements, is escorted by one or more adult volunteers according to group size and ages, typically with one adult at the front (the "driver") and one at the rear (the "conductor") (Mackett et al., 2005b; Pedestrian and Bicycle Information Center, 2011).

[44] A cycle train is similar to a WSB in concept and operation except that the adults and children are on wheels instead of walking. CT formation and operation is generally tied in with an at-school safety check and instruction session, sometimes supplemented with formal on-road training. A CT may have one or more adults, but typically includes one adult at the front (the "engineer") and one at the rear (the "caboose"). It is sometimes required that children in early grades be accompanied one-on-one by a parent or surrogate (O'Fallon, 2007; Pedestrian and Bicycle Information Center, 2011).

Table 16-50 Summary of Research Findings on Programs Seeking to Increase Grade School through Middle School Student Use of Non-Motorized Travel

Study (Date)	Program (Analytical Process)	Key Findings
1. Boarnet et al. (2005a) (see this section for more information)	SRTS sidewalk, traffic control, and crossing improvements were made within ±1/4 mi. of 10 studied California elementary schools. (Surveys distributed by teachers asked parents of 3rd through 5th graders if their children were walking/biking more to school relative to prior to the improvements. Children who would not be walking via improvements served as control subjects.)	Parents whose children passed via SRTS projects were more likely to report walk/bike increases (15%) than control subjects (4%). Roughly 1/2 passed a project. Increases by project type were sidewalks, 17% vs. 3% for control subjects; traffic signals, 16% vs. 4%; and crossing improvements, 12% vs. 6%. For reasons unknown, reported decreases were higher (18%) but differed little by walk route class.
2. Boarnet et al. (2005b) (see this section for more information)	Same program as described above. (Counts were made 2 days running of walking children at project sites, before and after improvement. At the sidewalk improvement sites, counts separately identified children walking on the street or shoulder.)	After-sidewalk-improvement counts showed a weighted average 5-site 46% increase in walking, with about an 82% reduction in the proportion walking in the roadway. After-signalization counts showed an average 2-site 24% increase. Crossing improvement site counts were, overall, inconclusive.
3. Marchetti (2010)	Auburn School District in Washington State received $306,000 in state/-federal funds through 2006 for sidewalks, bike lanes, other improvements. ("Success story" reporting.)	Student transportation costs avoided amounted to $220,000 in annual savings. For example, walking and bicycling reduced school buses needed at one of the schools from six to one.
4. Staunton, Hubsmith, and Kallins (2003) (see this section for more information including additional examples)	The Marin County, CA, 1st/2nd year SRTS program was a broad menu of outreach, route mapping, education, group walking and cycling, and incentives. (Fall/spring 2000-2002 classroom show-of-hands surveys by volunteers, 3-day averages.)	Fall 2000 to Spring 2002 before and after results, for the surveyed portion of the 9 to 15 participating public schools, included 21-month shifts as follows: walking to school up 64%, bicycling up 114%, carpooling up 91%, single-student-occupancy private vehicles down 39%.
5. McKee et al. – 2004 as summarized by Ogilvie et al. (2007)	Multifaceted school-based information/promotion intervention in Scotland including maps, workbook, goals, and parent/teacher guidance. (Non-randomized controlled trial.)	Distance walked on school commute increased after 7 weeks by 555 meters (1/3 mile). (Study validity score 4-out-of-7 quality evaluation criteria met).
6. Rowland et al. – 2003 as summarized by Ogilvie et al. (2007)	School travel coordinator interaction and travel plan assistance at parent/teacher level in London schools, 16 hours/school per school year. (Randomized controlled trial.)	At 14-month follow-up 70% of London schoolchildren at schools with the program were walking to school as compared to 71% for control group schools. (Validity score 4-out-of-7 quality evaluation criteria met).
7. TAPESTRY – 2006 as summarized by Ogilvie et al. (2007)	Local school travel campaign linked with UK "Walk to School Week." (Controlled repeated cross-sectional analysis with nested cohort; validity score 2-out-of-7 criteria met).	The proportion of children walking to school at least once a week increased from 75% to 76% in schools with the campaign versus a 78% to 77% change for control schools.

(continued on next page)

Table 16-50 (Continued)

Study (Date)	Program (Analytical Process)	Key Findings
8. Pedestrian and Bicycle Information Center (2011)	Morton Way [elementary] School in Brampton, Ontario, has 6 years of experience with Walk-to-School-Week, Walking Wednesdays (with WSBs), and student walk-tracking cards with rewards and recognition. ("Success story" reporting.)	Of 870 students, 96% live within walking distance. In 1999 almost half were regularly driven to school. Six years later 80% to 95% walk, cycle, scooter, or blade on Wednesdays. Auto drop-offs are down other days also, with overall averages down from 75 to 55 drop-offs.
9. Pedestrian and Bicycle Information Center (2011)	Lytchett Matravers Primary School, Dorset, England, launched a "Passport to Health" incentive involving 400-plus children. Passports are stamped each day for distance walked. ("Success story" reporting.)	A 16% increase in walking/cycling rates and an 18% drop in school area motor vehicle use have been measured. Walking from auto drop-off points a specified distance away counts, as does walking measured distances at school.
10. Mackett et al. (2005b) (see this section for more information including additional examples)	WSBs were set up to serve nursery school through grade 6 in multiple Hertfordshire County, UK, schools; first WSB established in 1998. (May 2002 survey of schools with and without WSBs, and of individual WSBs; 5 WSB case studies with 3 to 4 interview cycles over 21 months in 2002-03; descriptive analysis).	Numbers of WSBs were 1 in early 1998, 68 in Jan. 2002, and 26 in Jan. 2003. Of children covered by mail survey, 62% "used to travel by car" but this was a likely overstatement. Among WSBs disbanded (of 12 surveyed), 9 reported lack of volunteers; 5, too few children; 3, lack of coordinator; 1, bad weather; and 1, lack of incentives.
11. Johnston et al. – 2006 as summarized by Moudon, Stewart, and Lin (2010)	At an inner-city Seattle public school with a baseline walk-to-school rate of 19%, 3 WSBs were implemented. (Physical activity research, 2 nearby schools used as controls.)	The walk-to-school rate rose to 26% (a 37% increase), attributed mostly to walking with an adult. Parent involvement in the school rose. The 2 control schools had a decline in walking.
12. O'Fallon (2007) (see this section for more information including additional examples)	In late 2006, prior to 2-mo. summer break, 7 CTs were set up at 4 schools in Nelson, New Zealand (pre-start survey; interviews 10 weeks after start with child, adult, trainer, and administrative participants; 5-month follow-up; qualitative analysis).	Of 95 students indicating interest, 34 joined the CTs (2% of the combined student body). CT size was 2 to 7 children, aged 7 through 11. After summer break substantial CT/WSB turnover took place, including schoolchild "graduation" from WSBs to CTs.

Note: Where substantial additional information on individual studies is provided in accompanying text and tables this is noted in the first column.

Sources: As indicated in the first column.

Infrastructure and Traffic Engineering Improvements. Physical improvements to pedestrian and bicycle infrastructure as part of SRTS programs are more commonly found in U.S. programs than overseas. Given the lead time involved in such improvements, available analyses of results are largely limited to SRTS projects preceding the U.S. federal program. Research analyses of the initial California statewide program thus fill a critical gap (Moudon, Stewart, and Lin, 2010). These California studies link SRTS travel outcomes directly to specific types of infrastructure improvement and traffic engineering solutions, generating information rarely encountered elsewhere. The California legislation was signed in 1999, and in the first two rounds of funding, improvements were made at 186 sites (Boarnet et al., 2005a, Boarnet et al., 2005b).

The first rounds of projects and studies accomplished under California's SRTS program focused on engineering solutions designed to increase safety and encourage walking and cycling on routes to school. Elementary schools with projects within or close to 1/4 mile of the school were selected for study. The convenience sample of ten schools reflected the practicalities of achieving study timing in sync with project completion and school willingness to participate. The studies are included in Table 16-50 as the 1st and 2nd entries. School population characteristics ranged from Hispanic-dominant to white-majority, with median household incomes from $23,500 to $101,000. Of the ten schools studied, five received sidewalk improvements, two received traffic signals replacing four-way stop signs, and three received crosswalk improvements ranging from two varieties of in-pavement crosswalk lights to one instance of adding countdown pedestrian signal indications.

Two approaches to determining effects on walking and cycling prevalence were employed. One involved asking parents—in a second survey following SRTS project completion—if they believed their children were walking or bicycling more, less, or about the same relative to before the improvements. Surveys were distributed by teachers of 3rd through 5th graders. Children who would logically be walking or biking via improvements were considered to be the affected students, and those who would not be passing the improvements served as control subjects (Boarnet et al., 2005a, Boarnet et al., 2005b). The other approach was to take before and after counts, two days each, of child pedestrians and bicyclists at the improvement sites. In application, it was not always possible to separately identify the students of the ten schools in question—all children observed were counted (Boarnet et al., 2005b). Perhaps of greater concern is lack of reporting on seasonality of the counts.

Table 16-51 consolidates the results of both study approaches for each of the ten schools studied. Not shown is the circumstance that an average of 18 percent of parents perceived that their children were walking or cycling less than before. Reasons for this were unclear, but may have been related to a highly publicized daylight abduction of a southern California 5 year old. In any case, the decreases were fairly uniform across affected versus control groups of students, and thus were not included in individual project "walk/bike more" calculations.[45] (Overall, 17.5 percent of children with a project along their route and 18.6 percent lacking a project along their route were reported to walk or bike less.) It is also instructive to note that despite the net loss one would calculate taking the "walk/bike less" reports into account, the actual pedestrian counts almost all showed increases in walking activity (Boarnet et al., 2005a).

[45] An extended analysis is available that did separately examine the "walk/bike less" results for the "project enroute" and "not enroute" subgroups. The only substantive effect on findings was to render the survey results for the Murrieta school sidewalk project inconclusive (Boarnet et al., 2005b).

Table 16-51 SRTS Project Results at Ten California Schools as Derived from Two Study Methodologies

Location of School (City in California)	Type of Improvement	Survey Results: Walk/Bike More			Count Results: Amount of Child Walking		
		Project En route	Not En route	Difference	Before Project	After Project	Difference
El Sobrante	Sidewalk gap closures	15.6%	0.0%	+16%	138	152	+10%
Yucaipa	Sidewalk gap closures	11.6%	0.0%	+12%	64	89	+39%
Fontana	Sidewalk gap closures	28.6%	7.4%	+21%	692	1146	+66%
Malibu	Edged gravel pathway	6.7%	0.0%	+7%	274	302	+10%
Murrieta	New sidewalks	13.7%	2.4%	+11%	2	19	+850%
Bell Gardens	New traffic signal	20.6%	6.2%	+14%	1701	2047	+20%
Chino	New traffic signal	10.9%	0.0%	+11%	143	250	+75%
Glendale	In-pavement x-walk lights	12.0%	7.7%	+4%	n/a	974	n/a
Alta Loma	In-pavement x-walk lights	3.1%	0.0%	+3%	51	57	+12%
San Bernardino	Pedestrian countdown signal indications	19.0%	5.7%	+13%	193	137	-29%

Note: Survey results presented here are as set forth in Boarnet et al. (2005a).

Sources: Boarnet et al. (2005a) and Boarnet et al. (2005b).

All results reported in Table 16-51 are in the expected direction, that of more walking and cycling to school, except for the count results at the San Bernardino countdown-signal location. Not all differences reported are statistically significant, however, and consideration of "walk less" survey results rendered the Murrieta school survey findings inconclusive.

Overall, parents whose children had sidewalk projects en route reported walking and cycling increases 17 percent of the time, or 14 percent adjusted to deduct frequency of increases reported by the pertinent control group parents. The weighted average pedestrian count increase was 46 percent for the five sidewalk improvement sites, and the proportion of children walking in streets and on shoulders was reduced by about 82 percent overall. Taking statistical significance and related factors into account, the three sidewalk gap closure projects were demonstrably successful in achieving objectives. The two projects involving a new path or sidewalk exhibited more limited (Malibu) or no (Murrieta) evidence of success from a statistically rigorous perspective (Boarnet et al., 2005a, Boarnet et al., 2005b).

The two replacements of four-way stop signs with full traffic signals both demonstrated statistically sound evidence of success in improving driver yielding to pedestrians, but mixed evidence regarding speeds. The increases in walking were consistent but did not reach statistical significance guidelines. Parents whose children encountered the sites en route reported walking and cycling increases 16 percent of the time, or 12 percent adjusted to reflect control group responses. The weighted average pedestrian count increase was 24 percent for the two signalization projects.

At the three sites with crossing improvement projects, parents with children passing the sites en route reported walking and cycling increases 12 percent of the time, but adjustment to reflect control group responses lowers the increase to only 6 percent. Neither walking increases nor pedestrian count changes were statistically significant, with before-count problems at the Glendale site a factor, along with a pedestrian count decrease observed at the San Bernardino site. Improved driver yielding was anticipated at the sites gaining in-pavement crosswalk light installations, and did occur, with statistical significance in one instance (Boarnet et al., 2005a, Boarnet et al., 2005b).

Not included in the tabulations or discussion above are a painted and signed crosswalk installation as part of the overall Yucaipa project and installation of on-street bicycle lanes at the Murrieta school. The standard crosswalk installation produced no significant effects, although modest increases in yielding were observed. Bicyclist volumes before and after the bicycle lanes installation were 4 and 14 cyclists, respectively, numbers too low for making inferences (Boarnet et al., 2005b).

The 3rd entry in Table 16-50, pertaining to the Auburn, Washington, SRTS program, provides in essence a footnote to the California studies of engineering solution outcomes. State-level pilot project funding by the Washington State Department of Transportation (WSDOT) allowed construction of sidewalks and walking paths, placement of curbing at crosswalks, installation of four-way stops and also bike lanes, and signage that marks pedestrian-friendly routes. These actions have been accompanied by educational outreach, including a physical education curriculum in many elementary schools that offers "bonus point incentives for walking to school." With subsequent federal SRTS program elements beginning to come on line, 20 percent of the school district's children were walking to school. The one before-and-after measure available is the transportation (school-bus) expenses of the Auburn School District. The cost has been reduced by $220,000 annually, 80 percent more than the one-time pilot state grant alone, and equivalent to 72 percent of the total state and federal grants (the latter only partially implemented) through 2007 (Pedestrian and Bicycle Information Center, 2011).

Multi-faceted Encouragement Programs. Preliminary U.S. SRTS federal involvement started in 2000 with two pilot programs, one in Arlington, Massachusetts, and one in Marin County, California. Both were programs relying primarily on multi-faceted walking-and-bicycling-to-school encouragement for inducement of shifts to NMT modes of school access.

The Arlington pilot program (not entered in Table 16-50) focused on safety fixes, safety training, encouragement including "frequent bicyclist/pedestrian cards," and WSBs. One report indicates that the *proportions* of children walking to participating schools in Arlington after 2 program years were 56 percent for elementary schools and 24 percent for middle schools, versus 42 percent and 19 percent, respectively, beforehand. Other reporting gives the walking *increase* at the two involved elementary schools as 10 and 12 percent, and at the participating middle school as 6 percent, representing a three-school total walking-trip-per-day increase of 213 (National Safe Routes to School Task Force, 2008, National Center for Safe Routes to School, 2010).

The formal Marin County pilot program and evaluation (see 4th Table 16-50 entry) covered 2000 through 2002, the first and second school years of Marin's SRTS Program. The urbanized portion of Marin County consists primarily of middle- and upper-class suburbs north of San Francisco's Golden Gate. The broad menu of actions included outreach and assistance to the schools and communities, volunteer walking and mapping—with professional assistance—of safe pedestrian and bicycle routes to each school, improvements suitable for short-term implementation, materials and tools for volunteers, WSBs, CTs, various events and promotions, performance-based rewards and contests for the children, and classroom education addressing safety, transportation choices, environmental implications, and health. Substantial infrastructure needs were identified and remedial funding was obtained (Staunton, Hubsmith, and Kallins, 2003), but it appears that the two pilot program years necessarily focused on "soft" program elements plus crosswalk and signage improvements.

The 2000–2001 program covered nine schools and about 3,500 students, while the 2001–2002 program covered 15 schools and 4,665 students. The program expanded to 21 schools with 7,609 students the next school year, out of a Marin County total of about 34,000 school-age children. Elementary and middle schools were involved, including a few private schools. A volunteer approach to running of the surveys resulted in use of a "convenience" sample. Of involved schools, 1/2 to 2/3 were surveyed, not including all classrooms. Only two schools surveyed in 2000–2001 were surveyed again in 2001–2002. On the plus side, the overall survey findings and outcomes for those two schools were found to be similar. Volunteers took shows of hands—covering travel modes used that morning—for 3 days running during each survey. An average was calculated for each set of 3-day results, fall and spring. Mode share findings are summarized in Table 16-52 (Staunton, Hubsmith, and Kallins, 2003).

Table 16-52 Marin County, California, 2000–2002 Student School Trip Mode Shares

Travel Mode	Fall 2000	Spring 2001	Fall 2001	Spring 2002
Walk Share	14%	22%	18%	23%
Bike Share	7%	11%	12%	15%
Carpool Share	11%	18%	15%	21%
Driven Alone	62%	44%	53%	38%
Schools Surveyed	6	6	7	7
Students Surveyed	1,743	1,756	2,097	1,611

Notes: School bus shares are not shown.

Only two schools were surveyed continuously (first and second years).

Source: Scaled from Figure 1 in Staunton, Hubsmith, and Kallins (2003).

Mode shifts between the fall of 2000 and the spring of 2002 led to a reported 64 percent increase in walking to the surveyed schools, a 114 percent increase in bicycling, a 91 percent increase in carpooling (two or more students driven by an adult), and a 39 percent decrease in single-student private vehicle arrivals (Staunton, Hubsmith, and Kallins, 2003). Table 16-52 illustrates that bicycling grew steadily through all four surveys, but that the pattern for walking, carpooling, and single-student private vehicle arrivals suggests some regression away from active modes and carpooling over the summer. The import of this is not clear, because so many new schools joined the program the second year. In any case, the two fall surveys taken together indicate year-to-year progress in all environmentally friendly travel mode categories, as do the two spring surveys. The pair of fall surveys and the pair of spring surveys suggest a 29 percent (fall) or 5 percent (spring) 12-month growth in walking share, a 71 percent (fall) or 36 percent (spring) growth in cycling share, a 36 percent (fall) or 17 percent (spring) growth in carpooling share, and a 14 percent decline (fall and spring) in the share of children driven alone.

The Scottish multifaceted information and promotion program summarized as the 5th entry in Table 16-50 seems comparable to the Marin County pilot program, and similarly had positive results. The outcomes apparently reflect parental willingness to let children walk farther to school with the information, guidance, and encouragement offered (Ogilvie et al., 2007).

Encouragement Coordination and Campaigns. The United Kingdom school travel coordinator and "Walk to School Week" studies (6th and 7th entries in Table 16-50) are of special interest in that rather than being "success stories" they are statistically evaluated trials of these two approaches. As can be seen in the tabulation, these particular travel coordinator and walk to school week applications appear to have been lacking in efficacy (Ogilvie et al., 2007). They were, of course, only one study each, and transferability to U.S. conditions of much lower ambient walk-to-school rates may be open to question. In areas where walking or bicycling to school is practically non-existent, walk-and-bicycle-to-school-day types of activities may serve to move parents/children from the "pre-contemplation" to the "contemplation" stage of school-access mode-shift decisionmaking, and to address inertia and fear of the unknown during the "contemplation," "preparation," and "action" stages. (The stages referred to here are presented in the "Attitudes and Modal Biases" discussion of the "Other Factors and Factor Combinations" subsection, within the "Underlying Traveler Response Factors" section.)

For example, prior to Spartanburg, South Carolina's SRTS safety education program (not entered in Table 16-50) and activities such as "Walk and Bicycle to School Day," "Walking Wednesdays," and traffic law enforcement, "few parents had even thought of letting their child walk to school" (Pedestrian and Bicycle Information Center, 2011). Similarly, before institution of "Walk and Roll to School Day" and a cycle train at Mason Elementary in Duluth, Georgia, "bicycling to school was unheard of at Mason" (National Center for Safe Routes to School, 2010). Incentives can also help put meat on bare-bones education and encouragement programs. At Alpine Elementary School, Alpine, Utah, in the school district with the lowest funding in the nation, a meals for miles encouragement program was included and small-scale infrastructure improvements were made. Relative to a student population of 780, the number of students walking/bicycling to school increased by 118 and the number of motor vehicles decreased by 59, on average (Marchetti, 2010).

Walking Tracking and Recognition. Morton Way Public School in Brampton, Ontario, Canada (8th entry in Table 16-50), has 6 years of experience with various special-day and special-week programs in support of walking and cycling to the elementary school, including "Walking Wednesday" WSBs. Perhaps most important, however, is the student body use of "IWALK" club cards to track number of days walked, and the individual receipt of small rewards and recognition at 10 and 50 walk thresholds. Positive Wednesday and all-week results were summarized in Table 16-50 (Pedestrian and Bicycle Information Center, 2011).

Another SRTS program example with a tracking-and-reward-theme comes from the Lytchett Matravers Primary School, Dorset, England (9th entry in Table 16-50), where a child's "Passport to Health" is stamped each day according to zones walked (a rough measure of distance). A 16 percent increase in walking/cycling rates is reported. A mileage tracking scheme worthy of note, even though conventional traveler response information is lacking, is that of the Maurice Cody Public School in Toronto (not entered in Table 16-50). The students pool their mileage and "walk" across a map with it. In the 2003 school year they "walked" across Canada from Toronto, then down the continent, "reaching" the Panama Canal (Pedestrian and Bicycle Information Center, 2011).

A Boulder, Colorado, SRTS program at the Bear Creek Elementary School (not entered in Table 16-50) has included both a role-model oriented ongoing challenge to students and at least three WSBs, along with intersection safety improvements and repair of a trail bridge serving the school. The challenge—to walk, cycle, and rideshare more to school—is backed up with monthly tracking sheets and recognition. Of students, 67 percent live within 2 miles of the school. Before any SRTS activities, 25 percent walked or biked. A tally at the onset of federal funding found 41 percent of students reporting walking or bicycling to school. After 2 years of the program 70 percent were making walking or cycling "a daily habit." A city study found a 36 percent vehicular traffic reduction, presumably in the school vicinity, after 1 year (National Center for Safe Routes to School, 2010).

Walking School Buses. Many WSB implementations have been made as part of multifaceted programs such as a number of those discussed above. Multi-pronged approaches appear to be reasonably effective, but make assessment of individual components (such as WSBs) difficult. The research conducted in Hertfordshire, England (10th entry in Table 16-50), is thus of particular interest, both for its focus on WSBs and for its multi-year county-wide and case study WSB tracking. The basic research parameters are given in the table.

At the core of the research was in-depth case study of five WSBs, three part of the Hertfordshire County SRTS program, and two outside that initiative. In addition to timing and mapping of each route, and observations of implementation-stage meetings, there were four stages of interviews covering the head teacher, the WSB coordinator, and participating parents and children. Entering students at two of the schools were above average in attainment while students at the other three schools were average in ability. One school had a significant ethnic minority population and 60 special needs students, while another had 17 percent from homes where English was not the first language.

The first Hertfordshire WSB was implemented in early 1998. A Department for Transport survey in 2001 found that 50 of 102 local authorities had by then started one or more, while another 31 had WSBs in the planning stage. The number of actually registered WSBs apparently peaked around January of 2002 with 68 at 41 schools. A year later there were 26 at 23 schools. A May 2002 survey mailed to the head teacher of each involved school received 26 responses (three partial), some covering WSB routes that had already been withdrawn. Most WSBs were 5 days a week, but all except one were morning only (Mackett et al., 2005b).

Average numbers per WSB, in May 2002, were three to four adults with 11 children in active WSBs and 10 children in WSBs that had been disbanded, giving an average of one adult for each three children. The WSBs were operating under recommendations that nursery-age children be accompanied by one adult per two children, that older children up through second grade have one adult per four children, and that children in grades 3 through 6 be accompanied at a one to eight ratio. Ages were obtained for children interviewed as part of the case study research. Age distributions were affected by the nursery and school grades covered in the individual schools. Among the 94 interviewed children the age range was from 4 to 8 years, excepting one child of age 3. The average age was 6-1/2 and the median age was 7. The gender distribution was 53 percent girls.

Route lengths of the five case study WSBs, including an unofficial extension of one, ranged from 897 meters (0.56 miles) to 1,154 meters (0.72 miles). Time actively spent walking ranged from 13 to 17 minutes, and total time including stops was from 14 to 21 minutes. There were from two to five (later reduced to four) “boarding” locations, although most children joined the WSB at its outermost point. The mail survey probed school objectives. Three objectives were reported by more than two schools each: 20 schools sought “to reduce congestion at the school entrance,” 12 had an objective “to give the children more exercise,” and seven others “to increase walking to school.” The perceived success rates in meeting these objectives averaged 60, 79, and 50 percent, respectively (Mackett et al., 2005b).

The mail survey found an average 62 percent of children in WSBs “used to travel by car.” The case study interviews suggest, however, that this percentage is likely simplistic and probably an overstatement. The case study interviews found the previous mode to school was often a mix of trips by car and trips made by walking. Furthermore, WSB users were not using their WSB everyday it operated, and sometimes were driven to school. Some, for example, used it only 1 day a week. Taking these factors into account, the researchers estimated that the effective shift from auto use averaged 26 percent for the five case study WSBs.

Both the previous mode to school and the alternate mode used on days the WSB was not joined were examined by frequency of use. There did not seem to be a strong relationship to WSB use frequency. Overall, for the 66 case study schoolchild WSB users for whom prior mode information was obtained, 26 percent were previously driven consistently, 21 percent had been driven some days and walked others, and 53 percent had walked consistently. Among the 42 schoolchild WSB users reporting they were not daily users, 31 percent were driven on days they did not join the WSB, 21 percent reported a mixture of being driven and walking, and 48 percent reported walking independent of the WSB (but not necessarily unaccompanied) as their alternate mode. Considering that about 3/4 of auto drop-offs were made in combination with other auto trip making, it was judged by the researchers that "even where the walking bus has had an impact on [. . .] the number of cars around the vicinity of the school, the actual impact on [overall] car use may be negligible" (Mackett et al., 2005b).

For 64 out of the 73 interviewed case study WSB children it was possible to compute the additional walking achieved, making use of the information on prior modes, alternate modes, frequency of use per week, and distance data. The average additional walking amounted to 513 meters (0.32 miles) per day. This average includes days the WSB is not joined and reflects the morning-only operation of most Hertfordshire WSBs. The average walking speed was calculated to be 4.2 km/hour (2.6 miles per hour). The added distance thus equated to 36 minutes of additional walking per week.

The additional walking varied considerably according to the mode of travel used previously. Children who had consistently walked before joining the WSB gained an average of only 19 meters (62 feet) of walking per day. Children with a mix of modes in the prior condition averaged 309 meters (0.19 miles) per day, while children who were consistently driven to school before joining their WSB gained an average of 1,549 meters (0.96 miles) of walking per day, almost a full mile "and a very useful volume of physical activity for a child who previously traveled by car." Perceived benefits of the WSBs went beyond exercise gained, however. Other institutional and personal benefits included the making of "a public statement of the benefits of walking" and a chance for interaction among children of different ages and between children and adults other than teachers or family (Mackett et al., 2005b).

The WSB lifecycle pattern observed in Hertfordshire indicates that to be successful, a WSB program must be cognizant of the forces leading to WSB discontinuation and be prepared with strategies to avoid or remediate this outcome. A key WSB characteristic to be dealt with is the high turnover of children and, correspondingly, volunteers, a characteristic seen not only with the Hertfordshire WSBs but also with the Nelson, New Zealand, CTs examined below. Among the five Hertfordshire case study WSBs, the newest one grew throughout the study, but the other four shrank, with one being disbanded. Table 16-53 illustrates the turnover of children for each of the case study WSBs, as observed over four school terms (2 years).

Table 16-53 Turnover of Children on Each of Five Hertfordshire, England, Walking School Buses (WSBs) Over Four School Terms

Walking School Bus	Date of Launch	Number of Children at Launch	Children Leaving and Joining during Term: Spring Term '02	Autumn Term '02	Spring Term '03	Autumn Term '03	No. of Children at End of 2003
Hillshott	May 2001	15	-8, +7	-6, +1	-1, +2	-5, +3	8
Layston	Nov. 2001	26	-8	-4	+1	-12, +2	5
Lordship	June 2002	16	(pre-launch)	-1, +14	-6, +4	-6, +10	31
Mandeville	Sept. 2002	15	-1	-6, +4	-8, +2	-1	5
Millfield	Nov. 2001	29	-14	-7, +4	-12	(closed)	0
Net Total [a]		101	61	76	58	49	49

Note: [a] Number of children total on the five WSBs at launch, at end of term, or at end of 2003.

Source: Mackett et al. (2005b).

The experience with the five Hertfordshire case study WSBs tracked in Table 16-53 was actually better than the county-wide experience delineated in Table 16-50. The interviews illustrated that in the early stages of a WSB many leave because of finding it does not meet expectations or fit with the family schedule. In later stages reasons pertain more to external factors such as a job change, housing relocation, or graduation or transfer of the child to a different school. Children also were observed to grow out of their WSB, embarrassed by the special jacket worn, teased by schoolmates for continuing to walk with adults and younger children, and generally ready to get to school on their own.

Underlying the reasons given in Table 16-50 for WSB discontinuance appeared to be an unmet need for school-level assistance with recruiting new WSB participants and for more school involvement overall. It was found that the more formal WSBs, with schedules to ensure that each volunteer had a day off a week, had better lasting power than informal arrangements. The researchers also deemed the personality of the individual WSB coordinators to be critical.[46] Finally, the researchers found that following a path of least resistance, WSBs tended to be routed where there were candidate participants already walking who could be quickly grouped into an operating WSB. They felt that to better meet the objective of encouraging more walking there should be a conscious effort to design WSB routes through areas where auto use for school access was more prevalent (Mackett et al., 2005b).

Several analyses of WSB programs have been conducted in New Zealand (not entered in Table 16-50). In Aukland children participating in a primary school WSB program walked an average of 6.7 trips per week to or from school, reportedly resulting in some 20 fewer cars outside the school in the morning and afternoon. Interviews with WSB participants in Christchurch suggested that besides social benefits, WSB involvement also encouraged children's independent mobility (Moudon, Stewart, and Lin, 2010).

A fairly typical reporting of WSB activity in the United States involves the C. P. Smith Elementary School in Burlington, Vermont (not entered in Table 16-50). A Wednesday WSB was started on a route with sidewalks but worrisome traffic. Some six children walked this route to school prior to the March 2005 WSB initiation. Subsequently 25 to 40 children were reported to be using the "bus," with reduction in traffic perceived (Pedestrian and Bicycle Information Center, 2011). Usage of an individual WSB is of course not the same as the broader travel-demand impact. WSB research that homed in on school-wide effects is reported from Seattle (11th entry in Table 16-50). Introduction of three WSBs at an inner-city school was accompanied by a walk-to-school rate increase from 19 percent to 26 percent in 6 months, while walking at two neighboring schools declined. Immigrant parents, confident in their experience with walking for transportation, volunteered as chaperones and soon formed the core of the school's first functional PTA (Moudon, Stewart, and Lin, 2010).

Cycle Trains. A CT study in Nelson, New Zealand (12th entry in Table 16-50), did not track CT lifecycles to the extent of the Hertfordshire WSB evaluation. It nonetheless offers thought-provoking insights regarding cycles of student participation in WSBs and CTs. The age span of Nelson CT participants ranged from 7 to 11 years, with a median age of 9 years, similar to the 8 to 11 year age span observed in Belgium's 317 CTs operating during the 2004–2005 school year. The most common age in Nelson was 8 years, even though the original guidelines called for a minimum age of 10. The researcher suggests that CTs appeal to a slightly older age group than WSBs, with WSBs appeal-

[46] This is analogous to the longer-studied situation with adult vanpools, where characteristics of a successful driver/coordinator include "commitment, affability, [and] leadership" (See "Underlying Traveler Response Factors"—"Preferences, Privileges, and Intangibles" in Chapter 6, "Vanpools and Buspools"). A related matter of interest covered in Chapter 6 is the criticality of addressing vanpool driver and passenger turnover, much the same as needs encountered with WSBs.

ing to younger children aged 5 to 8 years, after which they are ready for CTs with their typical participant age span of 8 to 11.

Indication of availability to join a Nelson CT was given by 95 students in the initial survey of five schools. Only 34 actually become involved in the seven CTs formed at four schools as counted 10 weeks after the September, 2006 launch. That represented just under 2 percent of the combined student body. In February, 2007, following the southern hemisphere summer break, there was considerable adjustment. Most of the previous year's CTs resumed, one was added independent of WSB activity, and some WSBs operating in 2006 were changed over to CTs. Some older children wanted to cycle independently, motivated in part by not wanting to be seen cycling with adults or wearing the no longer "cool" high-visibility backpack covers (O'Fallon, 2007). These outcomes, and the WSB lifecycle trends observed in Hertfordshire (see above), suggest that schools with WSBs and CTs need to be prepared for WSB/CT participation turnover as participants mature, and have corresponding mechanisms in place for both replacement recruitment and post-participation support for independent walking and bicycling.

Of the students originally indicating interest in CT participation, 43 percent were being driven to school and 41 percent were driven home. However, prior travel mode was not ascertained for a subset of slightly more than 1/3 who actually joined. CTs may tend to be smaller than formal WSBs. Nelson, New Zealand's average count per CT was five children, with a range of two to seven, compared to 7-1/2 riders average in Belgium (O'Fallon, 2007). Participation in the Mason Elementary CT in Duluth, Georgia, on the other hand, started with 45 children on the first day (Pedestrian and Bicycle Information Center, 2011).

Walking/Bicycling Promotion and Information

Both transportation and health practitioners have sought to increase participation in active transportation, not only through improved facilities and programs, but also with marketing activities. Many transportation practitioners have as their primary objective the diversion of travel away from auto use to walking, bicycling, and public transit plus more productive use of existing facilities and services. Public health practitioners seek more physical activity, for which walking and bicycling are suitable and practical candidates, whether done as utilitarian transportation or simply for recreation and deliberate exercise. There is much useful overlap to be had in marketing methods, experience, and shared goals.

Likewise useful are conclusions drawn in Chapter 11, "Transit Information and Promotion." Chapter 11 findings are pertinent as a source of lessens, from transit ridership promotion, that provide broader context for NMT mode shift promotions and even physical activity promotions. Moreover, transit riding is itself active transportation, with its heavy reliance on walk access and egress. Summarized Chapter 11 findings are inserted in Table 16-54, provided below. They are also brought up in the overall "Walking/Bicycling Promotion and Information" discussion as appropriate.

This subsection first looks at outcomes of transportation-focused mass marketing promotions and other efforts at shaping environmentally friendly and/or active transportation mode preferences and use through social marketing. Next it examines results for individualized marketing, an approach that employs one-on-one techniques pairing dissemination of tailored information on available transportation options with encouragement. Finally it reviews findings about interventions designed to promote walking and bicycling as healthful exercise. Not included are walking and bicycling encouragement programs focused on children, which were covered under "Schoolchild-Focused Programs" in the preceding "NMT Policies and Programs" subsection.

One general measure of all types of walking and bicycling promotional effort is the capacity of advocacy organizations as estimated on the basis of organizational revenue or staffing levels per capita. A U.S. city-level regression analysis of such values against NMT commute shares from the 2007 American Community Survey (ACS) has shown a positive correlation ($r = 0.52$ for organization revenue and $r = 0.47$ for staffing). Though no causality can be demonstrated, it does appear that an active advocacy community is a marker for a city with strong walking and bicycling levels (Alliance for Biking & Walking, 2010). The role of advocacy is also discussed in connection with the policy and program experience of Davis, California (see "NMT Policies and Programs"—"New World Program Examples").

Transportation Mode Shift Promotions

The marketing results presented in this "Transportation Mode Shift Promotions" discussion concentrate on travel behavior outcomes. It is important to keep in mind, however, that promotions and information have other objectives as well. Enhanced appreciation of the public benefit provided by pedestrian and bicycle undertakings is one example. Table 16-54 summarizes results-related information on promotional efforts seeking to shift urban trip makers to use of active transportation modes.

Mass Market Information and Promotions. The first three entries in Table 16-54 give examples of mass market information and promotion campaigns and events in support of active transportation. The 4th entry summarizes the parallel outcomes of public transit mass marketing synthesized in Chapter 11 of *TCRP Report 95.*

Table 16-54 Summary of Research Findings on Mass-Market and Targeted Promotions of Shifting to Non-Motorized Travel

Study (Date)	Process (Limitations)	Key Findings
Mass Market Information and Promotion		
1. Hodgson et al. – 1998, as summarized by Ogilvie et al. (2007)	Multifaceted campaign, Maidstone, England, in support of sustainable transportation. Evaluated using controlled, repeated, cross-sectional analysis. (Validity score 3-out-of-7).	Insignificant and counterintuitive change in frequency of walking trips by household members in a typical week. Change of -0.07 in intervention area vs. +0.13 in control area.
2. Rose and Marfurt (2007) (see this section for more information)	Annual Victoria state "Ride to Work Day" event centered on Melbourne. Detailed analysis of 2004 event with 5-month follow-up survey, 66% response rate, statistical analysis. (No regional market share data.)	Of 5,577 participants registered, 17% to 22% were first-time bicycle commuters, 27% of these and 83% of prior riders rode at least once during survey week 5 months later. The behavior change impact was largest for female riders.
3. Luton (2010) (see this section for more information)	In British Columbia, Canada, Victoria's Ride to Work Week (annual since 1998) now focuses on health and fitness motivations and addresses key barriers such as safety anxiety and travel time concerns. (No data on cycling to work retention rates.)	Participation up from 1,075 in 1998 to 6,446 in 2008 (about 2% of the metropolitan population), with a new-cyclist proportion that has grown from none to 15%. Metropolitan bike to work share was 5.6% in 2006. Some 7.7% of PM peak-hour trips are by bike.
4. Eleven mass marketing studies summarized in Chapter 11 (see "Mass Market Information" and "Mass Market Promotions" for more information)	Retrospective examinations of various types of information- and promotion-based mass marketing of existing transit services, sometimes with free-fare incentives. Evaluated with surveys and/or time series ridership data. (Descriptive analyses lacking statistical tests.)	Most mass-marketing results were inconclusive. Any transit ridership gains primarily represented more frequent riding by pre-existing users. Isolated cases had short-term 10–12% gains from useful information. Special day/week events with incentives have seen 4–35% short-term gains. Little evidence of longer-term effects.
Group-Targeted Information and Promotion		
5. Haq et al. – 2004, as summarized by Ogilvie et al. (2007)	Targeted marketing of active travel bolstered with walking benefits leaflet, pedometer, and local walking maps, with booster reminders after 3 months. Evaluated with non-randomized panel study. (Study validity scored as 2-out-of-7 quality evaluation criteria met.)	Targeted-group primary-mode walk share for household trips increased from 8% to 18%, versus 9% to 8% control-group decline. Trips walked/week increased from 5.5 to 5.8/person, vs. 7 to 4 decrease for control group. No change in distance walked per week, vs. 0.1 km. decrease for control group.
6. Mutrie et al. – 2002, as summarized by Ogilvie et al. (2007)	Marketing targeted to employees already inclined toward active transportation at 3 Glasgow, Scotland, employers. Used self-help pack: activity diary, maps, several types of supportive information. Assessed using controlled, randomized trial. (Validity score 6-out-of-7.)	Increase in minutes spent walking to work per week by the targeted group was 64 minutes/week or 1.93 times the increase observed for control group members matched for before-marketing amount of walking. Increases were significant for persons who both did and did not walk to work at outset.
7. Twenty existing-transit-services-focused mass marketing studies summarized in Chapter 11 (see "Targeted Infor-	Retrospective examinations of information- and promotion-based marketing that was targeted by corridor, route, or other market segment, of existing transit services, sometimes with free-fare incentives, evaluated with surveys and/or time	Rough average short-term transit use gain of 10%, with minimums reported of 1–3% and maximums of 33–50%. The increase was typically at least 9/10ths increased riding by current users and less than 1/10th first-time riders. No overall difference seen

(continued on next page)

Table 16-54 (Continued)

Study (Date)	Process (Limitations)	Key Findings
mation" and "Targeted Promotion")	series ridership data. (Descriptive analyses lacking statistical tests.)	between cases with incentives and those without. Long-term effect evidence is very limited.
New-Options-Focused Information and Promotion		
8. Merom et al. (2003)	Celebration, brochure/map, and advertisement-based marketing — with a cycling emphasis — was targeted at potential users of a new 16.5 km. (10 mile) rail trail in Western Sydney. Pre/post walking and cycling levels were determined through surveys. (Very low overall trail traffic may have let exogenous factors dominate the evaluation.)	Mean pre/post 24-hour trail counts in Cabramatta increased from 11.4 to 14.7 bicycles weekdays and 17.6 to 24.0 weekends, and in Guildford from 16.8 to 19.8 weekdays and 24.2 to 26.2 weekends. Overall cycling by those with a bike available, living within 1.5 km. (0.9 mi.), increased significantly from 0.28 to 0.47 hours/week. All other changes were not significant and/or illogical.
9. Eight new-transit-services information and promotion studies summarized in Chapter 11 (see "Targeted Information" and "Targeted Promotion")	Retrospective examinations of information- and promotion-based marketing with ads or information packets, sometimes with free ticket, of new or improved transit services. Evaluated with market penetration surveys and/or time series ridership data. (Descriptive analyses lacking statistical tests.)	Awareness after promotion ranged from 33% (rail service improvements) to over 95% (new rapid transit line). Ridership impact difficult to isolate. Where identified, targeted group usage growth rates have ranged from 3% to 500% above average increases. Effects dissipated after a few months. (See accompanying discussion for more.)

Note: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within *TCRP Report 95* is given — in the first column. Referrals to Chapter 11 subtopics pertain to the "Traveler Response by Type of Program" section of that "Transit Information and Promotion" chapter.

The Ogilvie et al. (2007) summaries only report effects on walking.

Excludes individualized marketing (addressed below in a separate discussion).

Sources: As indicated in the first column.

The statistically insignificant results of the multifaceted sustainable transportation campaign in Maidstone, England (1st Table 16-54 entry), mirror the inconclusive outcomes typically observed in public-transit mass-market promotional efforts. Aside from isolated mass-market information distributions of particularly useful transit maps and schedules, the only mass marketing approach to transit marketing with a demonstrated record of attracting at least short-term ridership gains is the holding of special events with incentives. In transit marketing, the incentives are typically free or reduced fares for a day or other relatively short period.

The notable results of the annual Victoria state "Ride to Work Day" (RTWD) event in Australia, the 2nd Table 16-54 entry, thus has parallels in the more successful special event form of public-transit mass marketing (not to be confused with more targeted marketing forms discussed further on). Presented are results of the 2004 RTWD event, developed with the help of a follow-up survey taken after 5 months. A little over one-half of event participants who registered furnished readily usable email addresses, and respondents at those addresses filled in the survey at a 66 percent response rate. Of event registrants, 22 percent indicated they were bicycling to work for the first time. The survey found a first-timer proportion of 17 percent. These percentages, together about 20 percent first-timers, is somewhat higher than the 8 percent first-timer figure reported for two

Queensland, Australia, RTWD events and the 16 percent reported for the 2001 RTWD event sponsored by the Metropolitan Washington Council of Governments in the United States (Rose and Marfurt, 2007).

Table 16-55 summarizes key bicycle riding outcomes obtained from the Victoria state survey. Of particular interest is that 27 percent of first timers continued to cycle to work at least enough to have done it during the 5-month-followup survey week. This outcome compares with 38 percent who reported continuation of cycling to work after the Washington, DC, event. Also key is the high rate of continuation for prior riders. Although a difficult relationship to demonstrate conclusively, it is thought that the annual event is crucial to reinforcing the decision to regularly cycle to work. It is also believed that the substantially higher proportion of females than males cycling to work for the first time, 23 percent versus 12 percent, shows the group approach to be especially important for attracting women to bicycle commuting. As in the United States, bicycling in Australia is a male-dominant activity.

Table 16-55 First Timers Versus Prior Riders and Cycling Commute Continuation Rates, 2004 Victoria State (Australia) Ride to Work Day Event

Gender	Overall Gender Split	First Timers: As a Percent of Respondent Category	First Timers: Continuation Rate	Prior Riders: As a Percent of Respondent Category	Prior Riders: Continuation Rate
Males	59%	12%	22%	88%	71%
Females	41%	23%	30%	77%	60%
All	100%	17%	27%	83%	67%

Note: "First timers" are those who reported not having cycled to work prior to the RTWD event.

"Prior riders" are those who did report cycling to work before the RTWD event.

The continuation rate is the percentage of first-time, prior, or all riders found to have cycled to work at least once during the week of the survey taken 5 months after the RTWD event.

Source: Rose and Marfurt (2007).

The Victoria state RTWD researchers spell out the "model of the stages in behavior change" that they suggest helps give context to events such as ride to work days. The five steps encompass precontemplation (not yet thinking about making a change), contemplation, preparation, action, and maintenance. The group support provided by being part of a big cycling promotion event, seeing so many people bicycling to work, and joining the free breakfasts provided to RTWD participants through employer participation (the three event features reported by participants to be of top value), are postulated to overcome preparation inertia for first timers and provide vital behavior maintenance support for prior/continuing riders.

The average frequency of bicycling to work during the 5-month-followup survey week was 0.6 days per week for first timers and 2.2 days for prior riders. The resulting effective regional or sector mode shares were not documented, but it was found that the more frequent cyclists tended toward more active and environmentally friendly alternative modes. Walking served as the alternative mode roughly 8 percent of the time, public transit choice ranged upward from 30 percent for 1-day-a-week cyclists to 48 percent for 4-day cyclists, and private motor vehicle use went down from 65 percent for 1-day cyclists to 44 percent for 4-day cyclists (Rose and Marfurt, 2007).

In Canada's British Columbia province, the provincial capital, Victoria, has had a Ride to Work Week event since 1995, annual since 1998. The present motivational focus on health and personal fitness was adopted after research showed these behavior instigators were much higher in priority for cyclists than were environmental concerns. Barriers to cycling such as safety anxiety and lack of confidence in traffic are addressed with pre-event Bike to Work Skills Courses. Organizers attempt to allay concerns about time required to bicycle to work by promoting 25 to 30 bicyclist/driver races from various locations to a common point, races generally won by cyclists at least one-half of the time.

The 2008 cyclist registration rate of 6,446 represents a 12-fold growth over the provincial-employee-focused event of 1995 and a sixfold increase over the first annual event in 1998. Workplaces large and small are engaged to support the event and 679 workplace teams were registered in 2008, with 14 percent employee involvement at participating workplaces. In 1998 there were no "new" riders; in 2008 there were 979. The 2006 metropolitan work trip (census) bicycle mode share of 5.6 percent is the highest in Canada. Cycling for transportation was made a travel demand management (TDM) strategy in the mid-1990's in connection with deciding to concentrate provincial offices in downtown Victoria (Luton, 2010), thus the observed bicycle shares may represent the collective outcome of many efforts and factors.

Group-Targeted Information and Promotion. The first two studies under "Group-Targeted Information and Promotion" in Table 16-54 represent examples of targeted marketing focused on either walking or environmentally friendly and active transportation in general. Results are summarized only for walk trips. The first-listed study (5th table entry) reports more than a doubling of walk mode share, a lesser increase in trips walked, and a very small improvement—relative to control group performance—in distance walked per week (Ogilvie et al., 2007). These results seem either to be in conflict with each other or to be indicative of a shift from purely exercise and recreation walking to doing utilitarian walking in lieu of motorized travel.

The second-listed study (6th Table 16-54 entry) indicates a near doubling of walking to work in response to marketing targeted at employees already inclined toward active transportation (Ogilvie et al., 2007). This specific result obviously cannot be generalized to a less-selective marketing target such as all employees at a worksite. The limitations of both these examples leave one looking to other targeted marketing examples for guidance.

One set of targeted marketing examples to consider are the group-based promotion examples found in the discussion on "Physical Activity Promotions and Interventions" to follow. The group-based examples, along with the pedometer based support examples, seem to be the more effective forms of public-health-based walking interventions (see Table 16-62). The short-term walking increases in the range of 70 to 145 minutes per week, found in the more promising group-based studies, were reported in one example to have been sustained over the long term and in one other example to have been sustained for 1 year (but only in the case of previously inactive participants). The 50 to 180 minutes per week walking increases found in the pedometer-based support examples were found to have dissipated after 24 weeks to a year (Ogilvie et al., 2007).

Another set of targeted marketing examples of interest are the public transit marketing studies, summarized from Chapter 11, in the third entry under "Group-Targeted Information and Promotion" (7th Table 16-54 entry). As indicated, targeted marketing has been found to engender short-term gain in use of this active transportation mode on the order of 10 percent, with most of the increase coming from more riding by persons already using transit. Here again, there is little evidence in the 20 studies reviewed of ability to sustain gains over the long term. However, Chapter 11 notes that some transit-marketing experts have found targeted marketing to have the greatest potential over the long term as well as the short term.

Not addressed in Table 16-54 is perhaps the ultimate form of targeted marketing, namely, one-on-one marketing to individuals. This form of promotion and information delivery is the subject of the "Individualized Marketing" discussion below.

Promotion of New Options. The last two entries in Table 16-54 address outcomes of using information and promotion in connection with introducing new or improved facilities or services. This is a form of targeted marketing with the target being the tributary area of the new transportation option.

The Western Sydney trail promotion (8th Table 16-54 entry) utilized a study design with promise to isolate marketing impacts, given that the trail was in use before the opening event and initiation of promotional activities. Analysis was able to isolate a 68 percent increase in cycling levels concurrent with marketing among those area residents within roughly 1 mile of the trail who had a bicycle available. At the end of the 3-month campaign 1/3 of the local population knew about the trail, a reasonable proportion compared to known public transit market penetration outcomes. The low usage attracted by the trail may have muted other marketing lessons that could otherwise be had. The researchers did note that community and trail environment conditions may have lessened trail use, including "quality and completeness of the trail, and the number of busy road crossings" (Merom et al., 2003). The key lesson of this example may be that no amount of information and promotion can rescue a not particularly attractive product.

The final Table 16-54 entry (9th entry) summarizes Chapter 11 findings from eight marketing campaigns run in conjunction with new or improved transit services. Marketing campaign effects are often nearly impossible to fully separate from the inherent attractiveness of the option being promoted. Information available from promoting Chicago's Green Line elevated railway following a 2-year closure for reconstruction is particularly useful for understanding the potential role of marketing in connection with new options. It was found that 39 percent of riders recalled a promotional campaign theme. Of this group, 26 percent (roughly 10 percent of all riders) felt the promotion had positively influenced them to make increased use of the line. Another 35 percent did not think the campaign increased their riding, but did believe it made them feel more positive about using the line. (For more, see Chapter 11, "Transit Information and Promotion," under "Traveler Response by Type of Program"—"Targeted Information"—"Information Focused on Service Changes.") Despite the evaluation difficulties that prevent more definitive conclusions, it is safe to conclude that promoting new pedestrian and bicycle facilities speeds development of a user base, which in itself could make the difference between perception of attractiveness or failure.

Individualized Marketing

Individualized marketing was initially developed and applied in Europe. It was focused exclusively, at first, on inducing more public transportation use. That phase of its application was introduced, with selected findings, in Chapter 11, "Transit Information and Promotion" (see "Individualized Transit Marketing" under "Traveler Response by Type of Program"—"Targeted Promotion"—"One-on-One Personal Promotion"). The Chapter 11 case study "Individualized Transit Marketing in Europe" offers additional detail on procedures and outcomes for the original IndiMark™ protocol as developed by Socialdata GmbH of Munich.

Subsequently, the technique has been expanded to cover promotion of all environmentally friendly, active transportation modes, specifically including walking and bicycling. Variants have been applied by consultants other than Socialdata and by city/county agencies with their own staff. There have been extensive applications in Australia, a number of pilot and some full-scale projects in the United Kingdom, and also several demonstrations and full-scale applications in the

United States—now totaling worldwide in the hundreds. This chapter's final case study, "Variations on Individualized Marketing in the North West United States," adds detail for several of the U.S. applications.

Outcomes are discussed here in terms of walking, bicycling, and transit use impacts. The transit use aspect is of interest because of the walking—and to a lesser extent cycling—that is involved in accessing bus and rail stops, qualifying transit as an "active transportation" mode in addition to being environmentally friendly. The reporting of transit use outcomes also serves as an update for the Chapter 11 coverage.

Individualized Marketing Concepts and Coverage. Individualized marketing supports and encourages voluntary travel behavior change (VTBC) with interventions focused on delivery of targeted information directly to participants. It encompasses a range of techniques, emphasizing dialogue marketing and guidance tailored to the recipient. Personalized information delivery is often supplemented with incentives for overcoming habitual auto use and trying out the walk, bike, or transit alternatives. Most programs are home-based at the community level, but employer-based and school-based programs have also been tried (Department for Transport, 2005, Parker et al., 2007, Brög et al., 2009).

Broadening the approach to include active transportation alternatives has led to expanding the information and incentives beyond those described in Chapter 11, which concentrated on information about transit options and the offering of free transit tickets or passes (UITP and Socialdata, 1998). In U.S. projects, for example, information has included not only transit schedules, maps, and system use instructions, but also detailed community maps showing bikeways, walkways, and even public stairways (Hofbauer, 2007, Alta Planning + Design, 2009b, City of Portland, 2010).

Demonstration projects carried out as part of the U.S. Federal Transit Administration's Individualized Marketing Demonstration Program (FTA IMDP) also offered personalized journey plans, as they are typically in IndiMark-based interventions. Some one in ten of the persons interested in receiving personally tailored information also requested and received home visits by a bus driver or walking/cycling professional. Persons already using environmentally friendly modes were rewarded with their choice of an umbrella, pedometer, discount card for bicycle shops, or bike tune-up card. Information packets and gifts were delivered by bicycle in a reusable shopping bag (Brög and Barta, 2007, Hofbauer, 2007). More detail on information provided and recent program add-ons such as organized walks and bike rides, linkages to real-time transit time-of-arrival data, and neighborhood shopping discount cards, is provided in the "Variations on Individualized Marketing . . ." case study.

Individualized marketing programs structured on the original IndiMark model divide the selected target population into three groups (UITP and Socialdata, 1998), although as a practical matter there are in fact five groups or subgroups. First of all there is a set-aside category consisting of target area households not contactable, or refusing to be questioned, in the initial telephone screening. Then there are households that are "interested/interesting" (Group I) and agree to participate in receiving information. The category with two subgroups consists of households found to already be regular users of environmentally friendly travel modes (Group R). The "R with" subgroup is composed of regular users who would like additional information. An "R without" subgroup covers regular users not needing more information. Both subgroups are treated as participants and get small rewards for their environmentally friendly mode use. Finally there are those who are "not interested/interesting" (Group N). The most precise exposition of target area household distribution among groups comes from the audit of the South Perth IndiMark TravelSmart interventions, prepared for Western Australia Transport, and is set forth in Table 16-56 (Goulias, 2001). (The TravelSmart branding applies to IndiMark projects in Australia, North America, and the United Kingdom.)

In the United States, demonstration projects in the four locations selected for the 2003–2006 FTA IMDP provide an indication of the variation encountered in distributions of interviewed households among the Groups I, R, and N categories. (These statistics may be compared with the South Perth data in the lower-right section of Table 16-56.) The IMDP average for Group I (interested) was 42 percent, ranging from 37 to 51 percent. The average for Group R-with (regular users with information needs) was 6 percent and the average for Group R-without (no information needs) was 12 percent, totaling 18 percent for Group R. The four-city range for Group R combined was 9 to 32 percent, the lower number pertaining to Durham, North Carolina, and the higher number being for walkable and bikeable Bellingham, Washington. The average for Group N (not interested) was 40 percent, ranging from 31 to 49 percent (Brög and Barta, 2007). The Groups I, R, and N distributions seen in all six full-scale projects in Perth from 2000 through 2004, plus two additional Australian applications outside of Western Australia (Australian Government, 2005), all fall within these ranges established in the U.S. FTA IMDP interviews.

Table 16-56 Target Area Household Response Distributions for the Large-Scale South Perth TravelSmart Individualized Marketing Project

Category	Number of Households	Percent of All Households	Percent of Targeted Households	Percent of Interviewed Households
Project area households	18,626	100%	122%	139%
No listed phone number	3,359	18%	—	—
Targeted households	15,267	82%	100%	114%
Not contactable	967	5%	6%	—
Refused interview	918	5%	6%	—
Interviewed households	13,382	72%	88%	100%
Group I – interested	6,128	33%	40%	46%
Group R – user with info needs	1,667	9%	11%	12%
Group R – user without needs	670	4%	4%	5%
Group N – not interested	4,917	26%	32%	37%

Source: Goulias (2001), with elaboration by the Handbook authors.

U.S. Home/Community-Based Program Mode Share Results. In the United States, before-and-after individualized marketing mode share results are available in full detail for the four FTA IMDP pilot-scale applications (Brög and Barta, 2007), and for the subsequent 2008 large-scale application in Bellingham (Horst and Brög, 2010). They are also available for certain Oregon applications including a series of sector-by-sector community programs in Portland. The Portland applications started with a pilot program in 2003 and have been working toward full coverage of the city by 2012 (City of Portland, 2010). Mode share results for the FTA IMDP and Portland projects are summarized below, along with pedestrian and bicycle count substantiation from Portland. Results for the full-scale 2008 Whatcom Smart Trips program, covering the central area and coastal corridors of Bellingham, Washington, are detailed in the final case study, "Variations on Individualized Marketing in the North West United States." The case study also covers less proactive applications—exhibiting more of the characteristics of conventional targeted marketing—in locations ranging from Sausalito, California, to Seattle, Washington.

The four cities involved in the 2003–2006 FTA IMDP demonstrations were Bellingham, population 80,000, located on Puget Sound in Washington State near Canada; Cleveland, Ohio, where the bus and rail system is the nation's thirteenth-largest; Durham, North Carolina, in the low-density Research Triangle area; and Sacramento, California, where the demonstration focused on the Rancho Cordova suburban community with its rapid growth and light rail transit (LRT) access. Results were evaluated based on before-and-after mail-out self-administered surveys with one-day trip diaries, backed up with telephone motivation. The overall "before" survey response rate was 60 percent, ranging from 54 to 65 percent across the four cities, and the "after" survey response was 68 percent, ranging from 66 to 71 percent. There were 6,100 returns combined for the four-city before surveys, covering both target groups and control groups, and 6,031 returns for the after surveys. Mode shifts attributable to the individualized marketing were calculated with reference to secular trends exhibited by the control groups (Brög and Barta, 2007). Table 16-57 summarizes the combined four-city results, including both relative changes in mode share (percentage increase or decrease) and absolute shifts in share (percentage point difference—"after" compared to "before").

Table 16-57 U.S. Individualized Marketing Demonstration Program Mode Share Results

Travel Mode	"Before" Mode Shares	"After" Mode Shares	Relative Changes (Percent Up/Down)	Absolute Shifts (Percentage Points)
Walk	8%	9%	+20%	+1%
Bicycle	2%	3%	+25%	+1%
Public Transit	2%	2%	+25%	<+1%
Auto Driver	69%	66%	-5%	-3%
Auto Passenger	19%	20%	+6%	+1%

Notes: Absolute shifts calculated from before/after mode share percentages reported in integers.

Motorcycle mode omitted (less than 0.5 percent).

Source: Brög and Barta (2007), with calculation of absolute shifts by the Handbook authors.

Percentage point shifts in environmentally friendly mode shares were all consistently positive, although modest in scale.[47] Given the fairly low "before" shares in the FTA IMDP communities, the relative percent increases in four-city walk, bike, and transit mode shares were all in the 20 to 25 percent range overall. The individual-city relative changes are presented in Table 16-58.

[47] As described in connection with Australian individualized marketing outcomes, experience suggests that individual projects involving less than 5,000 households tend to produce lesser impact than larger interventions (Brög and Ker, 2008).

Table 16-58 U.S. Individualized Marketing Demonstration Program Relative Mode Share Changes by City, with Bellingham 2008 Large-Scale Project Comparison

Travel Mode	Bellingham, Washington	Cleveland, Ohio	Durham, North Carolina	Sacramento, California	Bellingham Large-Scale
Walk	+35%	+13%	+15%	+15%	+22%
Bicycle	+13%	+33%	+25%	+30%	+35%
Public Transit	+14%	+26%	+35%	+43%	+11%
Auto Driver	-8%	-4%	-7%	-2%	-13%
Auto Passenger	+10%	+5%	+6%	+1%	-3%

Notes: See Table 16-57 for overall four-city FTA IMDP National Demonstration relative and absolute changes.

See case study "Variations on Individualized Marketing in the North West United States" for details of Whatcom Smart Trips large-scale application in Bellingham.

Motorcycle mode omitted (less than 0.5 percent).

Sources: Brög and Barta (2007) and Horst and Brög (2010).

Results for the 2008 Whatcom Smart Trips large-scale IndiMark application, covering about 1/3 of Bellingham's households, are appended to Table 16-58 for comparison. The adjusted before-share total for active transportation modes going into the 2008 large-scale application (28 percent) was double the corresponding after-share total for the earlier demonstration program (14 percent). With somewhat larger relative shifts overall, and starting from a larger active transportation base, absolute active transportation mode shifts—and shifts away from single-occupant driving—were 2 to 3 times those observed earlier (Table 16-57) except for public transit. Walk mode share increased by 4 percentage points, the bike share increased by 3 percentage points, and the transit share increased by a small increment. The auto driver mode share decreased by 6 percentage points and the auto passenger share decreased by 1 percentage point, all in absolute terms (Brög and Barta, 2007, Horst and Brög, 2010).

Portland individualized marketing results are available for each year from 2003 through 2009, but full mode shift detail has been published only for certain years. Relative drive-alone trip reduction results are available for all years, however, and with one exception have ranged in the narrow band between 8.6 and 9.4 percent. The exception was 2006, with a 12.8 percent auto driver trip reduction. The full detail available for 2003 and 2006 is presented here. It covers a typical situation, 2003 (with a 9.0 percent auto driver trip reduction), and the exceptional year of 2006 (Portland Office of Transportation, 2006, Portland Bureau of Transportation, 2009, City of Portland, 2010).

The Multnomah and Hillsdale neighborhoods were the focus of the 2003 program, Portland's pilot study, and the 2006 program covered the Northeast Hub area. Control groups were established in both projects to measure impacts of external factors, and the 2006 Northeast Hub results were explicitly adjusted for rather large control group shifts thought likely to be related to gasoline price increases. The absolute gains for environmentally friendly modes in 2004 and 2006, respectively, were 2 and 5 percentage points (adjusted) walk mode share gain, 1 and 2 percentage points bike share gain, and 2 and 1 percentage points bus- and LRT-share gain (Socialdata, 2004, Portland Office of Transportation, 2006). Portland thus appears to have achieved somewhat larger gains than observed in the FTA IMDP demonstrations. This may in part reflect the walk- and bike-friendly environment and ongoing NMT improvements throughout much of Portland, along with an emphasis on good public transit service levels.

The annual Portland studies have, for selected years, included reporting of pedestrian and/or bicycle volume changes before-and-after individualized marketing interventions. Since such data are not presented for all years, it is not possible to judge whether the findings are representative or reflective of particularly notable outcomes. In any case, the volume changes tend to support the mode shift survey findings for the years in question. Analysis details and reported findings for the 2005 through 2009 Portland programs, including volume count results, are set forth in the "Variations on Individualized Marketing . . ." case study. Available results for the 2004 Interstate Corridor program, including the instructive response to LRT expansion with and without individualized marketing, are included within the discussion below of "Home/Community-Based Programs in Conjunction with System Changes."

U.K. Home/Community-Based Program Mode Share Results. The U.K. Department for Transport, in December 2002, awarded grants for pilot individualized marketing campaigns within England. They included eight, in seven cities, which targeted residential populations. Table 16-59 provides overall mode share results, weighted by targeted population, for the six of these 2003–04 projects that measured results across the entire target population. These were the community-based programs in Bristol, Cramlington, Nottingham (two target group projects), Quedgely, and Sheffield. The target populations totaled some 22,800 persons overall. The other two programs, omitted here for consistency, measured outcomes across only the intervention group (Department for Transport, 2005).

Table 16-59 U.K. Individualized Marketing Pilot Program Mode Shares, Six-Project Weighted Average Results

Travel Mode	"Before" Mode Shares	"After" Mode Shares	Relative Changes	Absolute Shifts	6-Project Range in Shifts
Walk	26%	30%	+15%	+4%	+2% to +5%
Bicycle	3%	4%	+19%	+1%	0% to +1%
Public Transit	8%	9%	+22%	+1%	+1% to +2%
Auto Driver	45%	40%	-11%	-5%	-3% to -6%
Auto Passenger	18%	17%	-4%	-1%	+1% to -3%

Notes: Relative changes (expressed as percentage increases/decreases) calculated from individual-program before/after mode share percentages reported in integers. Absolute shifts expressed in percentage points.

Motorcycle and other modes omitted (less than 0.5 percent on average).

Source: Department for Transport (2005), with calculation of relative changes and weighted averages by the Handbook authors.

These results are similar to those of the FTA IMDP in the United States, with the major exception of a much larger percentage point shift to walking (+4 percent) and a correspondingly larger reduction in auto driver trips. The larger shift to walking presumably reflects the shorter distances to destinations that would be typical of communities in England.

Australian Home/Community-Based Program Mode Share Results. Australian experiences with individualized marketing are of special interest not only because outcomes nationwide were assembled and assessed, as of 2005, but also because the degree of auto dominance in Australian cities is reasonably comparable to the North American context. Perth, in Western Australia, has been credited with the first extension of individualized marketing to include inducement of more walking and bicycling for transportation (Brög et al., 2009). Following its initial demonstration, Perth has progressed—on a sector-by-sector basis—toward covering the entire metropolitan region. The first six individual programs encompassed a total individualized marketing target population of 128,000 persons. Results have been analyzed based on survey samples totaling 6,155 households. Households randomly selected in each survey wave were utilized in one-half of the projects, and randomly selected panels were employed in the other half (Australian Government, 2005). Table 16-60 summarizes the overall results for the six Perth programs. The bicycling and especially the walking outcomes were somewhat stronger than for the U.S. FTA National Demonstration projects, and the auto driver mode share reduction was double that obtained in the U.S. demonstrations. The results are more like those reported for Portland, Oregon, and the Bellingham, Washington, large-scale application.

Table 16-60 Perth, Australia, Individualized Marketing Sector-by-Sector Project Mode Share Results for 2000 Through 2004, Six-Project Weighted Average Results

Travel Mode	"Before" Mode Shares	"After" Mode Shares	Relative Changes	Absolute Shifts	Six-Project Range in Shifts
Walk	11%	14%	+23%	+3%	+1% to +4%
Bicycle	2%	3%	+60%	+1%	0% to +2%
Public Transit	5%	6%	+19%	+1%	+1% to +2%
Auto Driver	60%	53%	-11%	-6%	-2% to -10%
Auto Passenger	22%	23%	+3%	<+1%	+2% to -2%

Notes: Relative changes expressed as percentage increases/decreases. Absolute shifts (expressed in percentage points) calculated from before/after mode share percentages reported in integers.

Motorcycle and other modes omitted (less than 1 percent).

Source: Australian Government (2005), with calculation of absolute shifts and weighted averages by the Handbook authors.

Individual major projects within Melbourne (2001) and Brisbane (2005) produced results within the ranges established in the six 2000–2004 Perth projects. Two very small 2001 and 2004 trials in Canberra, with about 100 households each in the intervention groups, were also generally consistent. A small 2002 pilot project in Adelaide, involving 353 households, was the one project that did not conform. Walking trips *decreased* by 12 percent in relative terms, although cycling increased 26 percent, bus use increased 48 percent, and train use increased 84 percent. Auto driver trips *increased* 2 percent, while auto passenger changes were negligible. This inconclusive outcome was tentatively attributed to before/after weather and daylight hours differences and a 6 percent gasoline price decrease (Australian Government, 2005).

One of the individual Perth TravelSmart projects subsumed in the statistics of Table 16-60 took place in the suburb of Cambridge in 2002. Ridership on local buses increased 16 percent on average over the following 12 months. The cumulative increase was up to 25 percent 28 months after the individualized marketing, a lessened rate of increase, but achieved with no further intervention (Australian Government, 2005). After 48+ months the overall net increase stood at 23 percent. If the data (from different reports/papers) are consistent, this suggests no further gain but very little backsliding. During the 4-year bus ticket monitoring period there was no change in public transportation supply, population size, or social structure (Brög et al., 2009).[48]

[48] Positive-appearing bus ridership comparisons have also been encountered for the South Perth large-scale application of 2000 (Department of Transport W.A., 2000), but relevancy—given the timeline of the pre-individualized-marketing bus service improvements, the bus ridership increase, and the individualized marketing intervention—is the subject of dispute (Morton and Mees, 2010; Ker, 2011). Therefore, these data are omitted.

Outcomes from multiple Australian programs have been analyzed in an effort to identify how area types and program size affect individualized marketing success. Two areas deemed to have poor NMT facilities and transit service along with high auto use levels were deliberately afforded individualized marketing programs to see how results would compare with those in communities more walk/bike and transit friendly. Mangaroo and Cambridge in Western Australia were the test areas selected. Relative auto use reductions achieved in these areas through diversion to more environmentally supportive modes were 4 percent and 7 percent, respectively. This compares with a median of 11 to 12 percent auto use reduction in some 24 project areas with better alternative-mode environments (Brög and Ker, 2008).

There has also been an effort to relate individualized marketing outcomes to urban form statistically. In Perth the relationship between mode shifts and an "accessibility" index measuring quality of the environmentally friendly mode environment showed a positive correlation, albeit not a strong one. The project area with the lowest index (Melville) violated the overall relationship, having the largest reduction of auto trips per person (Parker et al., 2007).

As previously noted in Footnote 47, the Australian experience indicates that applications involving less than 5,000 households produce lesser impact than larger interventions. This determination was based on the 24 projects noted above, which omitted Mangaroo and Cambridge and also one case in Darebin, Victoria, with questionable results. The difference is thought to result from greater opportunity for diffusion of interest and information among the target population of larger interventions. A formula was estimated for auto driver trip reduction as a function of project size (Brög and Ker, 2008):

$$\text{Percent reduction in auto driver trips} = 0.0098 * \ln(x) + 0.0381$$

Where x = number of households

Home/Community-Based Program Effects by Trip Purpose. An aspect of individualized marketing that makes it of special interest to Travel Demand Management (TDM) and environmental planning practitioners is that it addresses not just work purpose travel but instead most urban travel purposes (Horst, 2010a). Indeed, in the various United Kingdom pilot studies of 2003–04 the best reductions in auto use resulting from shifts to environmentally friendly modes were for trips involving shopping and leisure. Slightly lesser responses were achieved for personal business and education-related trips, with the least response for work trips (Department for Transport, 2005). Similar outcomes have been reported elsewhere. When participants in Portland's 2005 Eastside Hub program were asked what types of *new* walking and biking trips they had taken in the past 3 months the responses were (walk and bike, respectively): no new trips (12 and 28 percent), errands (38 and 23 percent), shopping (36 and 20 percent), fitness (33 and 23 percent), friend's house (24 and 17 percent), rail or bus transit access (24 and 6 percent), and work (6 and 15 percent) (Portland Office of Transportation, 2005).

Home/Community-Based Program Effects on Physical Activity. The across-the-board applicability of individualized marketing to most trip purposes gives it added relevancy to public health efforts to increase exercise. Several assessments have estimated increases achieved in active-transportation physical activity. Documentation of SmartTrips Northeast Hub results in Portland's 2006 application does not attempt inclusion of transit access contributions. It reports a 20-hour increase in the per-year walking and cycling rate in the control group, presumed to reflect weather differences between the March before survey and the September after survey, and a 33-hour-per-year increase in the walking and cycling rate for SmartTrips target area residents. This equates to 13 hours more of walking and cycling per year (Portland Office of Transportation, 2005).

The National Demonstration projects documentation reports a 12-hour or 20 percent per-person increase, from 62 to 74 hours per person per year, for pilot study target area residents. This tally explicitly addressed the net effect of total walking, cycling, transit access, and parked-car access travel time changes (Brög and Barta, 2007). Combined 2004 LRT introduction and TravelSmart in Portland's Interstate Corridor was estimated to have increased physical activity by 1/2 hour each week (City of Portland, 2005b), contributing one average day's worth toward the HHS weekly exercise recommendation (Department of Health and Human Services, 2008). Based on relationships set forth below, it appears that about 45 percent of the physical activity increase in this instance can be attributed to the individualized marketing. All three of these estimates place the amount of added physical activity attributable to individualized marketing itself in the range of 11 to 13 hours per person per year.

The 2008 Whatcom Smart Trips large-scale project in Bellingham produced a larger physical activity increase than any of the above. Prior to the 2008 intervention, target area residents were already obtaining an impressive 122 hours per year on average of walking and cycling time from walk-only and bike-only trips, transit access, and parked-car access. A 31 hour or 25 percent increase was obtained through individualized marketing (Horst and Brög, 2010). These observations may be compared with the 2-1/2 hours per week HHS recommendation, which equates to 130 hours per year, if one is willing to overlook the requirement that qualifying exercise should be in increments of 10 minutes or more. (The proportion of active travel below this threshold does not appear to have been explored in any of the individualized marketing investigations.) Accepting this analytical limitation, the pre-intervention value of active transportation exercise in the Bellingham target area averaged 94 percent of the HHS recommendation. The 2008 Smart Trips project pushed the average target area resident above the minimum to reach 153 hours per year, 118 percent of the target.

Home/Community-Based Programs and Mobility. The shifts to walking, cycling, and transit use associated with successful individualized marketing do not appear to be linked to any significant decrease or change in mobility as measured in terms of either daily trips or activities. In the 2003 Portland pilot study, for example, it was found that the average target area resident made 3.2 trips per day to reach 1.9 activities, both before and after the TravelSmart intervention. The total travel distance and time involved before individualized marketing averaged 19 miles and 56 minutes. Afterward it was 18 miles and 58 minutes (Socialdata, 2004).

Perth, Australia, findings were very similar. Across the six sectors with TravelSmart projects in the 2000–2004 period, total trips per person per day varied by neighborhood from 3.2 to 3.5 and activities per day varied from 1.9 to 2.2. Importantly, however, there were no changes between per-person before and after activity or trip averages within any given neighborhood, with one small exception. (The activities recorded in Cambridge per trip were 2.2 before and 2.1 after.) Purposes for travel showed the same distributions, before and after, in 4 of 6 suburbs. The purpose shifts in the other two sectors of Perth were minor, mostly relatively small movements between the discretionary and leisure categories. Average daily trip distance declined from 28 to 27 km., while average total travel time stayed at 58 minutes. The travel time averages obscure, however, a decline of over 6 minutes in Subiaco, and 1 to 2 minute increases in four other sectors (Australian Government, 2005). Across three continents, the mobility picture in response to individualized marketing is one of little or no change in numbers of trips or activity levels, no change or slight declines in total travel distance, and usually a slight increase in time spent per day in travel.

Home/Community-Based Programs in Conjunction with System Changes. The use of target group and control group segmentation in Portland's Interstate Corridor before-and-after surveys, done for the 2004 program, produced insights about applying individualized marketing in concert with facilities and service improvements. This TravelSmart intervention reached over 14,000 people residing in north and northeast Portland. The timing was later the same year the MAX yellow line LRT was opened through the area. The "before" survey, scheduled before both LRT introduction and the individualized marketing, found a 6 percent transit mode share. In the control-survey area, transit trips increased by 24 percent in relative terms, presumably because of the MAX yellow line. In the TravelSmart intervention area, the corresponding increase was 44 percent, suggesting that the individualized marketing had nearly doubled the shift to public transit, at least in the short-to-intermediate term (City of Portland, 2005b).

Portland's near-doubling of the shift to transit with rail service introduction, in the presence of individualized marketing, roughly paralleled the experience of eight German cities improving rail transit service. The average for all nine cities was a 23 percent increase in transit trips per person, without individualized marketing, and a 48 percent increase with it (Brög et al., 2009).

A somewhat comparable situation occurred in Portland in 2006, except instead of an environmentally friendly travel mode being enhanced, the auto-travel mode received a disincentive in the form of increased gasoline prices. Drive-alone mode choice decreased by 24.3 percent in the individualized marketing target area, and by 11.5 percent among control group survey respondents, producing a 12.8 percent net relative change (Portland Office of Transportation, 2006). Even this 12.8 percent net drive-alone decline was 42 percent more than the Portland individualized marketing norm of about 9 percent reduction. One might speculate that the higher gasoline prices heightened the receptiveness of the target audience to individualized marketing information on travel options.

Durability of Home/Community-Based Program Effects. There have been a number of surveys designed to explore the ability of individualized marketing to effect change with lasting influence. These surveys have found substantial retention of travel mode shifts identifiable after 1, 2, and even 4 years. There is increasing evidence of such sustainability (Brög et al., 2009), which is not generally found beyond a few months or a year with conventional promotions (see Chapter 11).

Table 16-61 illustrates findings across 4 years for the South Perth, Australia, large-scale project. Gains in walking and bicycling held for all 4 years, while transit riding gains apparently held for only 18 to 24 months (Australian Government, 2005). The fact that the before surveys were held in the summer while after surveys took place in the spring might be viewed as worrisome, but the earlier South Perth pilot project showed essentially no differences between spring and summer in after-intervention surveys. Pilot project walk shares were holding at 14 to 15 percent 2 months, 1 year, and 2-1/2 years after the intervention, compared to 12 percent before. Bike shares held at 4 percent and transit shares at 7 percent, compared to 2 and 6 percent, respectively, before TravelSmart (Department of Transport W.A., 2000).

Table 16-61 Before and After Individualized Marketing Mode Shares across Four Years in South Perth, Australia

Travel Mode	Before (2000)	After (2000)	After (2001)	After (2002)	After (2004)
Walk	12%	16%	16%	15%	16%
Bicycle	2%	3%	4%	3%	3%
Public Transit	6%	7%	7%	6%	6%
Auto Driver	60%	52%	52%	54%	54%
Auto Passenger	20%	22%	21%	22%	21%

Notes: Before-intervention survey in February (summertime) (Department of Transport W.A., 2000). After surveys in October and November (springtime).

Motorcycle mode omitted (less than 0.5 percent).

Source: Australian Government (2005).

Data from the original introduction of individualized marketing in Germany show strong retention of shifts to public transportation for as long as 4 years. Walking and bicycling were not addressed in these studies. Transit ridership was found to have increased by some 38 percent in Nürmberg at both 1 and 2 years after, and by about 53 to 58 percent after 1 year and 4 years in Kassel (UITP and Socialdata, 1998). (For more, see the "Individualized Transit Marketing in Europe" case study in Chapter 11, including Table 11-22.) In the case of Dalvik, Sweden, positive sustainable shifts occurred only in the case of public transit. The combined walking and bicycling share dropped from 24 percent before to 22 percent 6 months after in both target and control groups. The target group walk/bike share was 23 percent 1 year after and 22 percent 4-1/2 years after. The transit share, which was 11 percent before, held at 13 percent in all after-intervention surveys (Brög et al., 2009).

The 2001 Gloucester, England, project undertaken in the vicinity of Quedgeley was tracked for 3 years. Mode share increases gained in bicycling and transit use, and a decrease in auto driver share, all held up without any diminution discernible in the charting of results. Walking gains were reduced somewhat as of the second year but the reduction was less than one-half the original gain. An auto passenger share decline proved only temporary (Parker et al., 2007). A follow-up tracking of Bellingham, Washington, FTA IMDP demonstration results approximately 3 years after the original application suggests that mode shifts were more than sustained except in the case of bicycling, where the original gain had diminished by half. The gain in walking over time was more than twice that seen in the original "after" survey (Horst and Brög, 2010). In light of increased gasoline prices and continuing upgrades to Bellingham's NMT provisions and bus service, caution must be applied in drawing further inferences.

Home/Community-Based Program Cost Effectiveness. There is a growing assemblage of evidence that individualized marketing exhibits positive benefit/cost ratios and satisfactory rates of return (Parker et al., 2007) or other evidence of cost effectiveness. A particularly informative evaluation in the city of Linz, Austria, compared effectiveness of different marketing approaches. Focusing only on cost recovery from increased transit revenues, the first year rate of return for conventional direct marketing was found to be 0.5 (not cost effective), whereas for personalized dialogue marketing it was in the range of 1.1 to 1.6 (Ashton-Graham and John, 2006). Further cost effectiveness information is provided in the "Related Information and Impacts" section (see "Economic and Equity Impacts"—"Societal Economic Impacts"—"Transportation Revenue Benefits").

Home/Community-Based Programs and Public Satisfaction. Fostering of a positive attitude toward quality of life enhancement efforts by the City of Portland were anecdotally reported, based on 1,200 unsolicited positive comments received on the 2009 individualized marketing program, but there was no quantitative analysis of this aspect (City of Portland, 2010). The early 1990s transit-only applications in Germany, detailed in the Chapter 11 case study, documented increases in a public transit satisfaction index that more or less paralleled the increases in transit riding (UITP and Socialdata, 1998). More recently, the South Perth TravelSmart program surveyed public perceptions of transit service in 1998 before individualized marketing and in 2000 afterward. With "don't know" remaining constant at 14 percent, the proportion of respondents satisfied increased from 31 to 47 percent. The proportion perceiving betterment over 4 years previous, with "[stayed the] same" remaining constant at 54 percent, increased from 23 to 38 percent (Ashton-Graham and John, 2006). It has been noted that "there may be interest in a broader set of impacts from [individualized marketing] than [just] travel outcomes . . . includ[ing] attitudes towards transport modes/services, levels of physical activity, use of local [retail and] services, and social inclusion" (Parker, et al., 2007).

Critiques of Home/Community-Based Individualized Marketing Assessments. There is a body of critiques of procedures employed in the evaluation of home- and community-based individualized marketing (Brög et al., 2009) that is sufficient to warrant their review here, in context, rather than having only brief mention within the "Analytical Considerations" discussion of the "Overview and Summary." Voluntary travel behavior change works within the confines of incremental shifts of mode in an experimental environment easily clouded by many uncontrolled factors (Brög et al., 2009, Parker et al., 2007). The same can actually be said, to a substantial degree, of practically every pedestrian and bicycle facility change or intervention covered in this chapter. Ironically, as noted under "Analytical Considerations," it is individualized marketing that has—in a majority of instances—been evaluated with the more comprehensive and carefully controlled before-and-after surveys and control group utilizations. It has been observed that the skepticism derives not only from the complexity of the required evaluations, but also from a number of perceptions, including:

- A perception among transportation planners that the reported results are too good to be true, and that the cost is too little to possibly effect such changes, yet too much for something that may fail to deliver travel shifts as promised (Stopher et al., 2004).

- Disbelief among transportation economists that behavior can be subject to change without physical improvements or pricing mechanisms (Parker et al., 2007).

One concern has been that the information available on travel behavior outcomes for a majority of the individualized alternative-transportation marketing applications has been from one private source, namely Socialdata, the originators of the IndiMark protocol. At first the disclosure of analytical details involved in the IndiMark process was less forthcoming than a number of researchers and practitioners were fully comfortable with (Goulias, 2001, Ogilvie et al., 2007). A team of health-promotion researchers—after reviewing outcomes from across the British Commonwealth—was moved to suggest that "claims made for individualized marketing" should be tested "in an independent randomized controlled trial" (Ogilvie et al., 2007), a proposition of questionable practicality. This type of concern about individualized marketing validity should now be lessened given an independent audit in Australia (Goulias, 2001) and separate evaluations by the Australian government and the U.K. Department for Transport (Australian Government, 2005, Department for Transport, 2005, Parker et al., 2007). Indeed, consultants to the Department for Transport in the United Kingdom have taken the view that controversy about legitimacy of "personal travel planning" is a potential barrier to implementation of a sufficiently-proven concept (Parker et al., 2007).

A more fundamental issue is the one first noted—that individualized marketing involves incremental shifts in a difficult experimental environment. Uncontrolled factors may range, for example, from gasoline price changes to transportation facility or service improvements. One critique emphasizes that since individualized marketing is an experiment involving human rather than inanimate subjects, a "set of subtle yet potentially significant sources of systematic error" is introduced. Termed "artifacts" in psychology literature, these include "the expectancy effect" (inadvertent feedback between participant and experimenter), "the 'good subject' effect" (participant desire to report "good" outcomes), and non-response bias linked to participant desire not to report outcomes presumed by the participant to be undesirable (Morton and Mees, 2010).[49]

[49] These same authors assert that assessment of the Melbourne, Australia, Alamein Line project applied factoring procedures that amplify any response bias effect (Morton and Mees, 2010). Their process interpretation does not mesh, however, with the detailed description of IndiMark procedures available from the audit performed of the South Perth pilot study. That audit details how follow-up survey responses by interested, regular-user, and not-interested participants in the before survey are differentially factored according to corresponding stratified response rates. Tables 2.4b and 2.4c of the audit explicitly show that the reverse of amplification of potential bias occurs (Goulias, 2001).

Considerable effort has been expended—in a majority of applications—to minimize opportunity for such artifacts and other biases. The process as applied in the 2008 Whatcom Smart Trips project in Bellingham is summarized in the "Variations on Individualized Marketing . . ." case study under "Analysis." Differentiation of "before" and "after" surveys from the individualized marketing intervention itself defeats any serious possibility for conscious or unconscious tendencies of respondents to report "good" outcomes (Ker, 2011). In Bellingham, for example, survey subjects randomly selected in both "before" and "after" surveys were not told of the association with the individualized marketing program, and were asked about their travel in regional survey trip diary format, giving little clue as to what "good" answers might be (Horst, 2010b).

Intuition might suggest that panel surveys would provide more opportunity for artifacts like "the expectancy effect" and "the 'good subject' effect," worsening any potential to overstate individualized marketing results, but parallel tests in Australia of fully randomized versus panel surveys do not support this. The panel surveys showed lesser individualized marketing impact rather than more. In terms of auto driver diversion to alternative modes, the Brisbane North panel survey estimated an 11 percent shift while the fully random survey estimated 13 percent. In Victoria Park, the corresponding estimates were 12 percent and 14 percent (Brög and Ker, 2008). With respect to non-response in the self-administered trip diary surveys used in the IndiMark and some other projects, research based on comparing early-responder results with all-responder results (making the assumption that late responders are the closest to not responding at all) indicates that low response rates may actually lead to underestimation of the induced mode shifts (Brög et al., 2009).

In addition to the more-or-less global issues, there have been known individual instances of analytical/statistical problems. Included have been sample sizes later found to be insufficient (Parker et al., 2007), other quite small sample sizes (Portland Office of Transportation, 2005), and notably low survey response rates with substantial "after" survey drop-off (Alta Planning + Design, 2009b). Also, it should be understood that—in the original IndiMark approach—the target area evaluation sample excluded households without listed telephone numbers, households otherwise not contactable, and households refusing to cooperate. Such excluded households constituted, for example, 28 percent of all study area households in the South Perth large-scale application (Goulias, 2001). (In recent IndiMark applications households with unlisted or no land-line telephones are excluded only if they are not covered in commercial address listings [Horst, 2010b].) The quantity of unreachable households, if they could somehow be included to produce overall estimates of impact, would presumably dampen the calculated target area mode shifts.

There are certainly practical limitations to achievement of full confidence that potential survey biases have been controlled (Brög et al., 2009) and that sample sizes and techniques involved are sufficient to adequately "detect changes of the order of 5 to 10 percent in various travel behaviors" (Stopher et al., 2004). That said, the overall body of evidence appears to support the validity of individualized marketing. The user of information on outcomes from any particular project should examine the evaluation procedures utilized and compare them with those employed in other projects. (A condensed version of such a comparison is found in Table 16-140 of the "Variations on Individualized Marketing in the North West United States" case study.) The potential for "optimism bias" should be addressed, for example, in the selection of external evidence for corroboration. If the analysis appears sound in context with other well regarded projects, it should be reasonable to presume—after taking exogenous influences such as gradual NMT system improvement into account—that impacts have been realistically estimated.

Employer-Based and Schoolchild-Focused Individualized Marketing Results. In the United States, individualized marketing protocols have apparently not been applied—in and of themselves—in an employer context. If they were, they would be classified as a Travel Demand Management (TDM) strategy in the "support action" category. They would today almost certainly be implemented with an individual employer focus, as set forth in Chapter 19, "Employer and Institutional TDM Strategies" (see "Response to Support Actions" under "Response by Type of TDM Strategy"). Indeed, the inclusion of TDM elements in the overall Whatcom Smart Trips program in Bellingham, Washington, is handled in that way.

After early trials in the United States with government-based area-wide TDM programs, for example in the case of carpool matching programs, it was concluded that area-wide top-down government programs had "not been very productive" and that the "most successful areawide programs [were] those relying on heavy employer involvement." It was further observed that the "most individually effective" programs were those initiated and carried out by employers in support of their own organization's objectives (Pratt, Pedersen, and Mather, 1977). Individualized marketing experience can, however, clearly inform enhanced design of TDM information, marketing, and promotion support-action strategies, both at the employer level and in the context of government-provided TDM guidance and assistance to employers, especially those operating under trip-reduction ordinances and regulations.

The 2003–04 United Kingdom pilot studies included six varied workplace individualized marketing applications, all in England. Except for one program that focused on new employees and enrolled them automatically, employee participation rates were low, ranging from 0.4 to 5 percent. Among the small numbers of participants, single-occupant vehicle (SOV) use changes ranged from a 21 percent reduction to a 5 percent *increase.* (Note that these results are presented at the level of participating employ*ees.*) Four projects examined mode shifts in detail. In the project with the highest shift from SOVs, bicycling became the alternative mode for some 76 percent of former SOV drivers. In a second project nearly as effective, public transit was chosen by roughly 96 percent of former auto users. Only small shifts are seen in the other two cases of detailed findings. Effectiveness comparisons were developed using the metric of vehicle kilometers of travel reduced. On this basis, comparing the most cost effective of residential and workplace applications, the workplace programs were only about one-fourth as cost effective. For the least cost-effective programs in each category, the workplace program cost effectiveness was under one-twentieth the residential program effectiveness (Department for Transport, 2005).

Australia has had a larger number of employer-based programs identified as involving individualized marketing. Reported declines in auto commuting at four Western Australia employers ranged from 6 to 15 percentage points, with accompanying increases in environmentally friendly alternatives. A larger subset of 15 Western Australia employers exhibited auto mode changes ranging from 46 percent reduction to a 51 percent increase, with a simple average of an 11 percent reduction. These statistics are all at the level of participating employers, and do not represent overall sub-area effects. In general, researchers found these and other available evaluations too limited and poorly controlled to support reliable comparative analysis or robust conclusions (Australian Government, 2005).

School program results have been reported for both England and Australia. The programs divide into two categories. On the one hand are efforts that parallel Safe Routes to School strategies in the United States. These have been selectively covered in the "NMT Policies and Programs" subsection (see "Schoolchild-Focused Programs"). On the other hand are actual individualized marketing programs that seek to influence travel of the entire schoolchild's household, working through teachers and students. One such pilot program in England achieved a reported 9 percentage point increase in walking (a 22 percent relative increase) and a decrease in drive-alone trips of 7 percentage points (a 17 percent relative decrease). A large-scale application in Melbourne, Australia, had a reported overall relative increase in walking of 8 percent and decrease in auto passenger trips of 13 percent. Bicycling and transit use changes were either small or seemed (in Melbourne) to relate primarily to other instruction, at individual schools, stressing public transportation safety or bicycling safety. The school-based individualized marketing efforts proved heavily dependent on teacher interest and time availability, and survey execution reflected lack of much direct involvement by appropriately specialized practitioners (Department for Transport, 2005, Australian Government, 2005).

Recent Individualized Marketing Developments. Recent U.S. individualized marketing applications in the sector of the country extending north from the San Francisco Bay Area through Portland to Bellingham, Washington, have added to the menu of "convincing phase" enticements, particularly in the form of events. Evaluations of these innovative programs has mostly been too limited, and lacking in discernible outcome differentials relative to other individualized marketing projects, to support firm conclusions on effectiveness of expanded information and activity menus. These projects and their evaluations are the subject of the "Variations on Individualized Marketing in the North West United States" case study. It may be that the more important role of the walking and bicycling tours, workshops, and classes most of these projects have added is in the enhancement of perceptions concerning governmental efforts to improve active transportation facilities and services. They clearly are supportive of good publicity (City of Portland, 2010).

Chapter 11 reported in 2003 that an "avenue yet to be explored is the potential for making transit [information] websites part of individualized marketing efforts . . . " Evidence has still not been encountered of significant movement toward leveraging transit (and now bicycle) website personalized itinerary-planning tools and other website aids as part of individualized marketing information provision, thus the seeming potential remains speculation.[50]

Physical Activity Promotions and Interventions

Physical inactivity poses substantial risks to both personal and public health, as documented under "Public Health Issues and Relationships" in the "Related Information and Impacts" section. Seeking to increase physical activity has thus become a major thrust of contemporary public health policy. Walking, even at no more than 3 mph, fully qualifies as beneficial moderate intensity exercise. Walking for either recreation or transportation counts (Ogilvie et al., 2007), including walking to and from public transit (Besser and Dannenberg, 2005). Bicycling has similar health advantages (Department of Health and Human Services, 2008, de Nazelle et al., 2011).

Interventions to promote active transportation are often considered for public health programs. As with transportation marketing, however, questions arise as to effectiveness and the nature of outcomes. The need for information on results has been comprehensively addressed by a systematic review of published studies from many countries, but mostly the United States and Australia, prepared at the Scottish Physical Activity Research Collaboration (SPARC) of the University of Strathclyde. Any study that included promotion of walking was considered for inclusion, even if other modes of active transportation or exercise were promoted as well. To the extent possible, the researchers summarized outcomes in walking activity measured by minutes walked; thus very little mode share information is presented (Ogilvie et al., 2007). An added limitation from a transportation

[50] Portland's SmartTrips campaigns have since 2005 offered participants a popular personalized Transit Tracker™ card with the ID numbers of nearby bus stops. With these numbers the user can obtain real-time bus arrival times via telephone or a number of electronic options (Portland Office of Transportation, 2005; City of Portland, 2010). There has been no reporting found, however, of personalized-marketing outreach providing instruction or assistance in use of Internet transit or bicycle route-planning tools and related website maps, schedules, etc.

perspective is the lack of reporting on bicycling outcomes. Nevertheless, successes and failures in promoting walking have a useful degree of transferability to many aspects of cycling promotion.

Table 16-62 summarizes the conclusions drawn in the SPARC study on measures taken to promote walking in general. (Actions to promote walking for transportation were covered either in one of the two previous primary transportation marketing discussions or earlier under "NMT Policies and Programs"—"Schoolchild-Focused Programs.") Table 16-62 is organized by the five walking-in-general intervention approaches used in the SPARC categorization.

Table 16-62 Conclusions by Promotion Category about General Walking Interventions

Approach	Description and Analysis	Walk Exercise Outcomes
1. Brief advice to individuals (6 studies reviewed)	Brief tailored guidance was given face-to-face to sedentary adults (4 cases) or other adults by a medical or exercise specialist in a clinical or workplace setting. The studies were split evenly between the U.S. and Australia and 5 involved randomized controlled trials.	The 2 studies with follow-up periods of no more than 6 weeks found statistically significant net increases in self-reported walking (13-27 minutes/week). In the 4 studies with 6 to 12 month follow-up periods, only 2 found significant increases (30-44 minutes/week).
2. Remote individual support (3 studies reviewed)	From 12 to 16 counseling interventions over 12 to 24 weeks were communicated to sedentary adults via telephone or Internet. All studies were randomized controlled trials in the U.S.	All 3 studies found statistically significant net increases in self-reported walking of 32-62 minutes/week after 3 to 6 months.
3. Group-based promotion (6 studies reviewed)	Organized walks (3 cases) or group meetings/education (3 cases) for various adult groups. Of the studies, 3 were in the U.S. and one each were in Brazil, Scotland, and the Netherlands, with half involving randomized controlled trials.	The randomized studies were more likely to find a significant increase in self-reported walking (as much as 73-146 [a] minutes/week) than the non-randomized studies with lower validity rankings.
4. Pedometer-based support (7 studies reviewed)	Various forms of counseling and support to inactive or overweight (3 cases) or other diseased, healthy, or elderly groups (4 cases), from adolescent on up, reinforced by use of pedometers to help track goals achievement. Of reviewed studies, 3 were in the U.S., 2 were in Australia, and 1 each were in Canada and Scotland. All but 1 were randomized controlled trials.	Of 4 studies with follow-up periods of no more than 3 months, 3 found significant net increases in step counts or self-reported walking (54-181 [b] minutes/week) and 1 did not find results of significance. Of 3 studies with longer follow-up periods all found that significant net increases in step counts seen after 4-16 weeks were not sustained as measured at 24 weeks or 1 year.
5. Community-level promotion (5 studies reviewed)	Community-wide combinations of approaches, such as public relations events, walking groups, and newsletters or brief advice, and including a focus on path/park information (3 cases) and/or media campaigns (3 cases). The studies, 4 in the U.S. and 1 in Australia, were non-randomized panel studies (3) or repeated cross-sectional studies (2).	The 2 programs with the more substantial mass media components and supporting activities found significant net increases in self-reported walking (60-75 minutes/week) after 12 months or an unspecified period. A 5% increase in walking was found in 1 study. The other 2 programs had outcomes that were small and not significant.

Note: [a] Value of 146 minutes is estimated from the median walking differential of 7.3 miles/week found at 10-year follow-up. Increase at 2-year follow-up was 2.6 miles (52 minutes).

[b] Value of 181 minutes is for adolescent girls (the only non-adult trial).

Source: Assembled from Ogilvie et al. (2007).

The SPARC researchers concluded that people can be encouraged to walk more through interventions targeted at individuals or households and tailored to individual needs. Evidence was found less convincing in the case of measures taken at the institutional level, whether workplace, school, or community. The more substantial increases relative to baseline walking occurred with the most sedentary people, who also were the subjects of many of the general walking interventions. Targeting persons more motivated to change, common in programs focused on promoting environmentally friendly and/or active transportation, also led to larger increases in walking.

In summary, the SPARC researchers judged that "[t]he most successful interventions could increase walking among targeted populations by up to 30–60 minutes a week on average, at least in the short term." The successful transportation-focused individualized marketing examples they examined led to walking increases of up to 15–30 minutes a week. By comparison, getting 30 minutes of moderate intensity exercise on most days is the current minimum desirable activity recommendation. The researchers warn that, so far, the available intervention research presents stronger evidence of efficacy—the potential illustrated by ability to produce desired results in a controlled setting—than of effectiveness under real world conditions (Ogilvie et al., 2007). Additional evaluations of transportation-focused individualized marketing were provided in the preceding "Individualized Marketing" discussion.

A major question is sustainability of intervention results over time. Only five of the 27 studies covered in Table 16-62 examined this issue. One found evidence of intermediate and long-term sustainability of walking increases (7.3 miles/week more in a 10-year follow-up). It involved a program for post-menopausal women in Pittsburgh that was relatively intensive, starting with twice-weekly walking training for 8 weeks, and followed with encouragements and advice including some home visits. Another trial found intermediate term sustainability (12 months) for initially inactive participants but none for participants already walking 15–60 minutes/day at the beginning. Typical of the other three studies was an intervention with pedometers that found an increase of 1,500 steps/day at 12 weeks, dropping to under 700 steps/day at 24 weeks—no longer statistically significant (Ogilvie et al., 2007).

UNDERLYING TRAVELER RESPONSE FACTORS

The underlying factors that motivate or deter selection of non-motorized travel (NMT) as a means of conveyance and/or exercise are examined in this section. As with other modes of travel, trip-specific factors such as purpose, travel time, and cost play an important role. However, perhaps more than with other modes, there are also a host of environmental and user factors affecting the decision to walk or bicycle. These underlying factors do not necessarily work concurrently or with equal weighting in the decisionmaking process. Although the specifics for walking and bicycling do differ, the general categories of underlying traveler response factors are similar for both.

Responses to specific facilities, design treatments, programs, and promotion were addressed in the preceding section. Covered here—following a review of behavioral paradigms—are categories of influences on NMT behavior, including natural environment factors such as weather and topography; built environment characteristics including systems and surroundings environments; trip attributes such as trip purpose, time, distance, and cost; and user considerations like gender, age, income, and auto ownership. Also examined are interactions of factors working in combination, effects of predispositions or attitudes, and neighborhood choice (so-called "self-selection").

Behavioral Paradigms

The active transportation choice responses to various types of factors discussed in this "Underlying Traveler Response Factors" section may be thought of as occurring within one or more unifying behavioral frameworks. NMT activity choices have aspects in common with other travel decisions, but also aspects which are unique to walking and bicycling. Highlighted first is the role of direct achievement of satisfaction (characterized here as "direct-benefit demand") as an alternative to or in combination with the derived-demand decisionmaking commonly associated with utilitarian trip choices. Next is introduced a postulated mode choice decision paradigm which effectively combines the two. After that, differing choice sensitivities among mode choice, mode of transit-access choice, and route choice are addressed. Finally, the often quite different patterns of travel choicemaking by and for children and adolescents are examined.

The focus here is on mode choice (choosing to walk or bicycle versus traveling by motorized means) and route choice (such as deciding between use of a shared-use path and a sidewalk or bike lane). However, it must be remembered that other choices affect outcomes. There is the decision of whether to take a trip or exercise at all (trip generation). There is also the choice of a trip destination, such as between a store close at hand and a shopping center farther away (trip distribution). There are other choices as well, including where to live in the first place (neighborhood choice) and what time of day to travel or engage in active recreation (time of day choice).

Derived Versus Direct-Benefit Demand

Of special interest in the attempt to understand pedestrian and bicyclist behavior is a postulate—rooted in economic analysis—by researchers who have studied neighborhood walking relationships in Austin, Texas, for over a decade. They suggest that the derived-demand paradigm central to conventional travel behavior theory may not apply well to pedestrian behavior, insofar as a significant number of walk trips are taken wholly or in part for their own sake (enjoyment or exercise). The derived demand theory views urban trip-making as travel done primarily as an essential step in accomplishing some other activity of benefit, such as work or shopping (Cao, Handy, and Mokhtarian, 2006), making minimization of travel disutility a driving force in urban travel route and mode choices (Pratt, 1970). In contrast, when walking, jogging, cycling, or rollerblading for recreation or exercise, the actual activity may be the main objective. Conventional economic demand theory should apply in these circumstances where the "good" (the activity) itself is what is desired. Such cases could be characterized as "direct-benefit demand" in contrast to "derived demand."

Though developed in the Austin context on the basis of pedestrian research, the alternative perspective that some walking is a benefit demanded in its own right should apply equally well to bicycling. Indeed, it has been noted that when bicycling for exercise the path followed is itself the destination objective (Broach, Gliebe, and Dill, 2009a), much as when vacationers seek out a scenic highway. Questioning of walkers and cyclists on Indiana trails about reasons for trail visits uncovered substantial evidence of primary-purpose exercise or recreation use being combined with secondary-purpose commuting and other utilitarian travel (see ". . . Indiana Trails Study" under "Case Studies"). Similar combinations, without prioritization, were found in surveying users of the Goodwill Bridge in Brisbane, Australia (Abrahams, 2002). When there is a utilitarian purpose combined with exercise or recreation, the non-derived-demand component of the trip choice process probably affects mainly route and mode choice, possibly along with destination choice in the instance of some shopping and restaurant trips. When the motive and purpose for the activity is purely recreation or exercise, conventional non-derived demand would logically drive all aspects of the trip-making decision process including whether or not to engage in the activity at all.

The Austin pedestrian studies are covered more extensively in the preceding "Response by Type of NMT Strategy" section under "Sidewalks and Along-Street Walking"—"Sidewalk Coverage and Traffic Conditions." Also in the "Response by Type of NMT Strategy" section are several examples of active transportation behavior being fairly obviously influenced, at least in part, by conventional rather than derived demand theory. They are primarily found in the "Pedestrian/Bicycle Systems and Interconnections" subsection under "River Bridges and Other Linkages."

A Combined Mode Choice Decision Paradigm

A "Theory of Routine Mode Choice Decisions" has been proposed that encompasses elements of both derived-demand and direct-benefit-demand theory, and also draws from behavior-change-encouragement practice and includes considerations of special importance to walking and bicycling. This theory is based on study of the literature and findings of in-depth interviews and travel data collection (from persons making utilitarian-purpose tours with a shopping activity stop), including accompanying research model results. Most of the NMT trips intercepted and studied were walk trips rather than bicycle trips. The theory highlights five steps or components suggested as being critical in the choice-making process when selecting among the pedestrian, bicycle, transit, and automobile modes (Schneider, 2011):

1. **Awareness & Availability.** This component gives recognition to the reality that a person must actually have the mode in question available as an option for travel to their intended activity, and also must be aware of it, before the mode can possibly be selected.

2. **Basic Safety & Security.** One of three situational tradeoffs, this component suggests that a person must perceive that a mode offers a basic level of safety and security from traffic crashes and crime before the mode will be selected.

3. **Convenience & Cost.** Another situational tradeoff, this component acknowledges the importance of travel time, effort, and cost in the choice of a travel mode.

4. **Enjoyment.** The final situational tradeoff, this component introduces the concept that in NMT choice making, a person will a seek a mode that provides personal, social, and environmental benefits, with the personal benefits including physical (exercise), mental, and emotional considerations.

5. **Habit.** This component adds the concept that if a person regularly chooses a particular mode, that option is likely to be considered in the future as an option.

In this five-step theory, socio-economic factors are seen as influencing all of the first four steps or components, explaining differences in how a person responds in the course of each step (Schneider, 2011). This aspect and the "Awareness & Availability" and "Convenience & Cost" steps draw heavily from derived-demand urban travel analysis theory and practice. The "Enjoyment" step gives recognition to the direct-benefit aspects of obtaining exercise, fresh air, and recreation in the course of walking and bicycling. A major consideration of particular importance for walking and bicycling is brought in with the "Basic Safety & Security" step, and the "Habit" component draws from behavior-modification theory.

Other postulated paradigms offer additional perspectives. For example, one such proposal focused on barriers to walking and cycling. It asserted that a three-tiered decision process is undertaken, involving a process of considering: (1) initial barriers, (2) trip barriers, and (3) destination barriers. In this framework, trip barriers are only a consideration if the initial barriers to NMT are overcome.

Initial barriers might include safety or weather concerns. Trip barriers would include travel time, distance, and cost. Destination barriers, such as dress code, lack of showers, or lack of bicycle parking, may remain after initial and trip barriers have been overcome (Goldsmith, 1992).

Some decision paradigms are keyed more to steps found to be useful in encouraging certain behavior, such as promoting use of active transportation. The "Other Factors and Factor Combinations" subsection below (see specifically "Attitudes and Modal Biases") provides a five-stage "model of behavioral change" example adapted from smoking cessation programs.

Differential Sensitivities Among Different Choice Categories

The "Response by Type of NMT Strategy" section, in the introduction to "Pedestrian/Bicycle Linkages with Transit," provides definitions of *mode share, sub-mode share,* and *mode of access share.* In brief, mode share (or mode choice) refers to the distribution or selection among "prime modes," such as travel from origin to destination via private automobile, transit, walking, or bicycling. Sub-mode share (or choice) is a term normally applied to transit route choice involving alternative sub-modes such as local bus, express bus, and rail transit. The NMT equivalent would be something like the bicycle routing choice among cycling via a shared-use path, a bike-lane, or a street with no bicycle facility; however, no comparable term other than simple "route choice" has yet been applied to NMT analysis. Mode of access share (or choice) refers to the distribution or selection among different means of accessing or egressing transit service, such as access via automobile, feeder bus, walking, or bicycling.

Each of these choice categories exhibits different sensitivities. A highly sensitive choice relationship indicates that a modest change in parameters affecting satisfaction with a particular option or options, such as a change in the conditions outlined in the "Trip Factors" subsection below, will result in a relatively substantial shift in the travel choice involved. A choice relationship with lesser sensitivity indicates that the same change in parameters will produce a smaller shift (Pratt, 1971). Some of these relationships are only beginning to be explored in an NMT context, although mode of access choice modeling—in addition to prime mode choice modeling—has been common for some time. It is a logical assumption that relative sensitivities seen in a motorized transportation context can serve to suggest what order the NMT choice sensitivity hierarchy will take.

Relative sensitivities were initially explored in a mode choice versus transit sub-mode choice context. Sub-mode choice was found to be much more sensitive to conditions than prime mode choice. For example, sub-mode choice sensitivity in the north corridor of Chicago and its inner suburbs was found to be over 5 times the sensitivity of the prime mode choice. This meant that introduction of a new rail transit line, for instance, would cause more route shifting among persons already riding transit than between use of an auto and transit riding (Schultz and Pratt, 1971). The structure and "nesting coefficients" of modern nested mode choice models continue to show this greater sensitivity for sub-mode choice relative to prime mode choice, and also tend to indicate that the sensitivity of mode of access choice lies somewhere in between (Abdel-Aty and Abdelwahab, 2001).

Imputing the same basic relationships to NMT analysis, sub-mode choice (essentially route choice in the NMT context) is seen to be much more sensitive to changes in facility characteristics than the prime mode choice between auto, transit, walking, and bicycling. Mode of access choice between auto, feeder bus, walk, and bicycle is also more sensitive than prime mode choice, although probably with less of a relative difference than in the case of NMT route choice.

The implication for NMT planning and operations is that introduction of a new NMT facility will cause more shifting among routes and facility types than between travel modes. Thus providing a new bike lane, for example, will likely attract more bike riders from other routes than it will attract persons to the bicycling mode from other modes such as auto or transit. This circumstance is why it is difficult to assess the impact of, say, new bike lanes on the basis of counts alone, without knowing what proportion of the new riders on a street have simply made route choice shifts as compared to prime mode choice shifts. Similarly, facility improvements and land use improvements—such as having denser development close to transit stations—will normally lead to much higher shifts toward the walk mode for transit station access than toward the walk-only mode as an alternative to driving. This is why walk mode of access in Transit Oriented Development (TOD) will typically exhibit 70 to 100 percent walk shares, while transit use shares and walk-only shares will be less strongly (although significantly) affected by TOD designs. (Within the "Response by Type of NMT Strategy" section, see "Pedestrian/Bicycle Linkages with Transit"—"Transit-Oriented Development"—"Mode of Access Share Observations" for examples.)

Another example of relative sensitivity phenomena is provided by the mode shifts reported in the "Related Information and Impacts" section (see "Travel Behavior Shifts") upon opening of the Goodwill Bridge for pedestrians and bicyclists across the Brisbane River in Australia. Among four user subgroups defined by NMT mode (walk or bicycle) and trip purpose (commuter or non-commuter), only commuter pedestrians walking the bridge showed more mode changing (52 percent) than shifting of routes without a mode change.[51] Among the other three groups, only 19 percent to 34 percent changed modes as compared to shifting routes while continuing to walk or bike as before (Abrahams, 2002).

The Travel Choice Making of and for Children

It has been headlined that the travel behavior of children reflects "a world of difference" (Zwerts and Wets, 2006). Instead of the adult pattern of individual choice moderated by travel options availability and financial, familial, and some institutional responsibilities, the behavioral paradigm governing childhood travel choices is one of parental decisionmaking imposed "from above," with gradual diminution of parental control as the child grows toward adulthood.

The literature review for a 2010 appraisal of Safe Routes to School (SRTS) programs by the Washington State Department of Transportation (WSDOT) presents a conceptual framework for children's travel behavior originally developed by McMillan in the context of the elementary-school commute. The concept draws from both the transportation field, specifically the activity-based paradigm of travel behavior, and the public health field's social ecological model. The conceptual framework places parental decisionmaking at the center, posited to take place informed by mediating factors and moderating factors. Mediating factors are parental opinions developed in consideration of urban form characteristics, related neighborhood parameters, and transportation options. Moderating factors are exogenous to the trip to school and the immediate environment. The moderating factors intensify or diminish the impact on parental decisionmaking of the mediating factors. The conceptual framework is rounded out by presumption that the parental decisionmaking determines the child's mode of travel to and from school, which if active transportation to school (ATS) is selected, leads to health, environmental, and congestion relief outcomes through the mechanisms of physical activity, air pollution reduction, and traffic volume reduction (Moudon, Stewart, and Lin, 2010).

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[51] In this particular instance, many of the mode changes identified were not actually shifts in the primary mode of travel, but rather changes in the mode of egress/access to/from downtown Brisbane in connection with use of a motorized mode such as auto or train (Abrahams, 2002).

An example is provided by a trip from home to school that requires passing by vacant and dilapidated buildings. This urban form factor may cause the parent to believe that the neighborhood crime rate is high, a mediating factor. (Other examples of mediating factors might include perceptions of heavy or light traffic, condition or lack of sidewalks, or presence of crossing guards.) A mediating factor of perceived high crime levels may result in parental judgment that having a child walk to school would be unsafe. If the child is young, age being an example of a moderating factor, this fear may be intensified. (Other examples of moderating factors include cultural norms and attitudes.) In the example at hand, the mediating and moderating factors may lead to the child being driven to school, lessening the child's physical activity and increasing risk of obesity, a health outcome.

Some researchers have concluded that children's travel behavior is not so much dictated as negotiated between parent and child. Clearly parental control will be dominant in the case of younger children, but will tend to become less so as the child matures (Moudon, Stewart, and Lin, 2010). A child-travel-to-school mode-choice modeling effort has been constructed in this context, utilizing the 2001 NHTS as the database, and covering the auto passenger, school-bus/transit, and walk modes. The structure of the multinomial logit model assumes that parents, together with their children, choose the child's travel mode as a family unit to maximize household utility (McDonald, 2008). A broad definition of utility is implied here—a definition that could encompass such factors as child safety. Variables tested that clearly would fall in the categorization of moderating variables include age, gender, and number of siblings.

The modeled auto share elasticity for auto travel time was small (–0.08), and negligible for walk share (+0.01). On the other hand, the modeled walk share elasticity for walk time, though still in the inelastic range, was quite pronounced (–0.75). This elasticity suggests that a 10 percent longer walk time to school is associated with a 7.5 percent lower walk mode share. The walk share cross elasticity for auto travel time was small by comparison (+0.10). Population density exhibited a very small negative auto share elasticity (–0.02) and a modest walk elasticity (+0.12).

Among child characteristics variables, age was estimated to have an auto mode elasticity of –0.58 and a walk mode elasticity of +0.82. Each additional year in age was associated with a 1.4 percent lower auto mode share and an 0.4 percent higher walk share. Gender differences were insignificant in this formulation, which could not include bicycling for lack of sufficient data. Number of siblings had an auto share elasticity of –0.10 and a walk share elasticity of +0.15, perhaps reflecting both difficulties of chauffeuring more children to school and opportunities for family members to walk together. Race was an insignificant factor when other parameters such as walk time to school were accounted for. Higher income had a positive effect on being driven to school and a negative effect on walking to school, with elasticities of +0.21 and –0.26, respectively. Oddly, the vehicles per driver ratio exhibited a negative auto mode elasticity (–0.02). The corresponding walk elasticity was logical and somewhat more substantial (–0.15). The pseudo-R^2 for the model was 0.27 (McDonald, 2008).

The estimate of a higher walk share for each additional year of age presumably relates, at least indirectly, to growing rates of parental permission to walk or bike as children mature. SRTS parent survey data collected from 2007 through 2009 from over 1,200 schools in 47 states bears on this relationship. The cumulative percentage of parents reporting they would allow their child to walk or bike to school "without an adult" was, in order by grade, 1 (kindergarten), 4 (1st), 9 (2nd), 22 (3rd), 39 (4th), 58 (5th), 78 (6th), 90 (7th), and 100 percent (8th) (Marchetti, 2010).

Another set of figures relevant to parent versus child decisionmaking on school travel mode comes from parent and student surveys at elementary and middle schools in Hillsborough County, Florida (the greater Tampa area). A total of 489 classroom tally sheets and 3,213 parent survey forms were returned, representing response rates of 84 and 26 percent, respectively. The tallies covered five consecutive days of travel to and from kindergarten through 8th grade. It was found that 79 percent of students had asked permission to walk or bike to school, while 33 percent of parents reported allowing or planning to allow their child to do so at an elementary or middle school grade level they deemed appropriate. (It will be noted that this result does not fit well with the SRTS survey data reported above, which adds to 100 percent permission to walk or bike without an adult by 8th grade, likely because of differences in the survey question or its administration.)

On the average Hillsborough County trip tally day, 8.3 percent of boys and 13.5 percent of girls actually walked, and 4.6 percent of boys bicycled (no girls did so), for an average walking and bicycling to school rate of 13.2 percent (Zhou et al., 2009). This compares with U.S. SRTS student and parent survey results, for 2007–2009, that averaged about 15 to 16 percent walking or biking (Marchetti, 2010).

The Hillsborough County school travel data allows examination of differences in mode coming and going. Of 419 children reporting walking to and/or from school, 16.2 percent walked only to school, 7.4 percent walked only from school, and 76.4 percent walked in both directions. All 73 children who bicycled did so in both ways (Zhou et al., 2009). It may be assumed that mode choice differences by direction are commonplace in many situations, and for adults as well as children, but simplified reportings of mode share (as contrasted to reportings based on travel diary surveys, for example) often fail to take directional differentials into account.

The unique balance of concerns affecting child travel choices lead to a somewhat different set of factors being taken into account than seen with adult travel choices, and with a different ordering of priorities as well. Results of investigating child travel factors in the context of the trip to and from school are presented below in the “Trip Factors” subsection (see “Schoolchild Trip Factors”).

Environmental Factors

Two broad categories of environmental factors play a role in influencing the amount of walking and bicycling. In this chapter, these categories are organized for convenience of discussion rather than in any hierarchy of importance. First, is the natural environment, including weather, season, climate, topography, and daylight and darkness. This natural environment can to some extent be mitigated through facilities. For example, walkways can be heated and/or covered, ravines bridged, and pathways lighted. Many aspects remain, however, beyond practical means of human control.

Second, is the built environment, as expressed in land use configuration and transportation infrastructure. The density of development, mix of uses, orientation of streets, and presence and nature of facilities for non-motorized travel are key built environment attributes. Facility- and neighborhood-specific built environment factors and their effects were covered earlier in the “Response by Type of NMT Strategy” section. Within that section, see especially “Pedestrian/Bicycle Friendly Neighborhoods.”

In this “Environmental Factors” subsection a more over-arching view of the built environment is taken. This overview is expressed under “Systems Environment” in terms of *accessibility* and *connectivity,* and under “Surroundings Environment” in terms of *facility compatibility* measures and *ambiance.* Natural environment factors are covered first.

Natural Environment

Precipitation and temperature are, as would be expected, important factors in the day-to-day choice of biking or walking as travel modes. Seasonal effects are also observed. There may not be that much year-round climate impact, however, on overall annual non-motorized transportation (NMT) usage rates.

Rain or snow leads to fewer walking and bicycling trips during the weather event except for pedestrians having covered walkway systems available. Very hot or cold weather also reduces the attractiveness of NMT activity open to the elements. Nevertheless, although weather is regularly mentioned in surveys as a consideration in choosing to bicycle or walk, it is best viewed as a day-to-day factor. Weather appears to affect the incidence of walkable or bikeable days rather than the overall choice to walk or bike in general (Goldsmith, 1992, Heglund, 1980). This finding appears to hold true whether one looks at data for the United States or elsewhere.

For ease of presentation, weather, season, and climate effects on walking are treated separately from effects on bicycling. Those discussions are followed by all-NMT-modes data on seasonal variations. Effects of topography and daylight and darkness conclude the natural environment discussion.

Weather, Season, and Climate Effects on Walking. Studies in the Province of Ontario, Canada, and New York City have each illustrated that temperature extremes and precipitation are deterrents in the day-to-day decision to walk. Precipitation proved a greater impediment than temperature in the Ontario research, which was based on a stated preference survey. Extremely cold temperatures (less than 20° C (–4° F)) and hot temperatures (greater than 30° C (86° F)) each were estimated to deter more than one-third of Ontario respondents from walking. It was further estimated that about 70 percent would not walk if there was heavy snow.

In direct observations in midtown Manhattan, heavy rain reduced the number of sidewalk pedestrians on 42nd Street by 24 to 55 percent, depending on the intensity of the rain. Researchers found that most affected pedestrians either used the subway or changed or cancelled their itineraries. Finally, in Seattle, a locale known for its moderate temperatures and persistent but usually gentle precipitation, a survey found that 9 percent of respondents identified weather as a reason for not walking more often. The researchers cautioned that this figure may be inconsistent with other research, because the question focused on reasons for not walking more often, rather than about the specific effect of weather on walking overall (Goldsmith, 1992, University of North Carolina, 1994).

NCHRP Project 08-78, "Estimating Bicycling and Walking for Planning and Project Development," has reviewed the state of environmental-factors research as part of its work effort. It located direct weather-effect observations for Montpelier, Vermont, published by Aultman-Hall et al. in 2009. Pedestrian flows were obtained for an entire year with infrared sensor monitoring of a single downtown intersection. Temperature, humidity, precipitation, and wind speed data from a weather station 3 miles away were linked to the pedestrian count data hour by hour. Winter precipitation was found to reduce hourly volumes by 16 percent. Precipitation in the rest of the year was associated with approximately a 13 percent reduction. Weather effects such as cold and precipitation together consistently reduced overall levels of walking, but by an amount less than 20 percent. The estimated maximum combined effect of weather variables, barring extreme events, was a 30 percent reduction in pedestrian flows. The impact of winter overall (January through April) was significant with a 30 percent negative effect relative to the rest of the year, but it was not possible to know what proportion of that effect related to visitor and tourist traffic variations (Kuzmyak et al., 2011).

Spring/summer infrared counter monitoring, for 3-1/3 months, of sidewalks adjacent to 11 intersections in the San Francisco East Bay Area's Alameda County provides observations from a more temperate climate. Here, instead of a 13 percent reduction, measurable rainfall (≤0.01 inches) was associated with a 7.1 percent pedestrian traffic reduction relative to average flows. (There were only 8 hours of measurable rainfall in the study period.) Cloudy conditions, defined as less than 60 percent of the solar radiation average for the hour and place, were associated with 5.3 percent less walking activity. Temperatures at or below 50° F saw volumes lower by 2.3 percent while temperatures at or over 80° F, between noon and 6:00 PM, were accompanied by a 3.6 percent volume reduction. On the other hand, temperatures at or over 80° F during other hours were associated with an 0.4 percent pedestrian volume increase (Schneider, Arnold, and Ragland, 2009). Though the researchers did not report on the possibility, one might speculate that hotter weather induced some shifting of walking out of the heat of the afternoon into other hours.

The argument has been made that the perception of adverse weather may be a stronger deterrent to walking than the weather itself. This possibility has not been much researched, and neither has the effect of humidity (Kuzmyak et al., 2011). The low levels of walking in the southeastern and south-central United States have been well documented, as well as the parallels with higher temperatures (Alliance for Biking & Walking, 2010), but descriptive or bivariate analysis alone cannot separate heat and humidity effects from confounding factors such as prevalence of sprawling cities in much of the south.

Most regular pedestrians readily adapt to normal weather. An umbrella or rain coat make walking in the rain less unpleasant, and clothing can be adjusted to the temperature if dress codes allow or do not pertain. Nonetheless, weather extremes are significant deterrents, and experience from cities with skywalks clearly suggests a preference during inclement or uncomfortable weather for climate-controlled pedestrian environments. Data on skywalk versus sidewalk route choice in response to weather are found under "Response by Type of NMT Strategy"—"Pedestrian Zones, Malls, and Skywalks"—"Pedestrian Skywalks."

Weather, Season, and Climate Effects on Bicycling. Weather may have a greater impact on bicyclists than on pedestrians because it is not as simple to mitigate, especially in the case of precipitation. In addition to comfort considerations, precipitation introduces concrete safety concerns. Spray from passing motorists and the bicycle itself can prove messy and potentially hazardous. Traction and visibility can each be adversely impacted during rain or snow. Several researchers have observed that precipitation is probably the most important climactic factor for bicyclists. Respondents to surveys conducted in several cities (including Boston, Gainesville, Portland, and Vancouver) report adverse weather to be influential in the decision not to cycle (mentioned by 86, 90, 52, and 51 percent, respectively, with multiple responses allowed) (Goldsmith, 1992, Pinsof, 1982). There are significant numbers of all-weather cyclists, however, who dress warmly in the winter, coolly in the summer, and have appropriate equipment for precipitation days.

The existence of seasonal effects of heat, cold, and rain on bicycling is supported by empirical observations/counts made around North America and internationally. Chicago studies of bicycle paths found lower usage from December to February as compared to April through October, when at least half the days have low temperatures no colder than 40° F (Welzenbach, 1996, Pinsof, 1982). In Santa Barbara, 49 percent of users of a bicycle-transit trailer service said they would not use their bike in rainy weather, and the actual usage did decrease during the December-to-March rainy season (Newman and Bebendorf, 1983). In the Netherlands, known for extensive bicycling, there is nonetheless a reduction in winter. Weather there has been observed to have the strongest impact on recreational cyclists. On utilitarian-trip routings and in built-up areas the fluctuations per month are generally a maximum of 30 to 40 percent relative to the yearly average (C.R.O.W., 1993).

A Washington State study performed extensive field data collection and analysis of effects on bicycling of both weather changes and general seasonal trends. Weekday bicycle counts were gathered at five locations over a variety of conditions. In all locations observed, rider volumes were lower on cloudy days than on sunny days and lowest by far on rainy days. In the AM peak period, volumes of all cyclists recorded on rainy days were 45 to 60 percent lower than on sunny days, and volumes recorded on cloudy days were 10 to 20 percent lower than on sunny days. In the PM peak period, rainy day cyclist volumes were 55 to 68 percent lower than on sunny days, while cloudy day volumes were 25 to 41 percent lower. As in the Netherlands, the weather seemed to have the strongest impact on recreational cyclists. The researchers suggest that utilitarian riders are about one-half to one-third as sensitive to adverse weather conditions as recreational riders (Niemeier, Rutherford, and Ishimaru, 1995a). It has further been noted that the heightened effect in the PM peak hours likely reflects the higher proportion of non-commuter cyclists in those hours as compared to the morning peak. Studies in Austria and Australia confirm the higher sensitivity of recreational riders to weather extremes than bicycle commuters (Kuzmyak et al., 2011).

The Washington State researchers used selected counts and National Weather Service data to model seasonal impact on volumes, concluding that winter bicycle counts could be counted on to average about 50 percent of summer counts (Niemeier, Rutherford, and Ishimaru, 1995a). A number of additional studies find winter months to exhibit about one-half the cycling activity of summer months. This effect may, of course, relate in part to factors other than weather, such as vacation schedules. Examples of finding approximately a 2:1 cycling activity relationship between summer and winter include the National Omnibus Household Survey for November 2001 to October 2002, (Bureau of Transportation Statistics, 2002) and the 2001 NHTS. Seasonal adult bicycling daily rates established in the 2001 NHTS were 1.1 percent of the U.S. population in summer, 0.88 percent in spring/fall, and 0.56 percent in winter, relative to the annual average of 0.9 percent (Krizek et al., 2007). A Boston study found that cycling activity decreased when temperatures fell below 40° F, and that only 10 percent of the student population continued to cycle for a full 10–12 months of the year. That compared with 22 percent reported bicycling for 6 to 9 months (University of North Carolina, 1994).

Where the weather is more severe, wintertime differences may be greater. In a Toronto survey, 88 percent of utilitarian bicyclists reported cycling in the spring, 98 percent in the summer, 89 percent in the fall, but only 23 percent in the winter (City of Toronto, 2001). The Nonmotorized Transportation Pilot Program Evaluation Study avoided summer vacation effects by surveying from September 2006 into January 2007. The percentage of respondents reporting having bicycled on their survey day declined from 3.2 percent at the beginning of the survey down to 1.1 percent overall in the five urban areas surveyed, including a drop from 4.4 percent to 0.9 percent in Minneapolis (Krizek et al., 2007).

In contrast to seasonal-effect findings such as these, a 1990 Boulder (Colorado) Diary Survey revealed that “season of the year had little effect on mode choice” and that rainy weather tended to reduce bicycle and pedestrian travel by only 2 to 3 percent (University of North Carolina, 1994). However, a newer study of bicycle volumes on four trails in Boulder concluded that summer counts were 2.3 to 4 times higher than in winter across the four trails. Modeling of bicycle counts and weather data showed bicycling activity to increase with temperature up through 90° F. As daily highs exceeded 90° F, a decline set in. Modeled effects of snow and rain indicated bicycling reductions in response, but the results were not statistically significant. Fairly similar results have been reported by a study in the United Kingdom, where cycle count and weather modeling detected a 3 percent increase in cycling volumes per 1° C (1.8° F) increase, with no maximum established. The U.K. research suggested that whether it rained or not had more influence than the amount of rain (Kuzmyak et al., 2011).

Daily and seasonal effects notwithstanding, in descriptive and bivariate analyses of cycling levels and annual climate data for several cities (20 cities in the more recent such analysis), neither temperature nor precipitation showed any obvious correlation with a city's *average overall* bicycle-to-work mode share. These studies worked with annual measures of daily temperatures and the number of days per year with measurable precipitation. Essentially the same conclusion was reached in an analysis of bicycle commute shares in each of the 50 states, done using average winter and average summer temperatures as weather variables. In these studies the mode share data was derived in terms of usual travel mode and did not capture short-term, day-to-day impacts (Goldsmith, 1992, Alliance for Biking & Walking, 2010).

Three additional nationwide aggregate analyses, designed to investigate the impact of bike lane or lane-and-path system extent on commuter bicycling rates, took the further step of utilizing multivariate analysis. They again used U.S. Census or American Community Survey (ACS) journey-to-work data, and have been detailed in the "Response by Type of NMT Strategy" section (see "Bicycle Lane System Coverage"—"Bicycle Lanes and Routes"). The first utilized a cross-sectional model describing likelihood of bicycling for the work commute under average conditions in 16 cities. Mean daily temperature had insufficient significance for retention in the final model. Rain days during the year proved, on the other hand, to be a significant and negative explanatory variable. Nevertheless, each rain day had only fractional importance in comparison to either having one more mile of bicycle facilities per 100,000 residents or one percentage point more of college students among the population (Nelson and Allen, 1997). The second such study covered 42 large cities. It likewise found rain days to be the one statistically significant weather variable, when estimating overall commuter cycling share, though it was not a major contributor to explanatory value of the research models (Dill and Carr, 2003).

The third and largest such study also modeled aggregate city-level commuter cycling, facility-extent, and weather data, this one on the basis of 90 of the 100 largest U.S. cities. Number of days below 32° F and annual precipitation levels proved to have small and insignificant associations with bicycle commute share in preliminary bivariate statistical tests and were omitted from the final models. Annual number of days above 90° F did prove statistically significant in bivariate analysis and was included in the multivariate models. In these final formulations the measure had a negative relationship to cycling levels but failed to show statistical significance (Buehler and Pucher, 2011).

Given these various mixed results showing weak or no significant weather effects on annual (or equivalent) levels of commuter bicycling, it is likely that while temperature and precipitation clearly affect day-to-day cycling decisions, they do not overly constrain the annual market for bicycling to work in any particular area. There is insufficient information to draw parallel conclusions for either utilitarian or recreational non-work-purpose cycling or for walking.

Combined Walk and Bike Seasonal Effects. Seasonal usage rates have been obtained for a number of off-road shared use paths, covering all facility-user traffic in combination. Though the paths do serve some utilitarian NMT trips, almost all of those included are predominantly taken advantage of for recreation and exercise. Thus it would be inappropriate to assume, for example, that the seasonality-of-use extremes tabulated would apply to the likes of a downtown sidewalk or a transit station access route.

Table 16-63 gives percentages of observed or estimated path traffic in each season. The paths or path groupings covered are listed in increasing proportion of wintertime usage. Month by month detail for the Indianapolis and San Diego observations is provided within the "Related Information and Impacts" section (see Table 16-103 in "Facility Usage and User Characteristics"—"Off-Road Shared Use Paths"—"Path Volume and Usage Patterns").

Table 16-63 Path Use Seasonal Distribution Percentages, Walking and Cycling Combined

Trail(s) / Location	Type	Winter	Spring	Summer	Fall
30 Indianapolis locations, urban/suburban	Various	7.6%	25.4%	43.6%	23.4%
3 Hennepin Co. (Minneapolis) trails, urb./sub.	Rail trails	9.0	24.7	39.3	27.0
4 Rhode Island trails, suburban/towns/rural	Rail trails	9.2	29.4	31.5	29.8
Monon Trail, Indianapolis, urban/suburban	Rail trail	10.8	29.0	38.2	22.0
W&OD Trail, Northern Virginia, sub./exurban	Rail trail	12	28	39	27
Gilman Bike Path, San Diego, suburban	I-5 corridor	17.4	23.2	36.2	23.2
Iron Horse Trail, S. F. East Bay, exurban	Rail trail	18.2	28.0	28.0	25.9
Strand Bike Path, San Diego, urban/scenic	Beachfront	18.6	27.0	31.6	22.8

Notes: Indianapolis and San Diego percentages based on path counting, other values based on survey responses to questions on path use by season. W&OD Trail percentages as reported.

Count-based percentages treat December through February as winter, March through May as spring, and so on. Other values based on survey respondent perceptions of season.

Sources: Jones (2009), Hennepin County (2005), Gonzales et al. (2004), Bowker et al. (2004), East Bay Regional Park District (1998), with seasonal percentages calculated (except W&OD Trail) by the Handbook authors.

Despite derivation of seasonal percentage distributions utilizing disparate methodological approaches, ranging from counts to self-reported survey responses to questions in a variety of formats, the eight paths and path groupings in Table 16-63 form a logical progression when listed from lowest to highest relative wintertime usage. North Central and Northeast U.S. paths have the least wintertime usage, with the tightest mid-year concentration of use in the North Central states. The Mid-Atlantic W&OD Trail is clearly intermediate despite the questionable four-season total of 106 percent, and the least season-by-season variation is found in mild California climates.

Topography. Pedestrians and bicyclists both exhibit a resistance to change in grade. Climbing hills is more strenuous than traversing flat terrain and requires the individual to be more physically fit. Moreover, the exertion associated with difficult terrain may cause sweating to be more of a concern and reduce the number of willing participants where condition upon arrival is a concern. A study of bicycle commuters in England revealed a strong negative correlation between the hilliness of an area and the level of bicycle commuting. The resistance of pedestrians to climbing is among the factors that help explain reluctance to use many of the overpasses or underpasses that have been provided for crossing roadways (Goldsmith, 1992, AASHTO, 2001).

Quantitative confirmation of these observations on effects of topology is provided by the City and County of San Francisco travel demand modeling effort introduced earlier in the "Point-of-Destination Facilities" subsection (see "Other Destination Amenities") and more fully covered in Chapter 15, "Land Use and Site Design." Topology had the highest impact on work and work-based tours of five trip destination pedestrian environment characteristics scaled for model use by a Delphi panel. (Although presence of steep grades was the major component of the topology measure, other natural barriers were also included.) It was second to vitality in effect on "other" purpose travel and individual work-related trips within tours. Milder topology (flatter grades and fewer natural barriers) was found to be an indicator of higher mode shares for walking, walk-access transit use, and bicycling. The strongest effect was on choice of the bicycle mode for school trips (Cambridge Systematics et al., 2002).

Comparative sensitivities for slope, published in 2003 by Cervero and Duncan, were reviewed in NCHRP Project 08-78. Modeling of walk and bicycle mode choice using the year 2000 [San Francisco] Bay Area Travel Survey (BATS 2000) found both NMT modes to be negatively affected by steeper gradients but with almost twice the adverse effect on bicycling as on walking. Weather was not included in the bicycle-share model, but slope in the walk-share model—measured as rise divided by distance—was a shade more important (about 14 percent more) than rain on the travel day (Kuzmyak et al., 2011).

Explanatory modeling based on GPS-and-network-analysis of non-recreational bicycle route choice in Portland, Oregon, provides estimated elasticities that quantify the negative route choice effects of upgrades. Average upgrade slope (feet or meters of gain in elevation per 100 feet/meters), ignoring downgrades, was used as the analytical measure. An "elastic" response was estimated, with percentage decrease in cyclists choosing a route moderately exceeding the percentage increase in upgrade incurred. The specific elasticity estimated was about –1.3 (Broach, Gliebe, and Dill, 2009a). It was further estimated that for the typical utilitarian bicycle trip, a cyclist would be willing to go 27 percent more distance to avoid each 1 percent additional average upslope (Broach, Gliebe, and Dill, 2009b). This effect was found to be stronger for women than for men, and more pronounced for infrequent cyclists than for frequent cyclists (Dill and Gliebe, 2008).

These San Francisco and Portland research findings concerning topography pertain primarily or exclusively to utilitarian NMT trips. Cross-sectional modeling drawing on Seattle GIS data, down to the parcel level, and Walkable and Bikeable Communities project survey results, confirms the negative association between utilitarian walking and even moderate slopes. Recreational walking, however, had a positive association with slope. Both associations were statistically significant in most model formulations, but the strongest significance was found for the positive relationship between recreational walking and slope. Recreational walking was about 15 percent more likely to occur in the presence of grades averaging 8 percent (8 feet or meters elevation change per 100) within a 1 km. buffer. The researchers speculate, "Recreational walkers may like the views and greater exercise opportunities that come with a hilly landform." Effects on cycling were not examined (Lee and Moudon, 2006a).

Daylight and Darkness. A limited amount of research has been done on the discrete impact of daylight versus darkness on the choice of pedestrian or bicycle trip making. It is clear that visibility would be a concern of any pedestrian or bicyclist traveling after dark. In stated preference surveys, "adequate lighting" is often given as a consideration for such travelers. Visibility is important from the standpoint of being able to see where one is going, but also so that one may be seen by motorists. Perceived safety from crime is also related to daylight and good lighting as compared to darkness. Safety concerns are addressed further in the "User Factors" subsection, and in the "Safety Information and Comparisons" subsection under "Related Information and Impacts."

A Florida survey of NMT found that barely over two percent of trips were made at night. The remainder were nearly evenly split among the morning (29 percent), afternoon (30 percent), and evening (39 percent). Almost all of these trips were made under daylight conditions (95 percent). The remainder were made in the dark (2 percent) or at dawn or dusk (3 percent) (NuStats International, 1998).

The only research reviewed in NCHRP Project 08-78 that attempted to explicitly control for darkness was the previously mentioned walk and bike share model derivation done on the basis of San Francisco region BATS 2000 travel data. The mode choice model coefficients in that study indicated that cyclists are around 5 times as sensitive to traveling in the dark as pedestrians. The walk model darkness coefficient suggested "a minor but significant [. . .] deterrent effect" for walking in the dark (Kuzmyak et al., 2011). The deterrent effect of darkness was about 1/12 of the effect of having to walk an extra mile and between 1/4 and 1/5 as disadvantageous as precipitation. Choice of walking was 1/25 as sensitive to darkness as to slope expressed as rise/run for the entire trip. For bicyclists, darkness held roughly 1/10 the importance of slope, but was more than twice the deterrence of having to cycle an extra mile. Both models covered only non-work trips, under 5 miles in length, made for purposes/durations not likely to entail carrying large packages (Cervero and Duncan, 2003).

Other indications have been seen of the effects of darkness. When three poorly lit streets and a footpath in London received street lighting improvements, pedestrian volumes (stratified by gender and presumably after dark) increased by 34 to 101 percent; 51 percent on average (Cao, Mokhtarian, and Handy, 2007, Heath et al., 2006). The strong afternoon/evening walking and bicycling peak seen on six Indiana trails in year 2000 September counts was observed to move forward in time of day, and became compressed, with the onset of shorter days in October (Indiana University, 2001). These two studies are covered, respectively, in the "Response by Type of NMT Strategy" section (see "Sidewalks and Along-Street Walking"—"Individual Sidewalk Provision Examples" including Table 16-1) and in the "Case Studies" section under "Six Urban, Suburban, and Semi-Rural Trails—Indiana Trails Study" (see "Results" discussion including Table 16-136).

Systems Environment

The built environment has a role in influencing the prevalence of walking and bicycling that is every bit as important as the natural environment, if not more so. It has been rightly proposed that improved evaluation, planning, and design of bicycle facilities requires recognition that two components are necessary for such analyses, one for evaluating the overall system, and one for evaluating the links that make up the bicycle system's network (McCahill and Garrick, 2008). The same certainly applies with respect to pedestrian facilities, albeit at an even finer geographic scale.

The component addressing the system and network aspects of the built environment is covered here under the label "Systems Environment," and the component focusing on link evaluation is dealt with subsequently under the label "Surroundings Environment." With respect to "Systems Environment," accessibility is judged the most fundamental influence and discussed first, followed by connectivity, which together with land use and associated activity is what produces accessibility.

Accessibility. Accessibility as an analytical concept was originally developed within the transportation and land use planning community as a tool for forecasting land development, and valuing land, on the basis of existing and projected transportation facilities paired with defined land use patterns. It was later found useful as a mode choice forecasting parameter, wherein good accessibility to jobs, goods, and services via a particular travel mode indicates likely higher use of that mode than one with poorer accessibility. NMT accessibility measures are exceptionally useful for describing built environments amenable to the meeting of many daily needs by walking and cycling activity. They serve both as tools for pedestrian/bicycle-friendly development planning guidance and as walking and cycling activity estimation variables.

In his landmark exploratory paper on accessibility, Hansen defined it as "the *potential* of opportunities for interaction." Accessibility is thus an opportunity measure. It measures "the *intensity of the possibility of interaction* rather than just [. . .] ease of interaction." (Hansen, 1959). It is more than simply a measure of mobility.

Accessibility has also been defined, relying on more concrete terms, as "the ability to reach desired goods, services, activities, and destinations (together called *opportunities*)." Jobs are explicitly considered as opportunities. Such perspectives are as viewed from residences. When accessibility is viewed from the perspective of employers, merchants, or institutions, it becomes ability to be readily reached from the urban population. Four component factors make up personal and public accessibility (Victoria Transport Policy Institute, 2010):

- **Personal Mobility,** the ability to move about without incurring excessive travel time and cost. NMT mobility is provided by walking and bicycling, while motorized mobility is obtained through use of private vehicles, ridesharing, taxis, and public transportation.

- **Mobility Substitutes,** such as telecommunication allowing transfer of information or web-based sale of goods, and delivery services providing goods transfer that would otherwise require personal travel.

- **Transportation System Connectivity,** reflecting both the density of connection between the transportation network's links and directness of the individual links themselves, together arranged to provide direct and fluid passage through the overall network.

- **Land Use,** specifically the geographic arrangement of housing, activities, and destinations in general. If the geographic arrangement is compact and cohesive, then accessibility—and especially accessibility via walking and bicycling—will tend to be enhanced. If the arrangement is dispersed, as in urban sprawl, more mobility—motorized vehicle mobility in particular—will be required to maintain even a basic level of accessibility.

Accessibility can be complex to measure, particularly if all possible travel modes are covered and all mobility impedance factors are considered, including time, money, convenience, and risk. Ideally all impedances to mobility would be addressed through use of generalized cost measures (Victoria Transport Policy Institute, 2010). Gravity model formulations developed for trip distribution estimation are often drawn upon for sophisticated accessibility calculations.

Quite simple accessibility measures are nevertheless very effective in analyzing NMT accessibility. Since variations in everyday walking and bicycling speeds among facilities are much less than encountered with motorized traffic, and a significant factor in walking or cycling is simply the physical effort of locomotion, plain along-the-road (or path) distance measures can form the basis for robust accessibility calculations and comparisons. Number of activities within 1/4 mile, 1 mile, or 5 miles can be a very useful measure, with the distance selection being a function of the analysis objectives. "Activities" may be expressed in terms of jobs, retail jobs, or whatever type of destinations are of interest. Conversely, accessibility to employment, schools, institutions, or transit stations can be measured as number of households within the selected fraction or number of miles.

An example of applying this type of basic NMT accessibility measure is afforded by analyses made by the San Francisco area's Metropolitan Transportation Commission (MTC). MTC analyzed the population of, and travel generated in, all areas within 1/2 mile of commuter rail and Bay Area Rapid Transit (BART) stations, commuter ferry terminals, light rail transit (LRT) stops, and streetcar and cable car lines. (San Francisco Bay Area land use and transportation system layout is such that a large majority of the population relatively close to urban office and traditional urban on-street commercial areas was likely thereby included.) It was found that in these high accessibility areas, residents made 1/2 of their short trips (trips of 1 mile or less) by walking, compared to 1/4 for residents of other areas. It was also determined that for trips of any length, residents within 1/2 mile of rail/ferry stops were twice as likely to choose the walk mode of travel, three times as likely to choose the bicycle mode, and four times as likely to choose the transit mode (with its high likelihood of walk access and egress). Persons with both their residence and workplace within these highly transit-accessible areas made 42 percent of their commute trips by transit, as compared to 4 percent for those with neither home nor workplace in such areas (Gossen, 2006).

Recent research has also suggested that accessibility to typically interchangeable routine daily destinations such as grocery stores, banks, or libraries can be equally well or better analyzed in terms of distance to the nearest such facility instead of number of activities within a given distance (Lee and Moudon, 2006b, Moudon et al., 2005, Moudon et al., 2007). This type of accessibility measurement lends itself to a "directness" approach for computing an Accessibility Index. This is done by dividing direct ("airline") travel distance into the actual minimum travel distance to destinations. The lower the value, the better. The ideal is an index of 1.0, indicating that a truly direct walk or bike ride is possible. A value of 1.5 has been proffered as an acceptable average (Victoria Transport Policy Institute, 2011b, Litman, 2011b).

Directness research applications/outcomes are described within the "Pedestrian/Bicycle Friendly Neighborhoods" subsection of the "Response by Type of NMT Strategy" section of this chapter. The "Pedestrian/Bicycle Friendly Neighborhoods" subsection focuses heavily on the effects on walking and bicycling activity of enhancing land development density, diversity, and design, all contributors to enhanced accessibility at the fine-grained scale important to NMT trip attractiveness and practicality.

Most of the various topics covered in the "Response by Type of NMT Strategy" section address traveler response to some type of mobility enhancement involving new, improved, expanded, or better deployed NMT facilities and systems. Because many of these strategies are focused more on NMT mobility than accessibility, it is important to keep in mind that success rates may be lower in built environments with lesser underlying NMT accessibility. Accessibility environments for best transportation results are provided by compact, mixed-use development and fine-grained, high-connectivity transportation networks such as traditional grid street systems. In low-density, low-accessibility areas, residences and activity destinations are likely to be too far apart for most trip makers to contemplate utilitarian walking or bicycling even with improved facilities (Schneider, 2010).

Connectivity. Connectivity is a primary contributor to favorable walking and bicycling physical environments, largely because of its role as a key element of accessibility, but also because "directness" per se is favored by walkers and cyclists making utilitarian trips. Three measures taken together describe connectivity that is *useful* to NMT tripmakers:

1. Density of connections in the road and NMT facility network, providing more travel options and network resiliency (Victoria Transport Policy Institute, 2010 and 2011b).

2. Directness of links (Victoria Transport Policy Institute, 2011b), and interconnection into direct routes/paths. In studies of utilitarian trip making, turns—especially left turns—have been shown to render bicycle routings less inviting (Broach, Gliebe, and Dill, 2009a and b), and indications have been found that directness offers walk mode attractiveness above and beyond the benefit of walking distance saved (Moudon et al., 2007).

3. Alignment of interconnected links, in logical and direct routings, with travel needs (Alta Planning + Design, 2009a). It is in this manner that connectivity directly contributes to accessibility.

Various connectivity measures have been offered as a basis for Connectivity Indices. Examples include (Victoria Transport Policy Institute, 2011b):

- Number of roadway links divided by number of nodes, with the count of nodes including both intersections and cul-de-sac/dead-end-street termini. A grid nine square blocks in extent (not counting any exterior connections) receives a score of 1.5. It is suggested that "[a] score of 1.4 is the minimum needed for a walkable community."

- The ratio of street intersections divided by the sum of street intersections and dead ends. A score of over 0.75 is suggested as desirable.

Unfortunately, these and similar measures take into direct account neither the directness produced by the interconnections nor the association or lack thereof with desired destinations. The "directness" Accessibility Index introduced in the preceding "Accessibility" discussion encompasses all elements of connectivity more fully: direct ("airline") travel distance divided *into* actual minimum travel distance to destinations, with smaller ratios approaching 1.0 the more desirable.

A related measure, essentially *catchment area coverage,* is the proportion of the circular area described by a given radius that can be reached from the center within an actual walking or bicycling distance equal to the radius. Not only is the coverage always less than 1.0 because of the need to often angle through even a grid system, it also may be less because of cul-de-sacs, other system elements with poor connectivity, missing sidewalk links, and natural or man-made barriers. LRT station access examples in Chapter 17, "Transit Oriented Development," provide such a catchment area analysis (see the first-listed results in the Chapter 17 case study "Travel Findings for Individual Portland, Oregon, Area TODs"). The examples were constructed for walk access assuming the sidewalk and walkway system to be adequately represented, for computational purposes, by the street network. On this non-conservative basis it was estimated that only 21 to 57 percent of the areas within a 1/4-mile airline-distance radius around the four studied LRT stations was actually within a 1/4-mile along-the-road walking distance (Schlossberg et al., 2004).

Catchment area analysis can be elevated from a connectivity measure to an accessibility measure by bringing land use into the calculation. Such an approach was utilized to map and understand impediments to walking and bicycling to school in Hillsborough County, Florida. The county defines a "walk zone" of 2-mile radius around each school within which no school bus transportation is provided. (It has been suggested that this could better be described as a "parent responsibility zone" than "walk zone.") Land use was introduced into the analysis by making coverage calculations not on the basis of area per se, but on the basis of residential parcels. When this was done, at least one elementary school was shown to have dramatically inferior access from residential parcels than from undifferentiated land uses. The thrust of the remaining steps is best illustrated by example, for which the suburban Walden Lakes Elementary school is used:

Walden Lakes Elementary's school attendance area does not mesh perfectly with its so-called "walk zone"; in fact, only 81 percent of residential parcels in the attendance area are located within the "walk zone." The remainder are beyond a 2-mile airline-distance radius from the school. (Some portions of the "walk zone" are in the attendance areas of other schools.) When 2-mile walk distances are measured along the roadway system to delineate a "connected network zone" (similar to the Portland catchment area analysis, but not yet adjusted for highway barriers), then only 58 percent of the attendance area residential parcels are included. When the barrier effect of major roads is taken into account, only 49 percent of attendance area residential parcels are within a 2-mile walk without major impediments. The Walden Lakes Elementary situation is somewhat worse than that of the average Hillsborough County suburban elementary school—it serves only as an example of the analytical approach. The approach is designed to help involved parties better understand the impact of school siting and attendance area institutional decisions on school accessibility and walk-to-school possibilities (Steiner et al., 2008).

Motorized and NMT connectivity are not necessarily the same in any given situation, and may be separately calculated, and compared. Limited access highway facilities may prohibit walking and bicycling; they may also (along with major arterials) create barriers to NMT, and lack of sidewalks on busy streets may further inhibit walking. All such negative factors need to be taken into account in NMT accessibility calculation. At the other end of the scale, hilly neighborhoods may have stairways and pedestrian/bicycle ramps in lieu of steep street segments. There are subdivision and new-town designs (not typically found in the vast auto-dominated suburban housing tracts of the latter half of the 20th Century) that use pathway connections and path connectivity through small-and-medium-sized parks to facilitate pedestrian and bicycle flow similar to grid street/sidewalk systems while, at the same time, inhibiting through traffic. Such "Fused Grid" layouts have been estimated to increase the odds of walking by almost 10 percent (Victoria Transport Policy Institute, 2011b, Stover and Koepke, 2002).

Connectivity in application is the focus of the subsection "Pedestrian/Bicycle Systems and Interconnections" within the "Response by Type of NMT Strategy" section. For example, further information is found there on the mode choice effects of differential motorized and NMT connectivity, and on travel impacts of "Fused Grid" subdivisions (see "River Bridges and Other Linkages"—"Interconnections of Modest Scale," and the 14th entry of Table 16-21). Connectivity's full partner in producing accessibility—land use—is likewise addressed, along with design, in the "Pedestrian/Bicycle Friendly Neighborhoods" subsection within the same "Response by Type of NMT Strategy" section.

Surroundings Environment

The most obvious and direct manifestation of the link-level built environment for the pedestrian or bicyclist is the set of travel conditions encountered on a pedestrian/bicycle facility segment itself. This aspect is covered here in terms of "Facility Compatibility Measures." Next most immediate is the setting through which the facility segments pass. That is discussed under "Ambiance."

Facility Compatibility Measures. Similar to the familiar case of roadways designed for motor vehicle drivers, it is recognized that pedestrian and bicycle facilities should be designed, improved, maintained, and operated to meet the primary needs and preferences of non-motorized traffic and travelers. Preferences for certain types and/or designs of facilities may vary somewhat by trip purpose, length, and user characteristics. However, elements of safety, comfort, convenience, and minimal space conflicts are nearly universal.

A number of studies to define and quantify these preferences have been conducted, with most such studies surveying representative pedestrians and bicyclists about their satisfaction (or lack of satisfaction) with various physical elements of their walking or bicycling trip. Width of sidewalk or bike lane and separation from motor vehicle traffic are examples of physical elements addressed. When quantified into a single measure, these preferences have been given many names such as suitability criteria, compatibility criteria, level of service measure, and stress level. Measures of pedestrian and bicycle facility compatibility with user needs and preferences not only serve as design tools and improvement prioritization criteria; they also help describe facility attractiveness to present and prospective walkers and cyclists. Two comprehensive studies, one relevant to pedestrian preferences and the other to bicyclist preferences, are described here to illustrate the makeup of compatibility measures.

Multi-modal research utilizing field survey evaluations was the basis for development of a pedestrian level of service model for the Florida Department of Transportation. The equation for the pedestrian level of service is shown below and considers many of the physical elements that one intuitively uses to "grade" a particular walking experience. In particular, the presence of a sidewalk, and lateral separation from motor vehicle traffic, were significant determinants of pedestrian level of service.

Motor vehicle volumes and speeds in adjacent traffic lanes were also determined to be significant variables (Landis et al., 2001).

$$\text{Ped LOS} = -1.2021 \ln\left(W_{ol} + W_l + f_p \times \%OSP + f_b + W_b + f_{sw} + W_s\right) + 0.253 \ln\left(Vol_{15}/L\right) + 0.0005 SPD^2 + 5.3876$$

Where:

W_{ol} = Width of outside lane (feet)
W_l = Width of shoulder or bike lane (feet)
f_p = On-street parking effect coefficient (=0.20)
%OSP = Percent of segment with on-street parking
f_b = Buffer area barrier coefficient (=5.37 for trees spaced 20 feet on center)
W_b = Buffer width (distance between edge of pavement and sidewalk, feet)
W_s = Width of sidewalk, feet
f_{sw} = Sidewalk presence coefficient = $6-0.3W_s$
Vol_{15} = Average traffic during a fifteen (15) minute period
L = Total number of (through) lanes (for road or street)
SPD = Average running speed of motor vehicle traffic (mph)

The pedestrian level of service equation was developed using a stepwise multi-variable regression of 1,250 observations from an experiment using 75 walkers on a Pensacola, Florida, roadway course. The 75 walkers proceeded through a 21-segment (42-directional-segment) roadway course, with many starting at different segments and walking in different directions. The walkers were instructed to grade the segments immediately after they were walked, with the opportunity to re-grade previous segments based upon accumulated experience on the walking course. Walkers graded the roadway segments on a numerical scale of 1 to 6, corresponding to level of service A to F.

The pedestrian level of service model developed through this research was for use in the Florida Department of Transportation's multimodal corridor evaluation set of techniques as mandated by the state legislature. A similar field survey experiment was conducted for bicyclists in the mid-1990s and resulted in a similar bicycle level of service model (Landis, Vattikuti, and Brannick, 1997).

A team of researchers developed a Federal Highway Administration (FHWA) bicycle compatibility index in the late 1990s to quantify the "bicycle friendliness" of roadways. It was developed to allow practitioners to evaluate existing facilities to determine what improvements may be required, as well as determine the geometric and operational requirements for new bicycle facilities. The index is calculated as shown in Table 16-64. The significant variables include: (a) the presence and width of a paved shoulder or bicycle lane, (b) motor vehicle traffic volume and speed in adjacent lanes, (c) presence of motor vehicle parking, and (d) the type of roadside development (Harkey et al., 1998b and a).

Table 16-64 Bicycle Compatibility Index (BCI) Model, Variable Definitions and Adjustment Factors

$$BCI = 3.67 - 0.966BL - 0.410BLW - 0.498CLW + 0.002CLV + 0.0004OLV + 0.022SPD + 0.506PKG - 0.264AREA + AF$$

Where:

BL = presence of a bicycle lane or paved shoulder ≥ 0.9 m
No = 0
Yes = 1

BLW = bicycle lane (or paved shoulder) width *m* *(to the nearest tenth)*

CLW = curb lane width *m (to the nearest tenth)*

CLV = curb lane volume *vph in one direction*

OLV = other lane(s) volume – same direction *vph*

SPD = 85th percentile speed of traffic, *km/h*

PKG = presence of a parking lane with more than 30 percent occupancy
No = 0
Yes = 1

AREA = type of roadside development
Residential = 1
Other type = 0

$AF = f_t + f_p + f_{rt}$

Where:

f_t = adjustment factor for truck volumes (*see below*)

f_p = adjustment factor for parking turnover (*see below)*

f_{rt} = adjustment factor for right-turn volumes (*see below)*

Adjustment Factors

Hourly Curb Lane Large Truck Volume [a]	f_t	Parking Time Limit (min.)	f_p
≥ 120	0.5	≤ 15	0.6
60 – 119	0.4	16 – 30	0.5
30 – 59	0.3	31 – 60	0.4
20 – 29	0.2	61 – 120	0.3
10 – 19	0.1	121 – 240	0.2
< 10	0.0	241 – 480	0.1
		> 480	0.0
Hourly Right-Turn Volume [b]	**f_{rt}**		
≥ 270	0.1		
< 270	0.0		

Notes: [a] Large trucks are defined as all vehicles with six or more tires.

[b] Includes total number of right turns into driveways or minor intersections along a roadway segment.

Source: Harkey et al. (1998b).

In developing the bicycle compatibility index, the research team used the perspectives of more than 200 persons in three cities (Olympia, Washington, Austin, Texas, and Chapel Hill, North Carolina) to subjectively evaluate the perceived bicycling "comfort level" in different roadway environments. The approach used in this study relied on participants viewing roadway segments on videotape. Validation of the videotape method was accomplished with an on-street pilot study using 24 participants and 13 different roadway segments. After viewing the videotape for a particular roadway segment, each of the 200-plus participants was asked to "grade" the segment on a numerical scale of 1 to 6, corresponding to level of service A to F (Harkey et al., 1998b).

Various other compatibility or level of service measures have been developed in recent decades for both pedestrians and bicycles. Elements frequently used include type of facility provided, such as mixed traffic lane vs. bicycle lane vs. shared use path; sidewalk, path, curb lane, bicycle lane, or paved shoulder widths; some form of vehicular traffic volume measure (typically curb lane volume); motor vehicle speeds (speed limit is often used as a surrogate); presence and type of separation from motor vehicle traffic; roadway and driveway crossing conditions; and type of adjacent land use (Victoria Transport Policy Institute, 2011a). In addition to use as design and sufficiency study tools, bicycle compatibility criteria also can be employed to identify streets or highways particularly amenable to bicycle travel. Additional factors or variables can be used to supplement those already listed to determine those facilities most compatible for walking and bicycling and, therefore, most likely to elicit positive traveler response.

As useful as they may be as measures of suitability, compatibility measures such as link-based level of service share one substantial limitation. They can be used to identify network segments with substandard and unattractive characteristics, but they cannot be used to rank the importance of such links to the completeness or connectivity of the NMT network. A facility segment built to high standards may or may not be a crucial contributor to NMT network functionality. Conversely, a link may be identified as deficient, but some other segment—existing or yet unbuilt—may be more important to network completeness and connectivity (McCahill & Garrick, 2008). Broad level of service measures of continuity and connectivity have been proposed (Victoria Transport Policy Institute, 2011a), but inclusion of accessibility in compatibility measures apparently awaits further developments.

Ambiance. Various studies have, with somewhat mixed results, attempted to quantify the effect on choice to walk or bicycle of such features as tree shade, streetscape variety, opportunity to see people, building setbacks, and intrusion of automobile parking. On balance, there appears to be a modest positive effect of pleasant environment on walking (Cao, Handy, and Mokhtarian, 2006, Saelens and Handy, 2008, Ewing and Cervero, 2010). The relationships have proved difficult to ferret out, and are quite likely direct and robust only for "other" purpose trips such as shopping and strolling.

An effort to "comprehensively and objectively measure subjective qualities of the urban street environment" and then test them as walkability descriptors reached the point in early 2009 of setting forth operational definitions of five selected urban design qualities. Definitions development was facilitated by a panel of ten experts, each bringing different perspectives from diverse fields related to urban design and planning. Prior research, the panel's expertise, and a factorial design were utilized to organize a street-scene-aided process of rating over 50 perceptual qualities and winnowing them down into a set of urban design qualities capable of linkage with significant physical features. The rating process involved viewing by the panel of streetscape video clips covering 48 commercial district streets selected from dozens of cities across the United States. Statistical models were estimated with physical characteristics as independent variables and the ratings as dependent variables. These models indicated which physical characteristics are significantly related with each perceptual quality, along with the strength and direction of the association. Of eight urban design qualities carried through the entire process, three could not be defined operationally. The following five were those retained for further study and validation (Ewing and Handy, 2009):

- Imageability—Distinctive and recognizable quality of place that captures attention and creates a lasting impression.

- Enclosure—Visual definition of streets and other public spaces by walls, trees, and other vertical elements of proportions that create a room-like quality.

- Human Scale—Size, details, and articulation of physical elements matching the size and proportions of people and their walking speed.
- Transparency—Ability to see or perceive what is going on or lies beyond the street edge, specifically including human activity.
- Complexity—Visual richness of a place, including number and diversity of buildings, ornamentation, landscape and street furniture elements, and human activity.

Testing of these measures has been facilitated by a project to carry out urban design measurement of 588 block faces in New York City, representing a stratified sample from all five boroughs ranging in development intensity from Manhattan to partially rural Staten Island (Ewing and Handy, 2009). Initial unpublished results of development of a blockface pedestrian volume model incorporating as variables the urban design quality measures suggest that some but not all have statistical significance in describing pedestrian activity, at least in this particular application. The only one fully reaching statistical significance is transparency. Imageability "comes close." Both are positively related to higher pedestrian volumes. Enclosure is also marginally significant, but negative, suggesting that it is perhaps the least promising descriptor of walkability (Ewing, Connors, and Neckerman, 2011).

More conventional quantitative urban design variables were also incorporated. Significant and positive are floor area ratio (FAR), a measure of density; and walkscore, a measure of destination accessibility. An entropy measure of land use mix is positively related, but does not reach statistical significance. Significant and negative are distance to the nearest subway station and intersection density. The negative subway distance relationship relates to the added walking activity generally found around (not distant from) major transit stops. The negative intersection density relationship, which must be viewed in context with the generally high intersection density of New York City, is thought to reflect the associated greater use of land area for streets and the corresponding reduction of trip-generating acreage (Ewing, Connors, and Neckerman, 2011). In contemplating this it must be kept in mind that this is a pedestrian-volume direct-demand model, not a mode split model calibrated to estimate choice probabilities.

The most significant components of the statistically significant *transparency* variable are proportion of the first floor with windows and proportion of frontage with active uses. Less important is proportion of blockface with building frontage. The most significant components retained for validation of the other contributing urban design quality measure (*imageability*) are proportion of historic buildings; number of courtyards, plazas, and parks; and presence of outdoor dining. With these components, the two variables in question encompass all of the "physical features" describing activity and ability to perceive what lies beyond the street edge. Among the four non-contributing urban design quality measures only "complexity" includes such features, none of them as strongly related components (Ewing and Handy, 2009, Ewing, Connors, and Neckerman, 2011).

"Activity" and "ability to perceive what lies beyond the street edge" could well be characterized as "Jane Jacobs" variables—important to the life of cities. It is interesting to contemplate that these initial New York City validation outcomes may be identifying activity (or human presence or vitality) and eyes-on-the-street (or vice versa) as being particularly strong perceptual indicators of walkability.

Some of the more definitive already-published results with respect to ambiance come from an advanced travel demand modeling effort in San Francisco proper. Aside from topography, which in San Francisco tends toward the dramatic, the most influential destination pedestrian environment factor (PEF)—among those scaled for model use by a Delphi panel—proved to be urban vitality. The urban vitality characteristic, both in the case of work and in the case of other trip purposes, was an indicator of higher mode shares for walking, walk-transit, and also (for "other" trip purposes only) bicycling. Only destination (non-home) PEFs proved useful in estimating mode choice in the San Francisco modeling context (Cambridge Systematics et al., 2002).

There has also been one study that found high workplace and vicinity aesthetic appeal to be a marker for walk and bike work trip shares higher by an average of 0.7 percentage points (without Travel Demand Management financial incentives) to 1.3 percentage points (with incentives) as compared to sites with low aesthetic appeal. At least part of the underlying cause is presumably the secondary influence of having an employment area pleasant to get around in when making midday trips without an automobile (Cambridge Systematics with Deakin, Harvey, Skabardonis, 1994). These two Cambridge Systematics studies are more fully described in Chapter 15, "Land Use and Site Design," in that chapter's "Response by Type of Strategy" section (see "Site Design"—"Transit Supportive Design and Travel Behavior" including Tables 15-41, 15-42, and 15-44).

A University of California doctoral dissertation has closely examined factors pertaining to the choice between walking and auto use in the context of routine trip tours involving at least one shopping stop. For convenience of surveying and detailed interviews, the shopping activity selected was an intercepted visit to one of various pharmacies in commercial areas distributed throughout much of the San Francisco Bay Area. Complete trip and socioeconomic data were obtained in 959 out of 1,003 customer surveys for the tour intercepted, and these data were linked with travel and neighborhood characteristics data. Mode choice models were developed for three travel categories. For the 397 tours that visited solely a single shopping district, mode share to and from the district was modeled. For all 959 surveyed tours, tour mode choice was addressed. Lastly, a mode choice model was calibrated for only those trips within tours that took place entirely within one of the various shopping districts.

One ambiance-related environmental variable was included among the many socioeconomic, travel, shopping district, and attitude/perception factors. This shopping district variable was defined as tree canopy coverage within the public right-of-way of all multi-lane streets within 1/2 mile. The sample mean was 6.5 percent and the maximum was 18.1 percent. (These seemingly low percentages quite likely resulted from minimal tree canopy coverage over the central portions of the broad roadways involved.) The variable was significant in the "to and from" model of mode share for single shopping district tours, but not in the all-respondent tour-mode model or the shopping-district internal-trip model (Schneider, 2011).

Using the calibrated "to and from" mode choice model ($R^2 = 0.52$) it was estimated that 1 percent more tree coverage was worth, for the average respondent, taking 2.1 more minutes to walk. Sensitivity testing suggests that doubling tree coverage would have over 2-1/2 times the positive effect on walk mode share as doubling population and employment density, and 3 times the positive effect on walk share as halving the parking supply at the store. It is perhaps telling that one of the respondents in the 26 follow-up interviews stated: " 'Generally streets that also have trees are nicer streets . . .' " The dissertation finds that ". . . improving the quality of the street environment may extend walking distances and increase the pedestrian catchment area . . ." (Schneider, 2011). This measured conclusion seems appropriate. The sensitivity tests on one of three models provide a tenuous basis for any stronger judgment given that the other two models find no tree canopy coverage significance and, as the quoted interviewee implies, tree coverage may be standing in as a measure of overall street environment quality (a subject of interest in itself).

The shade from street trees has also been found to be important in Austin, Texas, research, but only for "strolling" recreational/exercise walking and not for shopping trips (Shriver, 1997, Cao, Handy, and Mokhtarian, 2006). Research focused on the city of Seattle concluded that architectural variety was related to frequent recreational walking but not utilitarian walking (Lee and Moudon, 2006a). The pertinent studies are summarized in the "Response by Type of NMT Strategy section" (see "Sidewalks and Along-Street Walking"—"Sidewalk Coverage and Traffic Conditions"). Additional relevant findings from the San Francisco trip tour modeling are also provided in that same discussion.

Detailed study of travel routes selected for walking to rail transit, combined with interview results, indicate that taking the most direct route dominates over considerations of ambiance for purposes of route choice when the walker has a crucial practical objective such as catching a train or getting to work on time (Weinstein et al., 2007). At the other end of the scale, walking and cycling done for recreation and exercise clearly follow a different decision paradigm than purely utilitarian NMT travel, as already discussed under "Behavioral Paradigms"—"Derived Versus Direct-Benefit Demand." For non-utilitarian trips, there tends not to be a precise destination, although for survey purposes the farthest point reached may be selected as an arbitrary trip end point. Global Positioning System (GPS) studies in Portland, Oregon, found—in the context of that region's multiplicity of bicycle facilities—that bicycle trips for exercise were typically structured as loops. The route followed is itself the "destination" for recreation and exercise trips (Weinstein and Schimek, 2005, Broach, Gliebe, and Dill, 2009a), and the ambiance—as expressed in factors such as views, scenery, and the strolling inducements identified in the Austin studies—likely has heightened influence.

Trip Factors

Trip factors include attributes of a specific journey including the origin-destination pairing, route, travel cost, trip purpose, and time of day. Trip distance is dependent on the origin-destination pairing and the route selected for getting from one place to the other. Travel time and cost will vary in accordance with both the trip distance and travel mode and route selection. Most travel models assume that individuals are aware of the distance, time, and cost associated with their potential choices and thus make a decision about how to travel on the basis of this knowledge. Of course, not all individuals think alike, have the same level of travel options knowledge, or have the same actual options available. In that context, this subsection is concerned with the general influence of trip factors on travel decisions. The next subsection, "User Factors," addresses how travel decisions are influenced by the characteristics of individuals.

Pedestrians and bicyclists are particularly sensitive to trip distance and are keen to seek out the most direct routes possible, particularly for utilitarian trips. This predilection is mainly attributable to the slower speeds at which persons walking or cycling cover the ground as compared to motorists and transit riders. Pedestrians and cyclists are also more exposed to their environment than are people inside vehicles. That circumstance can contribute to trip distance sensitivity, as people seek to minimize time spent in unpleasant or unsafe surroundings (Ewing, 1997).

For clarity of presentation, the following discussion of trip distance, time, and route characteristics is organized into separate parts for walking and bicycling as pertains primarily to adult travel. Within each is a discussion of average trip lengths, access to transit trips, and route choice. Factors as they pertain to the travel of children to and from school are introduced at the close of this "Trip Factors" subsection, following discussions of cost and trip purpose effects. The "Pedestrian/Bicycle Linkages with Transit" subsection within the "Response by Type of NMT Strategy" section provides additional information on impacts of distance on choice of walking or bicycling to access transit service.

Walk Trip Distance, Time, and Route Characteristics

Utilitarian walking is done to accomplish activities requiring travel to another location, while recreational walking is done for exercise or enjoyment. The two objectives may be combined (Cao, Handy, and Mokhtarian, 2006). Sometimes people will tolerate a longer walk because they enjoy walking or because they recognize the exercise benefits. Trip purpose is discussed more fully below, as a separate traveler response factor. However, it is important to bear in mind the potential blending of trip purposes and objectives as findings about walk trip lengths are reviewed.

Walk Trip Speeds and Lengths. The average pedestrian can walk between 3 and 4 miles per hour (mph). The most thoroughly studied walking condition, in terms of speed, is that of pedestrians crossing streets. Joint TCRP/NCHRP research, based on both original data collection and prior studies, provides a recommendation that a street crossing speed of 3.5 ft./sec. (2.4 mph) be assumed for the general population and that 3.0 ft./sec. (2.0 mph) be used for older or less able persons. These recommendations relate to intersection design and signal timing, however, and thus represent more conservative (lower) speeds than seen with typical walking. An Australian study of signalized intersections, for example, found 15th, 50th, and 85th percentile street crossing speeds for those pedestrians walking without difficulty or encumbrances of 4.27 ft./sec. (2.9 mph), 5.25 ft./sec. (3.6 mph), and 6.69 ft./sec. (4.6 mph), respectively. (Examples of encumbrances included large packages and small children in tow.) The corresponding values for pedestrians walking with difficulty or encumbrances (6 percent of the observations) were 3.74 ft./sec. (2.6 mph), 4.23 ft./sec. (2.9 mph), and 5.34 ft./sec. (3.6 mph). The mean speeds observed at midblock crossings with pedestrian-actuated signals were, for able-bodied, unencumbered pedestrians, 10 percent lower (Fitzpatrick et. al, 2006).

Walking speeds at signalized crossings may be affected by the pressure of the need to cross safely. They are thus are not necessarily representative of the speeds walked over longer distances, which are of interest to transportation planners and public health practitioners. Average unimpeded speeds suggested by NCHRP research for benefit analysis of pedestrian grade separations are 4.92 ft./sec. (3.4 mph) for normal conditions, 4.45 ft./sec. (3.0 mph) for commuters in busy downtown areas, and 5.33 (3.6 mph) for students. These were based on observed ranges of 4.50 to 5.00 ft./sec. (3.1 to 3.4 mph) in downtown Ottawa and 4.07 to 4.30 ft./sec. (2.8 to 2.9 mph) in more-crowded downtown Brooklyn. Note that these speeds exclude delays at street crossings, which are intended to be added in as a separate analytical step (Roddin, 1981).

Studies in Brisbane, Australia, took the further step of determining average pedestrian speeds along routes extending 1 to 9 blocks through intersections that were almost all signalized. Walking was thus subject to signal delays. Measurements were made using the pedestrian equivalent of the “floating car” highway travel time measurement technique. Speeds along 13 individual routes ranged from 40.6 to 84.1 meters/minute (2.22 to 4.60 ft./sec., or 1.5 to 3.1 mph), and averaged 66.9 meters/minute (3.66 ft./sec., or 2.5 mph). Speeds were observed to be affected by signal timing and coordination. This same Brisbane study also obtained free-flow measurements, observing 345 pedestrians away from the influence of traffic signals, and obtained a bell-shaped distribution with a mean of 90.0 meters per minute (4.92 ft./sec., or 3.4 mph) (Virkler, 1998)—identical to the NCHRP recommendation for “normal” conditions reported above.

A 10-minute walk at 3 to 4 mph can take a pedestrian 1/2 to 2/3 miles. Indeed, the 1990 and 1995 National Personal Transportation Surveys (NPTS) found average walk trip lengths (transit access walking excluded) of 0.6 and 0.5 miles, respectively. The 2001 National Household Transportation Survey (NHTS), with its enhanced walk trip surveying protocol, again found the average walk-only trip length to be 0.6 miles. However, the reported travel time averaged not 10 minutes, but 16.4 minutes.[52]

Walking is the mode of choice for nearly all trips of 1/10 of a mile or less. In contrast, for trips over 1/2 mile, walking is chosen only 10 percent of the time. Median distances are generally less than one-half the means for the various trip purposes (Ewing, 1997, Agrawal and Schimek, 2007).

The 2009 NHTS obtained a mean walk trip distance of 0.70 miles, a mean reported travel time of 14.9 minutes, a median walk distance of 0.44 miles, and a median walk time of 10 minutes. The mean calculated speed was thus 2.8 mph, while the median calculated speed was 2.6 mph (Kuzmyak et al., 2011). Despite the inaccuracies inherent in self-reported travel times obtained in surveys such as the NHTS, these speeds are within the range of 2.5 mph average impeded walk speed and 3.4 mph average unimpeded walk speed as determined in Brisbane. The median walk time finding lends further substance to the rule of thumb that 10 minutes is the typical amount of time devoted to a walk trip in the United States. Note, however, that the NPTS and NHTS results reported here are for walk-only trips and exclude transit access, parking facility access, and other walking for access to motorized transportation.

The shortest walk trips are most common in central cities where potential origins and destinations are located close together. The 1995 NPTS also found that people would walk longest for commuting purposes, and longer for recreational trips than for non-work utilitarian trips (Morris, 2001). A Florida survey found an average home-to-work walk trip length of about 0.7 miles (NuStats International, 1998). The 2001 NHTS likewise found non-work utilitarian trips to be the shortest on average. However, it found recreation/exercise walk trips to average 1.2 miles each way, more than the 0.8 miles average for walk trips to or from work (Agrawal and Schimek, 2007). The 2009 NHTS obtained longer work-related walk trip lengths, ranging from 1.0 miles for the work commute to 1.1 miles for work-related trips. Reminiscent of the 1995 NPTS, it found social/recreational walk trips to be longer than most non-work trips, but shorter than work trips. However, the social/recreational trip category used for the distance calculation of 0.8 miles included a broad range of activities from exercise to "get/eat meal" (Kuzmyak et al., 2011).

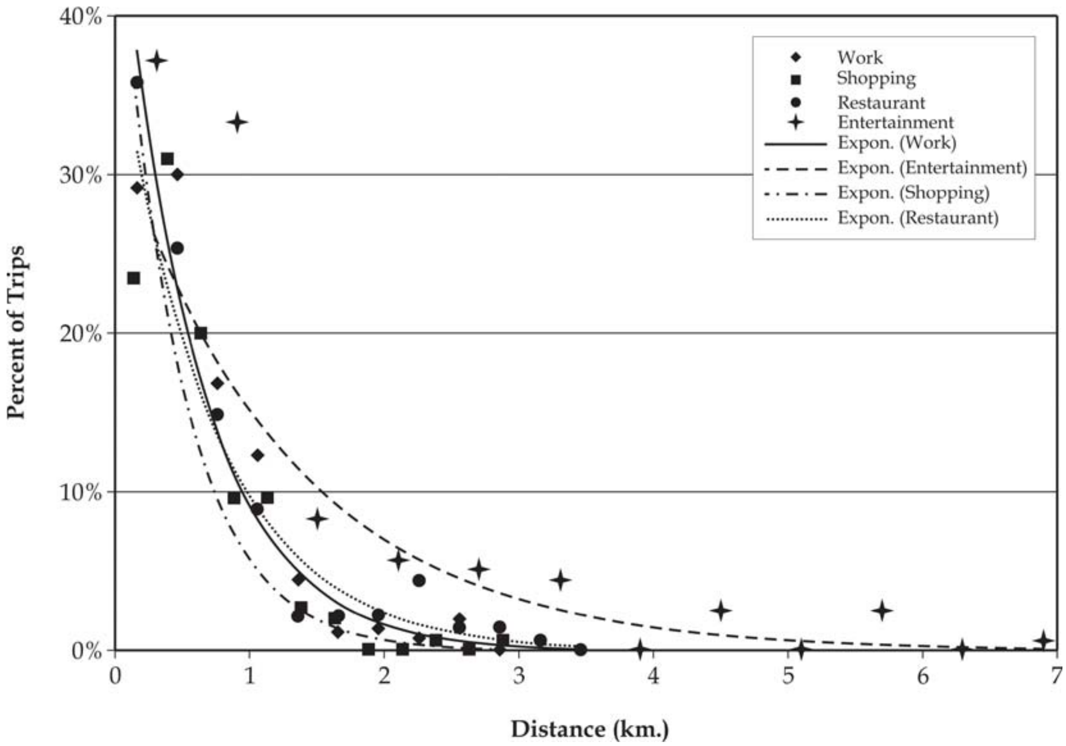
The relatively long distances covered by recreational walk trips provide one possible explanation for results from other surveys and studies that have derived longer average walking distances. For example, the 2002 National Survey of Pedestrians and Bicyclist Attitudes and Behaviors reported an average length of 1.2 miles for summer walking trips (NHTSA and BTS, 2002). The survey methodology, which focused on the most recent day a respondent walked rather than on a fixed survey day, would have over-weighted walk trips that occur less than daily—such as, perhaps, recreational trips. Another likely factor is the use in some surveys of round-trip mileage for "loop" or "out-and-back" recreational trips, a protocol employed by the BTS 2002 summer survey. More on national trip length statistics is found in the initial subsections of the "Related Information and Impacts" section, most particularly under "Characteristics of Walking and Cycling Overall"—"Trip Distance and Duration."

A University of Minnesota "Access to Destinations" research effort has looked at whether the old "one quarter mile assumption" used in community planning as a measure of walk access viability is truly valid. Data from the Twin Cities regional travel survey and complementary transit and trail

[52] This suggests an average speed of only 2.2 mph; however, travel surveys are an imperfect source of travel times, since respondents tend to round off start, finish, and elapsed times.

travel surveys were employed to plot "decay functions" of walking and cycling activity relative to increasing distance. A summary illustration of the walking prevalence data points and fitted exponential decay function curves for work, shopping, restaurant, and recreation trips is provided in Figure 16-8. One notable finding for walking was that there is not much difference among the decay functions for the work, shopping, and restaurant utilitarian trip purposes.[53] The researchers also concluded that "a surprising number of [walk] trips are made at distances up to and even exceeding 1 km. (0.6 mile)" (Iacono, Krizek, and El-Geneidy, 2008).

Figure 16-8 Walk trip distance decay plots with exponential curves.



Note: "Entertainment" includes recreation/fitness trips, predominantly recorded in terms of round-trip travel distances (Iacono, 2011, Filipi, 2011).

Source: Iacono, Krizek, and El-Geneidy (2008).

Others, as well, have seen neighborhood design implications in trip length consistencies among utilitarian walk trip categories. Litman, for example—noting that the mean "across many demographic groups and in different neighborhood densities" does not deviate far from 1/2 mile—suggests it may be reasonable for planning purposes to use this distance as the maximum many Americans are ordinarily willing to walk in satisfaction of travel needs (Victoria Transport Policy Institute, 2007).

[53] Entertainment, recreation, and fitness trips tended to cover longer distances, magnified in this instance by the recreation/fitness trips having been predominantly recorded in terms of round-trip distances (Iacono, 2011, Filipi, 2011).

Examination of the individual data plots from which Figure 16-8 is summarized shows a tendency for walk trip percentages to plateau at the shortest distance intervals rather than following the exponential decay function, a phenomenon familiar to modelers practiced in the conventional calibration of “gravity” trip distribution models. In other words, there is little empirical indication of walk trip travel choice differences at, say, 0.2 km. compared to 0.4 km. The sharp drop-off for work and shop trips, in particular, starts at distances higher than 0.5 to 0.6 km. (1/3 mile). Within the 1/3 mile walk trip threshold, approximately 55 to 65 percent of work, shopping, and restaurant trips occur. Beyond 1/3 mile, the decline in walking is steep, especially considering that each additional equal increment of distance from the central point encompasses a greater land area. Using this threshold as a design-guidance indicator might suggest that the preferred outer limit for advantageous accommodation of utilitarian walk trips may be 1/3 mile as measured along the walkway system. That equates to a pedestrian-oriented airline-distance radius of roughly 1/4 mile around the land use activity central point of interest, assuming a grid system of walkways, but with the space thus defined “bumped out” to 1/3 mile at streets and walkways radial to the center.

There is still another instructive way to look at the meaning of the Twin Cities utilitarian walk trip decay data, this one from the perspective of facility design. The decay plots and functions suggest that, in the interval between 1/3 and 3/4 miles of trip length, degree of walking is highly sensitive to walk distance. Walk network directness will, therefore, have a major effect on the choice of walking from origins in the critical band around the destination of interest. This band, if treated as ring or “donut,” is approximately 900 acres (1.4 square miles) in area. The formulae for the exponential curves in Figure 16-8 can be applied to produce an approximate estimate that 0.25 km. (820 feet) of walkway indirectness, affecting trips from within this critical band to the central point of interest, will result in a reduction in utilitarian walking of some 30 to 40 percent or more.[54]

Adding additional complexity is the phenomenon of tours, series or chains of work-related or non-work trips made starting at and ultimately returning to the same location. A short trip within a tour may not be a candidate for walking or bicycling because other travel within the tour requires use of an automobile (Schneider, 2010). It has been shown, using data on tours intercepted at pharmacies at various locations in the San Francisco Bay Area, that tour length is a good predictor of whether the walk or bike mode will be selected as the primary tour mode. Approximate walk mode shares for tours by distance were: 0.0 to 0.5 miles, 80 percent; 0.5 to 1.0 miles, 76 percent; 1.0 to 1.5 miles, 62 percent; 1.5 to 2.0 miles, 48 percent; 2.0 to 2.5 miles, 28 percent; 2.5 to 3.0 miles, 20 percent; and greater than 3.0 miles, 4 percent.

Whereas the median distance for all intercepted tours was 5.2 miles, the median walk tour distance was only 1.2 miles. Median tour distances for other primary tour modes were: bicycle, 3.1 miles; transit, 8.2 miles; and auto, 7.8 miles (Schneider, 2011).

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[54] To place 820 feet of indirectness in context, consider that a superblock 800 feet on a side, straddling a direct pedestrian route, will introduce that amount of indirectness unless the superblock is pierced by a midblock public walkway with suitable street crossings at each end. Or consider that elimination of a pedestrian cutoff saving about 800 feet was the subject of public debate, outcome uncertain, during an actual transit-adjacent development approval process affecting land and access at a Washington Metrorail station. Or that 1/2-mile spacing of pedestrian crossings of a suburban arterial introduces up to 2,640 feet (average 1,320 feet) of indirectness between intermediate local streets, bus stops, and/or building entrances on opposite sides of the arterial. Note that implicit in the decay functions are aerial coverage effects that render this particular application of the formulae an approximation likely to produce conservative impact estimates. The analytical assessments in this and the preceding paragraph, and in this Footnote, are solely by the Handbook authors.

The distances pedestrians are willing to walk are influenced by the built environment. A number of studies have concluded that interesting walks seem shorter than boring walks. The underlying hypothesis is that pedestrians latch onto intermediate goals or destinations as points of orientation along the way, such that the sense of distance and time is psychologically shortened. The researchers assert that for this reason pedestrians tend to walk further in areas with short block lengths or mixed land uses. More frequent intersections within a grid pattern can also mean shorter and easier trips when the straight-line path would be a diagonal. Other benefits of short blocks include the potential for greater dispersion of automobiles, thereby resulting in lower traffic volumes on adjacent streets and easier street crossings (Zehnpfenning et al., 1993, Ewing, 1996).

Topics related to block size, land use mix, and intersection frequency are covered conceptually in the preceding "Environmental Factors" subsection (see both "Systems Environment" and "Surroundings Environment"). They are examined in terms of specific neighborhood land use mix and design features in the "Pedestrian/Bicycle Friendly Neighborhoods" subsection of the "Response by Type of NMT Strategy" section.

Another line of inquiry suggests that a higher density of landmarks results in perceptions of space that exaggerate the actual distance involved. The underlying "feature accumulation hypothesis" states that when there are more intersections, turns, and other information to remember about an environment, distances are perceived as longer. Apparently unknown is whether the distance exaggeration reported to be perceived, in these circumstances, actually diminishes walking or not. One clear finding is that people estimate walking distance poorly. In research involving 910 usable responses from a 3,000-household survey in Minneapolis and two of its suburbs, only 38 percent of the distance estimates obtained fell into the correct 5-minute (up to 10 minutes), 10-minute (11 to 30 minutes), or over-30-minutes category. The Minneapolis researchers posit that to encourage walking, in addition to providing as many businesses close at hand as possible, it may be important to provide "consumer education" about opportunities to meet utilitarian travel needs by walking (Horning, El-Geneidy, and Krizek, 2008). (See the "Walking/Bicycling Promotion and Information" subsection of the "Response by Type of NMT Strategy" section for an examination of such approaches.)

Much of the available distance perception research concludes that people tend to overestimate the distances that they might walk. Distance overestimation may help explain some decisions not to walk even when distances are within typical walking norms (Goldsmith, 1992, Loutzenheiser, 1997). Other research, specifically the experiments in Minneapolis and its suburbs comparing perceived distances to network and also airline actual distances, have found distance overestimation among residents of closer-in areas where built-environment features are more concentrated and distance underestimation among people living further out in less dense environments. Various factors were associated with more accurate travel time estimation, but only having the closest destination within 5 minutes was consistently significant among destination characteristics as a predictor of accuracy. Closeness was a positive variable, and occurs more frequently, of course, where land uses are mixed and concentrated (Horning, El-Geneidy, and Krizek, 2008).

Mostly-newer research findings indicate that responses to the immediate built environment differ substantially by trip purpose, with recreational, exercise, and discretionary utilitarian trips (such as shopping) much more influenced by ambiance than non-discretionary utilitarian trips such as commuting (Cao, Handy, and Mokhtarian, 2006, Weinstein et al., 2007). These and related issues are among the findings covered in the "Ambiance" discussion at the end of the preceding "Environmental Factors" subsection.

Walk Access to Transit. Travel survey conventions are such that much of the data on average walk trip lengths in the preceding discussion pertain only to walk trips which use no other travel mode.

Thus different data, or at least different data compilations, are required to examine factors pertaining to choice and use of the walk mode for access to transit service.

Most transit patrons will walk about 1/4 mile to bus service and farther to rail service (Replogle and Parcells, 1992). In general terms, the greater the distance from a transit stop, the less likely a potential transit rider is to walk or even to use the transit service at all. A number of study and research examples demonstrating and further quantifying this phenomenon are provided in the "Pedestrian/Bicycle Linkages with Transit" subsection within the "Response by Type of NMT Strategy" section (see "Non-Motorized Access to Transit"—"Pedestrian Access and Egress"). Often overlooked in interpreting observed walk distances to bus transit is that the more intensive urban bus services are typically designed so that no more than a 1/4-mile walk is necessary. If there is no cause to walk over a 1/4 mile, then obviously there will be few observations of anyone doing so.[55]

Longer walk distances to rail services are encountered both because rail transit typically provides better service than the *average* bus line and because rail transit station and line spacings are further apart than those for urban bus services. (Bus rapid transit stations, such as those on the busways of Ottawa, Pittsburgh, and the San Fernando Valley Orange Line in Los Angeles, tend to be "lost" in overall bus-rider survey averages and may well actually attract walk access trips more like those to rail stations.) Actual distances traced on maps by West Coast survey respondents showed the walk distance to one Bay Area Rapid Transit (BART) station (El Cerrito, California), one LRT station in San Jose, California, and three LRT stations in Portland, Oregon, to average 0.52 miles overall. The 25th percentile was 0.27 miles, the 50th percentile (median) was 0.47 miles, and the 75th percentile was 0.68 miles (Weinstein et al., 2007).

Graphs showing the percentage of BART heavy rail transit patrons choosing to walk to their station, as a function of distance, were presented in Figures 16-4 and 16-5 of the "Pedestrian/Bicycle Linkages with Transit" subsection. As noted there, somewhat *more* than half of BART riders living 1/2 mile from urban stations elect to walk to their station. At suburban stations, however, where sidewalk systems are less likely to be complete and direct, the proportion walking is *less* than half even at only 3/8 miles distance.

Walk Route Choice. As already noted, walking is a slower travel mode; thus, having a direct route matters more. Pedestrians are very distance sensitive, tending to take the shortest convenient routes possible. Urban transportation modelers have had success in using intersection density as an indicator of greater propensity to walk (Lawrence Frank & Co., SACOG, and Mark Bradley Associates, 2008, Reiff and Kim, 2003), clearly because it acts as a surrogate for connectivity and corresponding ability to walk more directly to destinations. Sometimes minimum-distance paths are taken despite efforts to discourage or prohibit them. Mid-block jaywalking, diagonal crossings, walking in traffic, and unpaved short-cuts may be utilized by pedestrians seeking a direct path. At the extremes, pedestrians may scale or breech fences and directly cross high-speed facilities to avoid circuitous routings. Most pedestrians with motorized choices will, however, simply elect not to walk at all if a reasonable, safe, and secure route is not available (Zehnpfenning et al., 1993,

[55] An analysis of travel activity by transportation-disadvantaged persons in an area of sparse bus route coverage, the Hampton Roads region of Virginia, found bus use to be "fairly consistent up to a one mile distance" from the nearest bus stop for non-drivers not hampered by poor health or walker/cane use. A plot of percent using the bus on the survey travel day for this particular population suggests only a very slight decline with increasing distance up to the 1-mile threshold, with a sharp drop-off thereafter (Case, 2007).

AASHTO, 2001). The "Special Mini-Studies in Montgomery County, Maryland" case study provides quantified examples, under "More—Sidewalk Indirectness," of circumstances under which pedestrians have forged shortcuts.

The importance of time and distance to route choice for utilitarian walking is underscored by findings of the surveys in the San Francisco Bay Area and Portland, previously described, that focused on transit riders walking to rail transit stations. Both open-ended and structured survey question responses showed that such pedestrians believe minimizing time and distance is their primary consideration. Respondents ranked 11 attributes as being very important, somewhat important, or not important in their route choice. "Very important" ranking was attached to "shortest route" by 82 percent of respondents, to "traffic devices are present" by 55 percent, to "traffic drives at safe speeds" by 46 percent, and to "sidewalks in good condition" by 43 percent. Assigned importance (very and somewhat important) dropped off more sharply after these four attributes. The remaining attributes were all concerned with ambiance, amenities, and people-activity measures, except for one addressing traffic signals "where it takes a long time to cross" (Weinstein et al., 2007). These rankings would not necessarily, and probably don't fully, apply to walking for recreation or exercise.

Bicycle Trip Distance, Time, and Route Characteristics

As with walking, bicycling may be chosen as a travel/exercise mode for either utilitarian or recreational purposes. Some motivations, notably recreation and exercise, will lead to a greater tolerance of longer trips. Bicycling is relatively more dependent on facility improvements than is walking, especially parking provisions. Without adequate facilities, the market for bicycling may be curtailed.

Bicycle Trip Speeds and Lengths. As a rule of thumb, 10 to 12 mph has been used for average bicycle speed. Global Positioning System (GPS) data for 164 Portland, Oregon, adults—primarily but not exclusively regular cyclists—provide a refinement. Speeds for work, work-related, and school-purpose trips were found to be 12.0 mph (mean and median), speeds for exercise and organized rides were 11.3 (mean) and 11.7 (median), speeds for social/recreation trips were 10.1 (mean) and 10.3 (median), and speeds for shopping, dining, personal business, and miscellaneous trips were 9.6 mph (mean and median). Speeds for all adult bicycle trips overall were 10.8 mph (mean and median), but with women averaging only 9.8 mph as compared to 11.6 for men (Dill and Gliebe, 2008).

At 11 mph a 4-mile trip takes 22 minutes. Trip length is cited as the largest deterrent to cycling in most surveys. It is but one cycling-choice factor, but it seems to be the most recognized. Just how far is too far is a matter of debate and has yielded a range of answers. The 2009 NHTS found an average length of 2.3 miles for bicycle trips overall, but an average length of 3.8 miles for bicycle to work trips. Averages or means, in contrast to median values, may be boosted by a relatively few long trips. The median bicycle trip distance as derived from the 2009 NHTS is 1 mile. A 1981 study found that 90 percent of work trips and 84 percent of other utilitarian trips taken by bicycle were 2 miles or less in length. This is fairly consistent with a 2009 NHTS-based finding that 74 percent of all bicycle trips, including those taken for recreation and exercise, are 2 miles or less (Goldsmith, 1992, Kuzmyak et al., 2011).

Other researchers have, however, derived average one-way bicycle commute trip distances of up to 6 miles. The 2002 summer survey performed by NHTSA and BTS obtained, for all bicycling trip purposes together, a 3.9 mile average trip with 57 percent less than 2 miles. Survey differences relative to the NHTS included a focus on the day when bicycling most recently occurred, rather than on a fixed survey day, and use of round-trip distance for trips starting and originating at the home without an intermediate stop (Goldsmith, 1992, NHTSA and BTS, 2002). An intercept survey in Washington State found regular bicycle commuters willing to travel slightly longer distances than occasional bicycle commuters, with neither willing to cycle for more than 1 hour each way (Niemeier, Rutherford, and Ishimaru, 1995b).

Table 16-65 lists the median and mean trip lengths obtained for each reported travel purpose for bicycle trips tracked using GPS technology in the Portland, Oregon, research. As in the NHTSA and BTS reporting, round trip distances are given for out-and-back and "loop" exercise trips, with one-way distances for all other trips. Only adults participated, although a handful were accompanied by children (Dill and Gliebe, 2008). The high standard deviations, close to or exceeding the means, are indicative of high trip length variability. The presence of means consistently higher than the corresponding medians reflects distance distributions that are not normal distributions, but instead are skewed toward longer distances, inflating the means.

Table 16-65 GPS-Tracked Cycle Trip Distance by Destination Purpose in Portland, Oregon

Trip Purpose	Median (miles)	Mean (miles)	Std. Deviation	Observations
Exercise	8.5	12.7	13.2	94
Work	3.8	5.2	5.2	445
All Trips	2.8	4.3	5.6	1,777
Home	2.8	3.7	3.5	586
Social/Recreation	2.1	3.6	4.9	218
School (Adults)	1.8	2.8	3.1	20
Work-related	1.7	2.6	2.8	58
Shopping	1.3	2.4	4.4	117
Personal Business	1.3	2.4	2.6	142
Dining	1.0	2.0	2.3	54

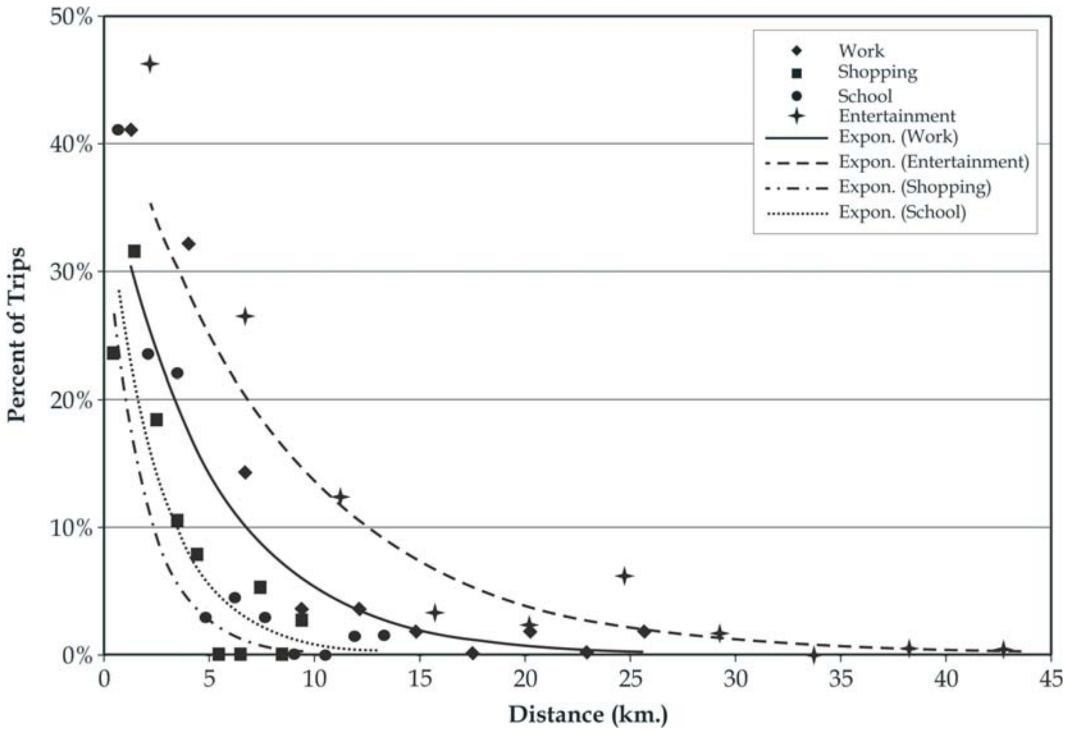
Note: Round-trip miles used for out-and-back and "loop" exercise trips; one-way miles used for all other trips.

Source: Dill and Gliebe (2008).

The University of Minnesota "Access to Destinations" research effort introduced in the "Walk Trip Distance, Time, and Route Characteristics" discussion (see Figure 16-8) developed Twin Cities regional bicycle trip decay functions in parallel with the walk trip analysis. Illustrated in Figure 16-9, the fitted exponential decay functions relate proportion of cycling activity to distance. The figure shows cycling prevalence data points and decay function curves for work, shopping, school, and entertainment trips (Iacono, Krizek, and El-Geneidy, 2008). As with walking, prevalence of long bicycle trips is highest for entertainment, recreation, and fitness purposes. (Again, recreational/fitness trip distances were predominantly recorded in terms of round trips.) However, whereas walking trips for recreation ("entertainment") tail off at about 6 km. (3.7 miles), some long cycling trips for recreation occur in the range of 30 to 40 km. (18.6 to 24.8 miles). Bicycle trips for work purposes, while much shorter than recreational trips overall, are similarly observed to extend 5 to 7 times further in length relative to walk trips for work purposes.

Unlike the case for walk trips, there is substantial difference between the bicycle trip decay functions for the work and shopping utilitarian trip purposes, with the shopping trips being much shorter. School trips lie in-between. Only the shopping bicycle trips exhibit the close-in plateauing (actually peaking) seen for both work and shopping walk trips, with the highest prevalence at roughly a 1-1/2 km. (about 1 mile) trip length. Caution must be applied in interpretations, as the cycle trip sample sizes were less than 70 observations total for each purpose displayed in Figure 16-9. Nevertheless, the broader reach of bicycle trips as compared to walk trips is clearly evident (Iacono, Krizek, and El-Geneidy, 2008).

Figure 16-9 Bicycle trip distance decay plots with exponential curves.



Note: "Entertainment" includes recreation/fitness trips, predominantly recorded in terms of round-trip travel distances (Iacono, 2011, Filipi, 2011).

Source: Iacono, Krizek, and El-Geneidy (2008), with curve-labeling errata resolutions per El-Geneidy (2011).

The Portland, Oregon, bicycling route choice studies compared bicycle trip travel time with estimated auto travel times for each GPS-tracked trip. All but a handful of the bike trips took longer than driving would have, 13.4 minutes longer on average, with a median difference of 9.5 minutes. The time difference for trips of under 3 miles in length was, however, less than 5 minutes (Dill and Gliebe, 2008).

Bicycle Access to Transit. The sparse data available on bicycle trips for purposes of accessing and egressing public transit service limits the certainty with which broad conclusions can be made. The one comprehensive data source encountered requires extrapolation from bike-on-bus access and egress rather than bicycle-park-and-ride activity, and is also limited to Florida locations. For distance comparisons with bike-only trips, it seems reasonable that access and egress distances be summed, as has been done in several walk-transit-walk trip investigations. Such comparisons remain inconclusive, however, given lack of bike-on-bus information for travel purposes other than the work commute, and other data issues. Bike-on-bus access trips are longer than walk access to transit trips, as demonstrated in Table 16-35 within the "Response by Type of NMT Strategy" section, under "Pedestrian/Bicycle Linkages with Transit"—"Bicycles on Transit Vehicles"—"Bike-on-Bus Programs."

Table 16-66 provides bicycle access and egress trip length distributions for three Florida bike-on-bus operations. The trip length distributions are for work-purpose trips only, thereby encompassing 72 percent of the surveyed bike-on-bus activity. "Access" pertains to the bicycle trip from home to the boarding bus stop, and "Egress" pertains to the bicycle trip from the bus stop of alighting to the workplace. The median work-purpose bike-on-bus access distance for these three Florida systems is 1 mile, and the median egress distance is 1/4 mile (Hagelin, 2005).

Table 16-66 Work-Purpose Trip Bicycle Access and Egress Distance Distributions for Three Florida Bike-on-Bus Operations

Distance (miles)	Hillsborough Area Reg. Tran. (N=55)		Miami-Dade Transit (N=60)		Pinellas Suncoast Tran. Auth. (N=47)		Three-System Total (N=162)	
	Access	Egress	Access	Egress	Access [a]	Egress [a]	Access	Egress
< 1/4	5.5%	14.5%	6.7%	18.3%	3.6%	20.0%	5.6%	18.5%
1/4	7.3	30.9	10.0	30.0	5.5	27.3	8.0	30.9
1/2, 3/4 [b]	16.3	34.5	28.4	33.4	20.0	18.2	22.9	30.2
1	38.2	10.9	16.7	6.7	41.8	10.9	33.3	9.9
2	23.6	7.3	18.3	5.0	12.7	7.3	19.1	6.8
3	5.5	1.8	5.0	0.0	1.8	1.8	4.3	1.2
4	1.8	0.0	3.3	0.0	0.0	0.0	1.9	0.0
5	1.8	0.0	1.7	0.0	0.0	0.0	1.2	0.0
>5	0.0	0.0	3.3	0.0	0.0	0.0	1.2	0.0
Unreported	0.0%	0.0%	6.7%	6.7%	0.0%	0.0%	2.5%	2.5%

Note: [a] The published bicycle access/egress distance distributions for Pinellas Suncoast Transit Authority total ±85.5%, not ±100%.

[b] Lumpiness in the self-reported Florida bike-on-bus access and egress distances resulted in less than 2 percent of respondents reporting a 3/4 mile access or egress distance.

Source: Hagelin (2005).

Bicycle Route Choice. Route choice for bicyclists may not be quite as distance sensitive as in the case of pedestrians, but distance and travel time are still the most important considerations when choosing a bicycle route. Greater perceived safety or even better pavement surfaces can attract cyclists to a particular route, but most cyclists are found to divert very little from minimum paths. Research in the 1990s on bicyclist route choice found one-half of cyclists to use a route less than 6 percent longer than the shortest distance possible and less than 5 percent more time consuming than the quickest time route identified in the network. Journey time seemed slightly more important than distance as a choice factor, but imperfect or insufficient information on the part of the cyclist may have been responsible rather than a conscious choice of time over distance. Over 70 percent of cyclists studied had selected routes that were within 10 percent of the minimum time network path (Aultman-Hall, Hall, and Baetz, 1997, C.R.O.W., 1993).

Newer GPS-and-network-based research in Portland, Oregon, shows slightly more willingness to divert from minimum-distance routings, possibly because the sample was designed to give roughly equal representation to women and to include as many less-frequent cyclists as possible.[56] In this study only one-half of the GPS-tracked utilitarian trips were less than 10 percent longer than the shortest possible routing. Almost 5 percent were over 50 percent longer (Broach, Gliebe, and Dill, 2009b). Table 16-67 compares bicycle miles of travel on the shortest paths, derived from a computer network, with bicycle miles of travel on the observed paths actually used. Male cyclists (864 observed trips) and female cyclists (713 trips) are separately shown, as are frequent cyclists (1,337 trips) and infrequent cyclists (204 trips). When the actual bicycle trip miles (i.e., bicycle miles of travel) on a facility type are proportionally less than the minimum-path bicycle trip miles allocated to that facility type, as is consistently the case with arterials lacking a bike lane, then cyclists overall are shown to be deliberately avoiding that type of routing. When the reverse is the case, as consistently seen with low traffic streets, bicycle boulevards, and off-road trails, cyclists overall are shown to prefer that type of facility (Dill and Gliebe, 2008). The methodology compensates for facility orientation relative to the trips being made, providing preference indications that are relatively independent of convenience of facility location.

[56] It may also be relevant that the primary 1990s North American research discussed above, done in Guelph, Ontario, Canada, was conducted on the basis of a trail system with minimal extent of hard-surfaced facilities. A majority of the trails involved were surfaced with limestone screenings, and most of the remainder were unsurfaced (Aultman-Hall, Hall, and Baetz, 1997). Portland's primary trails are hard-surfaced and thus may be more attractive for utilitarian travel.

Table 16-67 Percentage of Utilitarian Bicycle Trip Miles by Facility Type in Portland, Oregon—Minimum-Distance Routings Versus Actual Routings

Type of Bicyclist	Type of Path or Statistic	Arterials, No Bike Lane	Low Traffic Streets	Streets with Bike Lanes	Bicycle Boulevards	Off-Road Shared Use Trails
Male	Minimum	38%	31%	25%	4%	6%
	Actual	20%	36%	30%	8%	15%
	Difference	-18%	+5%	+4%	+5%	+8%
Female	Minimum	32%	42%	22%	5%	5%
	Actual	15%	51%	24%	13%	12%
	Difference	-16%	+9%	+2%	+8%	+7%
Frequent	Minimum	36%	35%	24%	4%	5%
	Actual	19%	41%	29%	11%	13%
	Difference	-17%	+6%	+5%	+6%	+7%
Infrequent	Minimum	34%	33%	25%	4%	7%
	Actual	16%	40%	24%	6%	20%
	Difference	-17%	+7%	-1%	+1%	+13%
All	Minimum	36%	36%	24%	4%	6%
	Actual	19%	42%	28%	10%	14%
	Difference	-17%	+6%	+4%	+6%	+8%

Notes: "Low Traffic Streets" category *includes streets with bike lanes and bicycle boulevards* (Dill, 2010).

"Minimum" paths are the least-distance routings determined with network analysis.

"Actual" paths are the routings observed with GPS tracking.

"Difference" statistics are in percentage points and may not match exactly due to rounding.

Percentages sum to more than 100% because bicycling on "Low Traffic Streets" with bike lanes, and also with bicycle boulevards, is included both under "Low Traffic Streets" *and* under the applicable bicycle-preference treatment category.

Source: Dill and Gliebe, (2008).

From Table 16-67 it may be concluded that aversion to bicycling on arterials with moderate to heavy vehicular traffic and no bicycle lanes applies regardless of gender or bicycling frequency (used here as a surrogate for skill level). Similarly universal, albeit showing some difference in strength of preference, is the propensity to use low-traffic streets and bicycle boulevards. (The negligible preference for bicycle boulevards by infrequent cyclists is hard to explain given the preference for low-traffic streets, and may well be an artifact of low sample size in the applicable classifications.[57]) Preference for off-road shared use trails is also universal, but with a near-doubling of apparent preference for such facilities among infrequent cyclists. There is a more mod-

[57] Only 204 bicycle trips by infrequent cyclists were tracked, and only 4 percent of Portland's bicycle facility mileage was composed of bicycle boulevards (Dill and Gliebe, 2008).

erate preference for bicycle lanes among most categories, with the preference among women being weak, and with a very slight aversion to bicycle lanes indicated for infrequent cyclists. Additional details on this study, along with alternative analytical perspectives on the route choice findings, are found in the "Response by Type of NMT Strategy" section (see "Bicycle Lanes and Routes"—"Popularity, Preferences, and Route Choice"—"GPS- and Network-Based Research").

The Portland GPS-tracking participants were also asked in structured questions about factors important to them in each of the route selection choices they made. They reported placing "highest importance on minimizing distance and avoiding streets with lots of vehicle traffic." In third and fourth place were presence of bicycle lanes and avoidance of lost time at traffic signals and signs. Comparing women to men, on the basis of both stated preference and revealed preference analysis results, the women were less likely to prefer riding on bike lanes on busy streets and more likely to prefer low-traffic streets. Responses pertaining to the small sample of trips made accompanied by a child (87 trips by 11 participants) indicate that, with a child, avoiding "lots of" traffic had significant additional importance and that added importance was also assigned to minimizing distance, riding on a path or trail, and avoiding hills (Dill and Gliebe, 2008).

Some of the Portland findings concerning different bicyclist valuations of alternative facility types, depending on bicyclist characteristics, were hinted at in earlier work. Stated-preference-experiment modeling done on the basis of mid-1990s conditions and responses in Edmonton, Alberta, Canada, stratified results by cyclist comfort levels and degree of experience. Relative unattractiveness of bicycling in mixed traffic decreased with both increasing levels of comfort and experience with cycling under such conditions. Persons with the highest levels of comfort in mixed traffic were relatively indifferent to bicycle facility type. Time on bike lanes was found more attractive than time on bike paths for respondents self-reporting higher comfort and experience levels. The opposite, preference for bike paths, was true for those reporting lower levels of comfort in traffic. Experience alone did not seem to much affect bike path preference (Hunt and Abraham, 2007).[58]

Travel Cost

The user costs of walking or bicycling are relatively little. Cycling does require ownership and maintenance of a bicycle, or rental, but the costs involved are small relative to owning and operating an auto. The most secure and convenient bicycle parking may entail a fee, but free bicycle parking is the norm. The primary influence of costs on the choice to walk or bike is thus the other-mode cost avoidance these NMT modes afford. Active transportation researchers and demand modelers focus primarily on the avoidable costs inherent in using competitive motorized modes, if costs are considered at all.

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58 Overall values for all survey participants were reported but must be used with caution because the convenience sample used for the questionnaire and stated preference survey reflected a bias toward inclusion of more frequent cyclists (the survey was attached to parked bicycles or handed to cyclists passing by). Also, Edmonton at the time had 102 kilometers of shared use paths and trails but only 3 kilometers of bike lanes. Be that as it may, cycling in mixed traffic by survey participants overall was estimated to be 4.1 times as onerous per minute as cycling on bike lanes, while cycling with pedestrians on paths and trails was estimated to be 1.4 times as onerous per minute as cycling on bike lanes. The latter comparison was "not highly significant in a statistical sense" (Hunt and Abraham, 2007).

In addition to travel time, most multimodal travel models assign major importance to motorized trip direct user costs, especially tolls, parking charges, and transit fares. For short suburban trips, however, there are generally no tolls or parking charges that bear on auto use. In urban core areas, vehicular parking charges are more common and therefore the cost benefits of walking and bicycling may become a more significant part of the decision process. Studies in Portland and Eugene, Oregon, each found that large numbers of survey respondents (37 percent and nearly one-half, respectively) cited the inexpensive nature of bicycle transportation as a mode choice decision factor (Goldsmith, 1992, David Evans and Associates, 1992, Lipton, 1979).

Historically, researchers have tended to find that regular ownership and operating costs of automobiles, even including fuel, are given less weight than other user costs in day-to-day mode choice decisions. Recent anecdotal and circumstantial evidence suggests, however, some NMT choice response to sharp gasoline price increases. U.S. retail gasoline prices rose over a 3-year period from $2.00/gal. in early 2005 to $3.00/gal. in February, 2008, and then climbed in only 4 months to $4.00/gal. in June (Energy Information Administration, 2008). Increased bicycle and accessories sales, particularly for commuting purposes, were being widely reported by early-to-mid-2008 (Emond, Tang, and Handy, 2009, Relyea, 2008). The Florida commuter rail system, Tri-Rail (Dade, Broward, and Palm Beach Counties) noted bike-on-rail increases from two to three bikes per rail car to six to seven bikes. Broward County Transit buses carried 68,000 bikes in May, nearly 6,000 more than in March, 2008 (Campbell, 2008), in a climate where approach of summer is not an explanation. It will be some time, though, before hard data allow quantification of the net effect on NMT mode choice of higher fuel prices counterbalanced by shifts to more fuel-efficient autos.

Pricing effects on transit riding affect walking as well. Walking in connection with accessing transit presently makes up 16 percent of all U.S. walk trips (see "Related Information and Impacts"—"Extent of Walking and Bicycling"—"Extent of Walking"). Walking is also a significant alternative mode for short transit trips, such that with reduced local transit fares or improved local transit service, there is not only the increase in walking that comes with more transit access activity but also a loss of walking with shifts from the walk mode to the transit mode. Transit mode shifts are discussed in Chapter 9, "Transit Scheduling and Frequency," Chapter 10, "Bus Routing and Coverage," and Chapter 12, "Transit Pricing and Fares."

On the other hand, if transit riding goes up because alternative motorized modes become more expensive or less attractive, then the added transit access activity will definitely effect a net increase in walking. U.S. transit riding overall increased 12 percent from 2004 to 2008. Highway VMT growth slowed starting in 2004, and then VMT dropped in 2008 to below 2004 levels (American Public Transportation Association, 2010). It seems reasonable to attribute a large measure of these effects to the doubling of gasoline prices noted above.[59]

Trip Purpose

The decision to walk or bicycle and the relative importance of the factors influencing that decision vary by trip purpose. Recreational trip makers want to get exercise and/or enjoyment from their trip and therefore may be more concerned about the environment in which they travel. Utilitarian trip makers are more interested in efficiency and other practical factors. For example, shoppers may consider ability to carry purchased goods and the variety of stores available within a reason-

[59] The 2008 highway VMT reduction probably reflected the approaching financial recession as well, even though transit riding continued its strong upward climb.

able distance. Commuters are particularly concerned with distance and need to minimize travel time. Bicycle commuters have added considerations of bicycle parking, road safety, and their clothing and clean-up (Zehnpfenning et al., 1993, Epperson, Hendricks, and York, 1995, Goldsmith, 1992, Pucher and Renne, 2003).

Purpose-Related Effects on Route Choice. The Portland GPS-tracking participant responses concerning route choice factors important to them, introduced in the "Bicycle Route Choice" discussion, were amplified by tabulating responses separately by trip purpose. Table 16-68 presents the results in terms of average route choice factor scores. The higher the average score, based on a 1 to 5 scale, the more important the factor. The major differences in priorities among trip purposes that stand out in the tabulation include the lesser concern with minimizing distance in the case of exercise cycling, the greater interest in using bike lanes when making a work or (adult) school purpose trip, the lesser importance of using paths/trails for shopping and other miscellaneous business trips (paths are probably not closely aligned with commerce), the lesser concern with avoiding hills when exercising, and the elevated interest in avoiding traffic control delays when making work and school trips (Dill and Gliebe, 2008).

Table 16-68 Importance of Factors Influencing Bicycle Trip Route Choice in Portland, Oregon, Quantified as Average Scores and Arrayed by Trip Purpose

	Trip Purpose				
Factor Description	**Work, Work-Related, School**	**Shopping, Dining, Personal Business, Other**	**Social/ Recreational**	**Exercise and Organized Rides**	**Home**
Minimize distance	3.8	3.6	3.2	1.6	3.6
Ride in bike lane	3.2	2.6	2.8	2.7	3.0
Ride on path/trail	2.4	1.9	2.1	2.5	2.3
Ride on signed bike route	2.8	2.3	2.6	2.3	2.7
Avoid streets with lots of traffic	3.6	3.4	3.4	3.6	3.7
Avoid hills	2.1	2.0	2.2	1.7	2.1
Reduce wait time at signs/lights	2.9	2.4	2.5	2.2	2.7

Notes: Average scores are means of individual scores on a 1 to 5 scale: 1 = Not at all important. 5 = Very important. Results cover adult cyclists only.

Source: Dill and Gliebe (2008).

Purpose-Influenced Relationships with Neighborhood Environment. Another proffered structuring of purpose-influenced relationships, this one in the context of neighborhood trip factors, employs a "proposed ecological model of neighborhood environment influence on walking and cycling." The suggested model hypothesizes the relative effects of various neighborhood physical environment factors on utilitarian-purpose NMT trip making on the one hand and recreation/exercise walking and bicycling activity on the other (Saelens, Sallis, and Frank, 2002):

- Density, land use mix, and connectivity—strong influence on utilitarian trips, but no effect of consequence on recreation/exercise NMT activity.

- Safety from traffic dangers and crime—weak factor for utilitarian trips, but a strong influence on choice to walk or bike for exercise.
- Sidewalks, paths, and bike lanes—weak influence on both utilitarian and recreation/exercise active travel decisions.
- Parks and other physical activity facilities—no effect on utilitarian trips, and a weak effect on recreation/exercise NMT activity.
- Aesthetics and topography—weak role in utilitarian NMT choice, but a strong role in recreation/exercise walking and bicycling decisions.

In this listing, the term "weak" is a relative one and is not intended to necessarily imply lack of significance. "Utilitarian trips" encompass both non-discretionary "transportation" such as trips to work or medical appointments, and discretionary "transportation" such as shopping or eating out. Discretionary travel may engender choice responses intermediate between those seen for non-discretionary utilitarian trips and recreational/exercise NMT activity. In any case, this represents but one set of hypotheses, and reference should be made to the "Response by Type of NMT Strategy" section and other discussions for prior and subsequent study and research findings.

The "ecological model" also encompasses individual user factors. Car ownership is posited to affect only utilitarian NMT choice, but strongly so. Income, age, and gender are hypothesized to have a weak role in utilitarian NMT choice, but a strong one in choice to walk or bike for recreation and exercise. The user factors are seen to be "mediated" by the neighborhood environment. All these NMT choices, whether with respect to utilitarian trips or recreation and exercise, feed into activity level and corresponding health maintenance and disease prevention outcomes (Saelens, Sallis, and Frank, 2002).

Purpose-Related Mode Choice Effects. As with automobile trips, non-work travel accounts for most pedestrian and bicycle trips. Indeed, in the case of non-motorized travel, an even greater proportion of trips are for non-work purposes. This is partly because the distance from home to work is fixed, and may be too long for a reasonable pedestrian or bicycle commute, while the distances to acceptable destinations for other trip purposes may be more reasonable. The higher proportion of non-work trips in the NMT travel mix also occurs because NMT non-work trips can be either utilitarian or for recreation and exercise (or both). One cannot achieve exercise through driving, but can obtain health and recreational benefits from walking or bicycling (Goldsmith, 1992). (See "Public Health Issues and Relationships" in the "Related Information and Impacts" section for more information on health benefits.)

These various considerations influence the travel mode shares seen for trips of different trip purposes. Table 16-69 illustrates the differing NMT shares exhibited by travel when grouped into four trip purpose categories. This is U.S. national urban data derived from the 2001 NHTS by excluding non-urban-area trips and trips over 75 miles in length (Pucher and Renne, 2003). Transit mode shares are tabulated along with the walk and bicycle mode shares because of the substantive walking that occurs in connection with most transit travel. It is reasonable that the higher walk and bike shares for the "social and recreation" trip purpose category may reflect individual interest in the exercise benefit.

Table 16-69 Surveyed U.S. Urban Walk, Bike, and Transit Mode Shares, by Trip Purpose, 2001 NHTS

Mode of Transportation	Trip Purpose				
	Work and Work Related	Shopping and Services	Social and Recreation	School and Church	All Travel Purposes [a]
Walk-only	3.4%	6.5%	12.7%	10.5%	9.5%
Bicycle	0.5	0.3	1.3	0.7	0.9
Transit [b]	3.7	1.4	1.0	2.2	1.7

Note: Includes only urban area trips 75 miles or less in length.

[a] These mode shares differ from 2001 NHTS results presented elsewhere because of the restriction of travel data to urban area trips.

[b] "Transit" excludes school buses. Transit mode shares are included as an approximate indicator for the substantive walking that occurs in connection with most transit travel.

Source: Derived from 2001 NHTS by Pucher and Renne (2003).

The lowest mode share in Table 16-69 is the 0.3 percent bicycle share for shopping and services trips. The impediment to bicycling of the need to carry goods pertains most directly in this case. An attitude survey in Portland, Oregon, found very high acknowledgement of the possibility that bicycles *could* be used to accomplish most travel needs. Nearly 88 percent of respondents indicated that use of a bicycle for a work trip would be appropriate. Similarly high responses were obtained for purposes of recreation (nearly 100 percent), school (96 percent), and most other utilitarian trip-making (83 percent). Shopping trips, however, scored much lower at 50 percent, an outcome attributed to the difficulty in carrying packages (Goldsmith, 1992).

In the 2009 NHTS, work trips were found to compose just 4.5 percent of all walk-only trips, or 6.2 percent if work-related business trips are included. In contrast, 29.8 percent of all walk-transit trips nationwide are work trips, or 33.4 percent including work-related business trips.[60] For bicycling, 10.9 percent are work trips, or 12.7 percent including the related trips (Kuzmyak et al., 2011). These and other purpose distributions are provided in the "Related Information and Impacts" section (see Table 16-95 in "Characteristics of Walking and Cycling Overall"—"Trip Purposes"). The purpose aggregations inherent in some Table 16-95 purpose categories do not lend themselves to precise allocation into the non-discretionary-utilitarian, discretionary-utilitarian, and recreational/exercise categories discussed above, but approximation is feasible:

- Of surveyed 2009 walk-only trips, 1-in-3 (or less) are non-discretionary utilitarian, 1-in-3 (or more) are discretionary utilitarian, and about 1-in-3 are recreation/exercise.

- Of walk-transit trips, 6-in-10 (or less, but over half) are non-discretionary utilitarian, roughly 3-in-10 are discretionary utilitarian, and 1-in-10 (or somewhat more) are recreation/exercise.

[60] Reflecting the constraints of published compilations, some mode-specific data involving transit use is presented in terms of total transit use ("transit") and some is presented in terms of "walk-transit," i.e., walking to/from transit service for purposes of transit access and/or egress. The primary difference between these categories is that "transit," while primarily walk-transit, includes park-and-ride and passenger-drop-off auto access trips and a small amount of bike-transit trips.

- Of bicycle trips, 1-in-4 (or less) are non-discretionary utilitarian, 1-in-4 (or more) are discretionary utilitarian, and almost 2-in-4 (almost half) are recreation/exercise.

Purpose Characteristics of Most Recent Trip. Many national surveys that have collected trip purpose information, aside from the NHTS and predecessor NPTS, were shaped by a decision to ask about the last trip taken as opposed to gaining a perspective on the universe of NMT trips taken. What these surveys do reveal is that while many who walk and bicycle do so for a variety of reasons, there are also many who walk or bicycle infrequently and primarily for recreational purposes. In surveys of "most recent walk/bike trip taken," recreation, health, and exercise appear as primary motivators for a very large portion of bicycling and walking trips, larger than would be seen in observed travel on any given individual day (Bureau of Transportation Statistics, 2003b).

The 2002 national survey on pedestrian and bicyclist attitudes and behaviors was such a survey, with information based on the most recent trip in 30 days. As seen in Table 16-70, recreational and exercise trips predominate from this viewpoint, even though this particular survey counted only once each round trip from home having no stop as a destination (NHTSA and BTS, 2002).

Table 16-70 Attitudinal Survey 2002 Trip Purpose for Most Recent Walk/Bike Trip

Purpose of Most Recent Trip [a]	Percent for Walk Trips	Percent for Bike Trips
Commuting to school or work	5%	5%
Personal errands	17	14
Visit a friend or relative	9	10
Recreation [b]	15	26
Exercise or health reasons [b]	27	24
Walk the dog/Bicycle ride	4	2
Other	12	5
To go home [c]	10	14
Total (all purposes)	100%	100%

Note: [a] A focus on the "most recent trip" puts more emphasis on less frequent travel, such as for recreation, than surveys that focus on the universe of walk or bike trips on any given day.

[b] The survey methodology counted only once each round trip from home that had no finite non-home destination, deflating the percentage of recreation and exercise trips relative to other "most recent" trips.

[c] Many survey evaluations identify trips reported as having a "to go home" purpose with the reason for being away from home (e.g., school or work) but this one, at least in some cases, did not.

Source: NHTSA and BTS (2002).

Purpose-Related Trip Distance Effects. As would be expected, not only mode share and prevalence, but also average trip length varies by trip purpose for pedestrian and bicycle trips. (Table 16-95 of the "Related Information and Impacts" section, in "Characteristics of Walking and Cycling Overall"—"Trip Purposes", provides U.S. national trip length and travel time means derived from the 2009 NHTS for various trip categories. Both walking and bicycling trips are covered.)

For walk trips, major-category averages are 1.0 miles and 16.2 minutes for work purpose trips, 0.6 miles and 14.5 minutes for school and house-of-worship trips, 0.6 miles and 12.7 minutes for shopping trips, 0.5 miles and 11.2 minutes for various types of personal business trips, and 0.8 miles and approximately 20 minutes for a social, recreational, and exercise trip category (Kuzmyak et al., 2011).

A breakout of recreation and exercise trips based on the 2001 NHTS serves to identify their unique nature when examined separately from "social" purpose trips. Recreational/exercise walk trips, measured between the starting point and the furthest point reached (to *or* from), averaged 1.16 miles and 25.3 minutes in 2001 (Weinstein and Schimek, 2005). To the extent that these trips were components of "loop" or out-and-back trips, the mean recreation/exercise round trip walk mileage would measure 2.3 miles.

In the case of 2009 NHTS bicycle trips, major-category averages are 3.8 miles and 21.2 minutes for work purpose trips, 1.6 miles and 15.2 minutes for school and house-of-worship trips, 1.3 miles and 14.0 minutes for shopping trips, 1.4 miles and 15.5 minutes for personal business trips, and 2.5 miles and approximately 22 minutes for the social, recreational, and exercise category (Kuzmyak et al., 2011). Miles, and also minutes, devoted to trip making for these major trip categories are all higher for bicycle trips than for walk trips. The travel time differentials all lie in the range between 5 percent higher (school trips) and 38 percent higher (personal business trips). Work purpose bicycle trips are the longest in terms of one-way distance, but this might not be the case if recreation/exercise trips were separated from "social" trips and examined separately.

Trip Purpose Overlap. With regard to identification of trip purpose, it is important to remain aware that most of the above discussion (and research in the field) treats utilitarian NMT travel and walk/bike activity for recreation/exercise as separate and discrete trip purposes, when in fact there is some—and perhaps much—overlap. Significant proportions of active transportation may fall into an area of purpose and motivation overlap, where the pedestrians and bicyclists involved are deliberately choosing NMT travel modes so as to obtain exercise and enjoyment in the course of accomplishing utilitarian travel. A full discussion of this circumstance and the paucity of relevant research, data, and even issue recognition is found in the "Analytical Considerations" subsection of the "Overview and Summary" section (see "Trip Purpose Versus Motivation"). Cross-referencing to other related information within this chapter is provided there, including an example with quantification in the "Response by Type of NMT Strategy" section (see "Pedestrian/Bicycle Systems and Interconnections"—"River Bridges and Other Linkages"—"Goodwill Bridge, Brisbane, Australia").

Schoolchild Trip Factors

Most of the school-purpose trip characterizations presented in the preceding "Trip Purpose" discussion pertain to both child and adult school trips, including those to and from technical schools, colleges, and universities. Moreover, much school-trip-specific information is lost in aggregation of school trips with work trips. It is thus important to separately examine trip factors as they pertain to the travel of children to and from school.

The previously introduced survey of parents of children attending schools in Hillsborough County, Florida (in this section see "Behavioral Paradigms"—"The Travel Choice Making of and for Children"), offers insights on what parents find important in choosing whether or not and how their children may walk or bicycle to school. Parents were asked about trip factors and related conditions from two perspectives: One way the question was explored was to ask which of a list of factors or conditions affected their decisions on allowing or not allowing their child to walk or bicycle to school. The other way was to ask if they would let their child walk or bike to school if the situation were improved. Table 16-71 provides the results for each mode of questioning, listing first those factors of highest priority according to the number of times they were selected. The two modes of questioning produced different prioritizations, but distance from home to school topped the list for both approaches (Zhou et al., 2009).

Table 16-71 Factors and Conditions Affecting Parents' Decisionmaking on Allowing Their Children to Walk or Bicycle to School, Ranked by Frequency of Selection

Factor/Condition	Percentage of Parents Reporting Factor as an Influence on Choice	Factor/Condition	Percentage of Parents Allowing Walk/Bike If Condition Improved
Home to school distance	67%	Home to school distance	26%
Traffic speed en route	54	Intersection safety	22
Traffic amount en route	51	Weather or climate	22
Violence or crime	42	Adults to chaperone	18
Intersection safety	38	Convenience of driving	15
Weather or climate	35	Sidewalks or pathways	12
Travel time	30	Extracurricular activity	12
Sidewalks or pathways	29	Crossing guards	12
Adults to chaperone	16	Travel time	10
Crossing guards	15	Traffic amount en route	10
Convenience of driving	12	Violence or crime	5
Extracurricular activity	6	Traffic speed en route	4

Source: Zhou et al. (2009).

It is not clear which, if either, mode of questioning should be given the most weight. The researchers posit that the percentage of parents who would allow their child to walk or bike to school with improvement in a factor/condition produces the ranking most relevant to SRTS improvement effectiveness (Zhou et al., 2009). In terms of combined average ranking, distance stands much higher than any other factor. Three traffic-safety-related factors come next in importance—traffic amount en route, intersection safety, and traffic speed en route. These are followed by weather and climate, and then violence or crime, status of sidewalks or pathways, travel time, and availability of adults for chaperoning the child. Last are crossing guards, convenience of driving, and extracurricular activity. Those three are either tied for next to last or are last, respectively, in the combined average ranking.

Distance, as mentioned previously, has been found consistently (in all of the 19 studies reviewed) to have a significant negative relationship with active transportation to school, and to be the strongest predictor of the amount. One study determined that a 1-mile increase in distance between home and school decreases the likelihood of walking by 71 percent (Moudon, Stewart, and Lin, 2010). Another estimated that for each 1 percent increase in walking time there is an 0.2 percent decrease in the likelihood of an elementary or middle school student walking. That study also undertook a descriptive analysis of 2001 NHTS data that showed 48 percent of elementary and middle school students living within 1 mile of school to be walking, as compared to 3 percent for schoolchildren beyond 1 mile. Only 20 percent of the children, however, lived within 1 mile of their school (McDonald, 2008).

User Factors

User-specific factors, largely related to user characteristics, help explain why different individuals facing the same environmental and trip considerations make different travel decisions. In this subsection, the differences among pedestrians and bicyclists across several demographic characteristics are presented from a global perspective and discussed in terms of effects on NMT choice. Characteristics examined include gender, age, income, automobile ownership, education, and ethnicity. In addition, selected descriptive information on facility-specific user characteristics are presented in the "Facility Usage and User Characteristics" subsection within the "Related Information and Impacts" section.

Multidimensional User Characteristics

Several researchers have attempted to define different multidimensional bicyclist types as a way to explain observed behavior. They argue that there is no such thing as a "typical" bicyclist. To some extent, comparable distinctions might be made about pedestrian types.

One author, in a manner similar to the transit industry concept of "choice riders" and "captive riders," identifies "voluntary" and "involuntary" bicyclists as two distinct types of bicycle users. Voluntary cyclists are identified as primarily cycling for recreational purposes and as being moderately to extremely proficient. Involuntary cyclists are typed as not having access to a car or public transit because of age, location, or circumstance. This group is identified as being less proficient and having to ride in more varied and hazardous environments as a matter of necessity. The "bicycle commuter" may possess attributes from both types of riders and have a variety of experience levels and needs (Epperson, Hendricks, and York, 1995). One aspect not covered in this particular characterization is the presence of cyclists-in-training amongst recreational "choice riders."

Another research team identifies four types of bicyclists; child, youth, casual, and experienced; and defines five "stress levels" that are determined by a combination of physical infrastructure attributes and user type. The researchers found that the different types of bicyclists vary in the way they perceive stress levels for attributes such as curb lane volume, curb lane width, and adjacent vehicle speeds (Sorton and Walsh, 1994). Still another camp divides the cycling world into those comfortable cycling with vehicular traffic and those who much prefer to avoid it. Another team argues that cyclists are better placed on a continuum of comfort level with traffic and that propensity to use the bicycle is related to the location of the cyclist on that continuum (Aultman-Hall, Hall, and Baetz, 1997).

Indeed, attitude surveys seem to confirm the preference for separated facilities among young and inexperienced riders and a preference for bike lanes and wide curb lanes by more mature and experienced bicyclists (Antonakos, 1994). Bicyclist route choice studies stratified by bicyclist characteristics have obtained results supporting this pattern of preferences and add cyclists uncomfortable in traffic and/or of the female gender to those preferring off-road facilities and quiet streets (Hunt and Abraham, 2007, Dill and Gliebe, 2008). Presented within the case study "Special Mini-Studies in Montgomery County, Maryland" are ". . . Off-Street Versus On-Street NMT User Mix" observations providing additional evidence that cyclist characteristics are reflected in actual route choice and also highlight the near-total selection of the off-road parallel route by walkers and joggers. The differential travel activity choices of various population groupings to factors of personal security and traffic risks are examined in the "Other Factors and Factor Combinations" subsection under "Security and Safety."

The possibility of making "voluntary" versus "involuntary" distinctions for pedestrians, to use the approach of the first-listed bicyclist characterizations above, is suggested by survey and analysis findings from Seattle-area pedestrian activity study observations already introduced. Six "urban" and six "suburban" similarly sized neighborhoods, each with its own commercial area, were compared. The "suburban" neighborhoods, with poor sidewalk systems, had one-third the measured pedestrian activity per resident of the "urban" neighborhoods. Walkers likely to represent "involuntary" pedestrians were markedly over-represented in the suburban neighborhoods and were forced to contend with the deficient infrastructure. In the "urban" neighborhoods, with better walking environments, the greater walking activity along with lesser observed over-representation of walkers likely to be autoless suggests larger numbers of "voluntary" pedestrians (Hess et al., 1998, Moudon et al., 1997).

The various typologies introduced here should be kept in mind as findings along the single-attribute dimensions of gender, age, income, and automobile ownership are reviewed. The Seattle-area comparative pedestrian research is summarized more comprehensively in the case study, "Pedestrian Activity Effects of Neighborhood Site Design—Seattle."

Gender

Men and women walk at similar, though not exactly, the same rates. A summer 2002 national telephone survey found 78 percent of men and 79 percent of women reporting having walked, run, or jogged outdoors for 5 minutes or more in the past 30 days (NHTSA and BTS, 2002). The 2007 ACS indicates that men tend to walk to work more than women, but not by a large margin. Walkers to work were 54 percent men and 46 percent women (Alliance for Biking & Walking, 2010). Results from three pairs of multivariate research model derivations based on 2001 NHTS daily trip diary data suggest that men and women have similar propensities to walk to work, but that men are 13 percent less likely than women to walk for recreation or exercise, other considerations being equal. The survey data exhibited no difference in average trip distance between the sexes (Agrawal and Schimek, 2007).

For bicycling, on the other hand, there tends to be a substantial difference between the trip making of males and females. In a large majority of surveys, male riders outnumber female riders, and for work trips the difference is particularly substantial (Goldsmith, 1992). In the summer 2002 national telephone survey, 34 percent of males rode a bicycle in the previous 30 days versus 21 percent of females (NHTSA and BTS, 2002). There is no evident leveling out over time. The 1990 commuter disparity was reported as 75 percent male versus 25 percent female (David Evans and Associates, 1992), while the 2007 ACS indicates the commuter comparison to be 77 percent male versus 23 percent female (Alliance for Biking & Walking, 2010). Some research has suggested that travel times tend to be similar among men and women (Shafizadeh and Niemeier, 1997), but Portland, Oregon, GPS-tracked cycling distance was significantly lower for female participants (5.0 miles/day average) than for men (7.2 miles). The number of daily bicycle trips was similar for both sexes at 1.6 for females and 1.5 for males, but as previously noted, average bicycling speeds were 9.8 mph for women versus 11.6 mph for men (Dill and Gliebe, 2008).

Examination of mode shares for men versus women tells a similar story. The 2001 NHTS data, including all purposes of travel, produced walk-only-plus-bike mode share totals of 10.6 percent for men and 10.5 percent for women. The modal breakdown differed, however. Bicycle shares were 1.2 percent for males and 0.5 percent for females, with corresponding walk-only shares of 9.3 percent for men and 9.9 percent for women (Pucher and Renne, 2003). One explanation offered for the markedly lesser amount of cycling by women in the United States is their greater need to undertake travel for household and family support activities, which in turn requires more transporting of goods and passengers. Another explanation is that women on average have a different perception of safety than men (Emond, Tang, and Handy, 2009). The safety issue is examined later on under "Other Factors and Factor Combinations"—"Security and Safety."

Public transit shares were 1.7 percent for males and 1.8 percent for females in 2001 (Pucher and Renne, 2003). Only a slightly greater tendency for women to walk in connection with transit use can be inferred from these mode shares. A Centers for Disease Control and Prevention (CDC) analysis of the 2001 NHTS to learn about walking for public transit access did not calculate the odds of making transit access walk trips per se. It did, however, examine the likelihood that people are meeting the Surgeon General's recommendation for 30 minutes of physical activity per day simply by walking to and from transit. This research found a 21 to 23 percent greater propensity for women to obtain 30 minutes or more a day of walking activity by riding transit than for men to do so (Besser and Dannenberg, 2005).

Cross-classification analysis of the 2009 NHTS by gender and age, made in terms of mode share percentages, produces results in general conformity with the gender tendencies identified in overall statistics. The analysis is displayed in Table 16-72. The mode share for women choosing to walk is slightly more than for men in the age categories above age 24, although not at younger ages. Adult males choosing to bicycle outnumber females doing the same by 3-to-1 or more (5-to-1 for seniors). The share of adult females walking to/from transit is larger than the share of males doing so in most age groupings.

Table 16-72 Surveyed U.S. National Walk, Bike, and Walk-Transit Mode Shares for All Travel Purposes Combined, by Gender and Age Cross-Classified, 2009 NHTS

Mode of Transportation	Gender	Age Category						
		5-15	16-24	25-34	35-44	45-54	55-64	>65
Walk-only	Male	14.2%	10.9%	11.6%	9.2%	9.8%	9.7%	8.5%
	Female	12.4	8.8	13.3	10.1	9.8	10.0	9.1
	All	13.3	9.8	12.5	9.6	9.8	9.9	8.8
Bicycle	Male	4.3	1.4	1.1	1.3	1.2	1.0	1.0
	Female	1.8	0.4	0.3	0.3	0.4	0.3	0.2
	All	3.1	0.9	0.7	0.8	0.8	0.6	0.6
Walk to/from Transit	Male	1.1	2.1	1.9	1.4	1.3	1.1	1.2
	Female	0.9	3.0	2.4	1.3	1.6	1.3	1.1
	All	1.0	2.5	2.1	1.4	1.5	1.2	1.1

Source: Derived from 2009 NHTS by Kuzmyak et al. (2011), with clarifications per communications of December 15, 2011.

Children, discussed further under "Age," exhibit a different pattern. Male children have higher mode shares than their female counterparts in each of the three primary NMT categories: walk-only, bike, and walk to/from transit (see Table 16-72 for derivation citation).

While males clearly bicycle more than females, it appears that women more or less make up the difference by walking. The percentage differences between sexes are larger for bicycling, but the smaller counterbalancing percentage differences for walking apply to a much larger segment of NMT trips overall. Confirmation is provided by the 2001 NHTS analysis of walk-only-and-bicycle trips reported previously (Pucher and Renne, 2003) and the 2009 NHTS finding (derivable from Table 16-72) that in five out of seven age categories, daily total walk and bike shares for women exceed the total for men (Kuzmyak et al., 2011).

Age

Adult walking and especially bicycling become less prevalent with age in most but not all countries. This trend is especially pronounced in the United States. The summer 2002 national telephone survey, as noted above under "Gender," asked respondents over age 16 whether they had walked or bicycled outdoors for 5 minutes or more in the previous 30 days. The 2009 NHTS asked if the trip maker (age 5 or above) had walked or bicycled in the past week. The results, stratified by age group, are summarized in Table 16-73, below. While the decline with age for walking is modest, the decline for bicycling is far more substantial and—among adults—starts earlier (NHTSA and BTS, 2002, Kuzmyak et al., 2011).

Table 16-73 Percentage Having Walked or Bicycled in the Past 30 Days and in the Past Week by Age Group

	Walked in the Past…		Bicycled in the Past…	
Age Group	**30 Days**	**Week**	**30 Days**	**Week**
5-15	n/a	76%	n/a	40%
16-24	82%	68	39%	10
25-34	82	70	33	9
35-44	82	68	34	10
45-54	80	68	26	7
55-64	76	66	18	6
65+	66	55	9	3

Note: "Ran or jogged" included with "walked" for 30-day data; not separately identified in "past week" data.

Sources: Past 30 days – NHTSA and BTS (2002). Past week – derived from 2009 NHTS by Kuzmyak et al. (2011).

These results parallel the findings for bicycling of a 1991 Harris Poll and other surveys. The Harris Poll distinguished between general bicycling and commuter bicycling. It found that the drop off with age in commuter cycling was the sharpest of all. Very little cycling to and from work was seen after age 40 (Goldsmith, 1992).

The drop-off in overall bicycling becomes even more dramatic when the 5 to 15 age group is included in the trend analysis, as in the mode share data of Table 16-72 and the "past week" data in Table 16-73. Looked at from the opposite perspective, the incidence of child bicycling is extraordinary. NMT-only travel by children aged 5 through 15 is disproportionately high for both walking and bicycling, as would be expected for an age group with no auto drivers. The prevalence of daily walking in this age group is almost 1/3 higher than the average for older age groups, and the prevalence of daily bicycling is over 4 times as high. Walking and bicycling differentials for children versus adults derived on the basis of numbers of trips rather than indirect comparisons are provided toward the end of this "Age" discussion.

Adult bicycling shares are highest during the age 16 through 24 transition into adulthood, as seen in Table 16-72, although they are nearly down to typical adult levels. Walking to access transit service actually peaks during the ages of 16 through 24 years, with higher shares than at younger or older ages, likely reflecting greater use of transit by young adults just entering the work force. Walk-only mode shares for adults peak later, at ages 25 through 34, and then stabilize at percentages established in young adulthood (but with some gender differences). In this 2009 dataset they decline slightly after age 65 (see Table 16-72 for derivation citation).

NMT mode share data and walking and bicycling activity data exhibit trends that are similar but not identical to each other. Table 16-74 presents 2001 NMT-related mode share data for five age groups. Walk shares over age 65 increase relative to ages 40 through 64 in this 2001 data, returning almost to younger-adult levels. An all-travel-purpose decline in bicycle mode shares at age 40 is apparent in the NHTS data. The bicycle share decline is not as steep, however, as seen for activity percentages such as those in Table 16-73. A major part of the differences seen, although survey methodology variance undoubtedly plays a role, is almost certainly the drop-off in absolute numbers of trips—irrespective of travel mode—as age increases beyond age 64. Trip making by any means of transportation has been shown by the 2001 NHTS to decline fairly steadily from 4.4 trips per day per person at ages 25 through 64 down to 1.9 trips per day per person at ages 85 and above (Pucher and Renne, 2003). Some of the declines with older age seen in Table 16-73 thus may be more related to reductions in trip-making than mode shifts.

Table 16-74 Surveyed U.S. Urban Walk, Bike, and Transit Mode Shares for All Travel Purposes Combined, by Age Group, 2001 NHTS

Mode of Transportation	Age					
	5 to 15	16 to 24	25 to 39	40 to 64	65 & over	All Ages [a]
Walk-only	15.2%	9.3%	9.2%	7.8%	8.9%	9.5%
Bicycle	3.2	0.6	0.6	0.4	0.4	0.9
Transit [b]	1.1	2.9	2.1	1.5	1.3	1.7

Note: Includes only urban area trips 75 miles or less in length.

[a] These mode shares differ from 2001 NHTS results presented elsewhere because of the restriction of travel data to urban area trips.

[b] "Transit" excludes school buses. Transit mode shares are included as an approximate indicator for the substantive walking that occurs in connection with most transit travel.

Source: Derived from 2001 NHTS by Pucher and Renne (2003).

There are striking differences between these walking and cycling trends, as people age in the United States, compared to the more age-resilient walking and cycling experience of certain European countries such as Germany and the Netherlands. These differences are highlighted and interpreted in the "Response by Type of NMT Strategy" section under "NMT Policies and Programs"—"European Programs and Comparisons."

Descriptive statistical analysis of 2001 NHTS daily trip diary data found that the primary variation in walking among age groups was in the proportion of survey respondents in each group who reported making walk trips at all. Among those who walked to any degree, there was much less variation in mean number per day, mean duration, or mean distance of such trips. Two out of three pairs of multivariate model derivations from the data, the two that exclude a confounding auto ownership variable, indicated that persons under age 18 are 45 to 47 percent more likely than non-senior adults to do utilitarian walking and 12 percent more likely to do recreational/exercise walking. The same pairs of model derivations indicated that persons over age 64 are about 25 percent less likely to do utilitarian walking but 39 percent more likely to do recreation/exercise walking. These comparisons are based on odds-ratio estimates that take into account other factors bearing on travel choices, such as family income and housing density. Comparable odds were not determined for public transit access trips, but descriptive statistics indicate that seniors made substantially fewer walk trips to and from transit than non-senior adults (Agrawal and Schimek, 2007).

As this information and Tables 16-72, 16-73, and 16-74 suggest, there are many child pedestrians and bicyclists. The NHTS, with its enhanced methodology for drawing out information on walk trips, found children from ages 5 through 15 to be taking 28 percent of all walk trips and 58 percent of all bicycle trips in 2001. This age range accounted for just 24 percent of the population. Conversely, with 15 percent of the population, adults over age 65 were taking only 9 percent of all walk trips and 4 percent of all bike trips (Alliance for Biking & Walking, 2010).

These aggregate childhood travel data obscure progressive shifts that take place with each additional year of age, from ages 5 through 15. Mode choice modeling of child travel to school, accomplished with 2001 NHTS data, suggests that each additional year in age—through elementary and middle school—is associated with a 1.4 percent lower auto passenger mode share and an 0.4 percent higher walk share (McDonald, 2008). This effect is presumably a reflection of increasing maturity and thus independence from parental chauffeuring. (For more on this research, refer back to "Behavioral Paradigms"—"The Travel Choice Making of and for Children.")

Income

The strongest relationship at the aggregate level between walking and income is encountered when examining the work commute. Among the 50 states, from over 30 to over 60 percent of people who reported walking to and from work in the 2005 ACS earned less than $15,000 per year (Alliance for Biking & Walking, 2010). This aggregate finding may, however, have as much to do with the location of neighborhoods where lower-income households dominate as with the predilections of lower or higher income commuters.

The NHTS provides the most detailed information on propensity to walk or bicycle for all travel purposes at differing household income levels. Table 16-75 provides all-travel-purpose NMT-related mode shares from the 2009 NHTS at five different income levels. A notable decline in mode shares for both walk-only and walk to/from transit trips may be observed between the lowest income level and the other income levels. No consistent income effect is discernible for bicycle travel, however, at this level of cross-classification (Kuzmyak et al., 2011).

Table 16-75 Surveyed U.S. National Walk, Bike, and Walk-Transit Mode Shares for All Travel Purposes Combined by Household Income Class, 2009 NHTS

Mode of Transportation	Household Income				
	Less than $20,000	**$20,000 to $39,999**	**$40,000 to $74,999**	**$75,000 to $99,999**	**$100,000 and over**
Walk-only	16.9%	10.3%	8.9%	8.9%	10.1%
Bicycle	1.1	1.3	1.1	0.9	1.1
Walk-Transit [a]	4.8	2.1	1.1	0.7	0.7

Note: All NMT trips, both urban and rural and of any length, are included in this tabulation.

[a] "Walk-Transit" includes only those transit trips involving walking to/from the transit stop or station.

Source: Derived from 2009 NHTS by Kuzmyak et al. (2011).

The Table 16-75 data cover all 2009 U.S. NMT travel. Investigation of 2001 data excluding rural trips showed similar relationships but with mode shares in the $20,000 to $39,999 category more like those in higher income categories (Pucher and Renne, 2003, Kuzmyak et al., 2011). While the data are not quite comparable, one may speculate that gasoline price increases and other economic pressures during the decade most affected the travel decisions of persons living close to but not in poverty, giving more impetus than before to choice of walking and walk-transit use as compared to driving.

Income, of course, is a major determinant of auto ownership. Ownership of a car "dramatically transforms travel behavior," including mode share, for both walking and bicycling (Pucher and Renne, 2003). (This effect can be clearly seen in Table 16-78, discussed under "Automobile Ownership.")

The combination of mode shares in each mode/income category and overall number of trips made by persons in each income stratum gives the number of persons making trips in each mode/income category. The lower overall per-person trip generation rates of lower-income persons affect the outcome, dampening the number of trips for each mode in the lower income categories (Pucher and Renne, 2003). Table 16-76 shows the resulting percentage distribution of trips among income groups for each NMT-related mode from the 2009 NHTS.

Table 16-76 Surveyed U.S. National Household Income Distribution of Walkers, Bicyclists, and Transit Users, 2009 NHTS

	Household Income				
Mode of Transportation	**Less than $20,000**	**$20,000 to $39,999**	**$40,000 to $74,999**	**$75,000 to $99,999**	**$100,000 and over**
Walk-only	21.8%	19.2%	23.0%	13.6%	22.6%
Bicycle	13.8	21.5	26.8	13.4	24.3
Walk-Transit [a]	39.8	24.3	17.7	7.4	10.8

Note: This table gives the percentage composition of each mode's users by household income class, thus, each row totals to 100%.

Income was not reported by 7% of households. Percentages were normalized accordingly.

All NMT trips, both urban and rural and of any length, are included.

Of persons and households, 16% to 20% are in the less than $20,000 category, about 20% are in the $20,000 to $39,999 category, about 25% are in the $40,000 to $74,999 category, 12% to 14% are in the $75,000 to $99,999 category, and 15% to 20% are in the $100,000 and over category.

[a] "Walk-Transit" includes only those transit trips involving walking to/from the transit stop or station.

Source: Derived from 2009 NHTS by Kuzmyak et al. (2011).

A variety of studies relying on aggregate data have, overall, come to mixed conclusions about the relationship between income and bicycling. The U.S. Bureau of Transportation Statistics found in 2002 that 58 percent of persons who bicycle earn $50,000 or more in income. The BTS, in making this determination, did not stratify by trip purpose and allowed all levels of usage to qualify. Thus, the findings are overweighted by occasional, likely recreational, cyclists. Although the same overall finding of cyclists having higher income was noted for persons reporting 6 or more days per month of bicycling, the difference was smaller (51 percent earning more than $50,000 versus 49 percent earning less) (Bureau of Transportation Statistics, 2002).

Similar information from the 2009 NHTS shows a steady but small increase with higher income in percentage of survey respondents bicycling within the previous week, ranging from 10 percent in the less than $20,000 category to 16 percent in the $100,000 and over category. Walking results are similar, though with higher percentages, starting with 67 percent in the less than $20,000 category and then ranging from 65 percent in the $20,000 to $39,999 category up to 72 percent in the $100,000 and over category (Kuzmyak et al., 2011).

Tabulations from both the 2001 NHTS and 2009 NHTS, the latter as seen in Table 16-75, suggest that there is little variation—or at least no consistent variation—in bicycle mode share among income groups when all travel purposes are considered in the aggregate (Pucher and Renne, 2003, Kuzmyak et al., 2011). It has been suggested that further analysis might show more bicycling for utilitarian purposes among lower income groups and more cycling for recreation among higher income groups (Alliance for Biking & Walking, 2010). Evidence presented following Table 16-77 indicates that such relationships do pertain for walking.

Studies focused exclusively on bicycle commuting have also tended to produce mixed or inconclusive results vis-à-vis income. An analysis of Orange County, California, survey data found no correlation between income and bicycle commuting. Other research found that higher income survey respondents tended to report longer bicycle commuting travel times than other respondents. That analysis also concluded that commuting travel time decreased as income increased for suburb-to-suburb commuters but identified the opposite relationship for suburb-to-CBD commuters (Goldsmith, 1992, NuStats International, 1998, Shafizadeh and Niemeier, 1997). Commuting cyclists are more heavily represented in the employment categories of sales, clerical, service, and laborer than in professional or technical positions (MacLachlan and Badgett, 1995).

Table 16-77 presents results from a 1991 Harris Poll with respect to prevalence of cycling-to-work activity within each of six income strata (Goldsmith, 1992). The income classifications are dated, as a result of inflation, but the distribution of bicycle shares from low to high income clearly supports a finding that cycling to and from work in 1991 was more prevalent in the lowest income categories. This finding, presuming it is still valid, is consistent with the suggestion that lower income groups undertake more bicycling for utilitarian purposes. It does not address income relationships with incidence of bicycling for enjoyment and exercise.

Table 16-77 Percentage Commuting by Bicycle in Previous Month by Income, 1991

Income	Percentage
$7,500 or less	23%
$7,501 - $15,000	14
$15,001 - $25,000	6
$25,001 - $35,000	7
$35,001 - $50,000	1
$50,001 and Over	7

Note: Income as of 1991, in 1991 dollars.

Source: Harris Poll as reported in Goldsmith (1992).

Model derivations from 2001 NHTS daily trip diary data (the three previously mentioned pairs of models) add some clarity in the case of walking. The two model pairs without a confounding auto ownership variable indicate a steady decline in the likelihood of utilitarian walking as household incomes increase from under $15,000 to $30,000 dollars. From that threshold on, persons with more income are roughly 40 percent less likely to make utilitarian walk trips than persons with less than $15,000 in family income. In contrast, the likelihood of recreation/exercise walking increases steadily with income once the $30,000 dollar threshold is reached, according to all three models, until at over $80,000 family income such trips are 22 to 25 percent more likely (Agrawal and Schimek, 2007).

The I-PLACE3S travel demand and health modeling effort in King County, Washington, found, relative to middle-income households, that Seattle area households with incomes under $50,000 had slightly fewer walk-only/bike-only trips and miles. Households with incomes over $100,000 had slightly more. Given that the I-PLACE3S model estimated absolute numbers of trips/miles rather than mode shares, this outcome likely reflects—at least in part—the higher trip activity that comes with higher income (Lawrence Frank & Co., SACOG, and Mark Bradley Associates, 2008) and possibly also a greater propensity to maintain a recreational/exercise walking or cycling regimen. On the other hand, the amount of walking seen in lower-income households would certainly increase if the model set were structured to identify the walking that occurs when accessing most transit trips.

CDC analysis of the 2001 NHTS indeed found likelihood of meeting recommended physical activity guidelines solely by walking to and from transit to be inversely related to income. A person with family income in excess of $70,000 was determined to be less than half as likely to walk 30 minutes a day for transit access than persons with family incomes below $15,000. Mean daily walk times in connection with transit use progressed upward from 20 minutes for the highest income category to 29 minutes for the lowest (Besser and Dannenberg, 2005). This distance variation appears to provide roughly half the explanation for the income-related transit access walking activity difference, with the remainder presumably being accounted for by higher incidence of transit use by lower income persons.

Automobile Ownership

Lower automobile ownership (fewer operating vehicles per household, or fewer vehicles than adults or licensed drivers) is correlated with additional pedestrian and bicycle trip making. The phenomenon pertains whether NMT activity is expressed in mode share or absolute numbers of trips. Walk and bicycle mode shares for persons in zero-car households that are triple the equivalent shares in one-car households suggest that bare-bones necessity plays a major NMT choice role when there is no vehicle. Lesser automobile availability in the household may also diminish the “initial barrier” to contemplating a pedestrian or bicycle trip. Alternatively, it may be that some such households have chosen to forgo purchasing an automobile because they live in a dense area, want to save on the expense of automobile ownership, or favor pedestrian or bicycle travel, and are in a good position to meet daily needs by walking or cycling. For example, Portland, Oregon planners have found automobile ownership to be significantly related to the pedestrian environment (Goldsmith, 1992, Pucher and Renne, 2003, Lawrence Frank & Co., SACOG, and Mark Bradley Associates, 2008).

The investigators for the 2010 Benchmarking Project covering U.S. bicycling and walking stress that “the causation might run in both directions.” They find, in any case, that lower levels of auto ownership are strongly related to higher levels of walking and cycling to and from work ($r = 0.81$) based on the 2007 ACS (Alliance for Biking & Walking, 2010).

Table 16-78 provides NMT-related mode shares associated with different auto ownership levels, derived for urban trips from the 2001 NHTS. The precipitous drop in these mode shares between zero and one car households, compared to lesser differences among vehicle ownership levels once household auto availability is established, appears to serve as a measure of necessity of walking, cycling, or walking to access transit (Pucher and Renne, 2003). Equity implications are discussed in the "Economic and Equity Impacts" subsection under "Related Information and Impacts." Results from the 2009 NHTS (including rural trips, and trips of any length, but excluding non-walk-access transit trips) are virtually the same in round numbers, except that walk-only shares in the two and three-or-more vehicles categories are higher by about 1 percentage point (Kuzmyak et al., 2011).

Table 16-78 Surveyed U.S. Urban Walk, Bike, and Transit Mode Shares for All Travel Purposes Combined by Number of Vehicles in the Household, 2001 NHTS

Mode of Transportation	Total Number of Vehicles in the Household			
	0	1	2	3 or more
Walk-only	41.1%	12.5%	7.8%	6.3%
Bicycle	2.4	0.7	0.9	0.8
Transit [a]	19.1	2.7	0.6	0.5

Note: Includes only urban area trips 75 miles or less in length.

[a] "Transit" excludes school buses. Transit mode shares are included as an approximate indicator for the substantive walking that occurs in connection with most transit travel.

Source: Derived from 2001 NHTS by Pucher and Renne (2003).

One pair of the previously discussed pairs of research model derivations, from 2001 NHTS data, contained an auto ownership variable. The relevant derivations indicated that utilitarian walking is over three times as likely for a person from a zero-car household, as compared to households with one car per driver. (This ratio is similar to relationships obtained with descriptive analyses.) Other differences in auto ownership levels did not produce clear cut model outcomes. The propensity for recreation/exercise walking increased slightly but not significantly with higher auto ownership, supporting a hypothesis "that driving is not the major substitute for recreational walking" (Agrawal and Schimek, 2007).

Owning no cars is a stronger influence on walking and bicycling than simply having fewer cars than drivers in a household. Data from the 2009 NHTS show that active transportation (walk, bike, walk to/from transit) accounts for 8 percent of all trips by persons in households with either three or more vehicles or more vehicles than drivers. However, active transportation is used for 63 percent of all trips by persons in zero-car households, versus 17 percent of all trips by persons in households with fewer vehicles than drivers (Kuzmyak et al., 2011). Looking at such relationships from a nearly opposite perspective, a circa 1980 study in Santa Barbara, California, found that while over 90 percent of the general population owned at least one car, along with 80 to 85 percent of general transit users, the corresponding rate for bicycle users was 70 to 75 percent owning at least one car (Newman and Bebendorf, 1983).

Descriptive analysis of walk-transit trips, with statistics drawn from the 2001 NHTS, showed that the average person in a zero-car household is 14 times as likely to make a walk-transit trip on any given day as a person in an auto-owning household. Moreover, each zero-car household walk-transit trip-maker takes such trips at a 17 percent higher frequency during the day and spends

19 percent more time walking per walk-transit trip (Agrawal and Schimek, 2007). Persons from zero-car households were almost 50 percent to over 100 percent more likely to obtain 30 minutes of physical activity per day, solely by walking to and from transit, than either the primary driver or non-primary drivers in auto-owning households (Besser and Dannenberg, 2005).

Education

The 2009 NHTS data presented in Table 16-79 illustrates that both walking and bicycling are most common among the least educated and persons with a college or graduate degree (Kuzmyak et al., 2011). Similar to equivalent mode share versus income cross-classifications, Table 16-79 leaves open the question of whether or not there might be a different pattern for utilitarian trips as compared to recreational/exercise trips, such as the intuitively satisfying but possibility dated supposition of higher utilitarian walking and cycling among those with the least education balanced in large measure by higher recreational/exercise walking and cycling in households with more education. Walking in connection with transit use follows a somewhat different pattern, with by far the highest prevalence among the lesser educated and continued decline with more education until a graduate or professional degree is obtained, at which education level walk-transit use rises.

Table 16-79 Surveyed U.S. National Walk, Bike, and Transit Mode Shares for All Travel Purposes Combined by Education Level of Household Head, 2009 NHTS

	Highest Educational Level Attained by Household Head				
Mode of Transportation	Less Than High School Graduate	High School Graduate or GED	Some College or Vocational/ Associate Degree	Bachelor's Degree (BA, AB, BS)	Graduate or Professional Degree
Walk-only	13.3%	8.7%	8.6%	10.2%	12.5%
Bicycle	1.1	0.5	0.5	1.0	1.1
Walk-Transit [a]	3.4	1.9	1.3	1.0	1.4

Note: All NMT trips, both urban and rural and of any length, are included in this tabulation.

[a] "Walk-Transit" includes only those transit trips involving walking to/from the transit stop or station.

Source: Derived from 2009 NHTS by Kuzmyak et al. (2011).

Analyses of 2001 NHTS data using multivariate modeling provided statistical insights into the relationships between the odds of walking and measures of education and ethnicity. The educational level findings did not exactly parallel those for income. Aside from minor inconsistencies, the higher the education *and with other factors controlled for,* the more likely a person is to choose utilitarian walking. The relationship is similar and even clearer for recreational/exercise walking. For both categories of walk-only trips, a person with a graduate degree is twice as likely to choose to walk on any given day as a person with only a high school diploma. Making particular reference to recreational/exercise walking, the researchers conclude that: "Although education and income are generally highly correlated, it is clear from these results that educational attainment is a much more important factor than income in determining the odds of walking" (Agrawal and Schimek, 2007). Such findings imply that it is other factors, such as larger proportions of zero-car households or high NMT accessibility characteristics of low-income neighborhoods, that result in larger NMT mode shares for the least educated.

In contrast, bivariate analysis suggests that as education level increases, the likelihood decreases of walking 30 minutes or more a day in connection with using public transit. The estimated likelihood was half for graduate degree holders when compared to those without a high school diploma. Multivariate analysis, however, controlling simultaneously for other variables, estimated equal propensity for such walk-transit activity by persons with less than a high school diploma and persons with a graduate degree. A lesser propensity was estimated for persons with intermediate levels of education (Besser and Dannenberg, 2005).

Ethnicity

The effects of ethnicity on walking are complex, as illustrated by NHTS results. Moreover, observed rates of walking are likely to be influenced by the housing patterns of minorities, including concentration in inner-city areas and older suburbs more likely to feature sidewalks, higher densities, neighborhood shopping, neighborhood schools, and more transit stops and service.

An illustrative example is provided by descriptive and multivariate analysis of choice of mode for school access by elementary and middle school children. Descriptive analysis of 2001 NHTS results indicates that while 10 percent of white children walk to school, 22 percent of African American children do so. However, when included in a multivariate analysis using a multinomial logit model with variables such as auto and walk travel times, population density, income, and vehicles per driver (all in addition to race), the race and ethnicity variables make little explanatory contribution (McDonald, 2008).

For all age groups taken together, descriptive statistics for 2001 showed all minorities, and particularly African Americans, to be engaging in both utilitarian-trip walking and walking in connection with transit trips more often than non-Hispanic whites. Whites and Asians, on the other hand, were shown to be engaging in recreational/exercise walking more than other groups (Agrawal and Schimek, 2007). Aggregate data for 2009 indicate bicycling is most common amongst whites, followed closely by African Americans (Kuzmyak et al., 2011).

When ethnicity was included in multivariate models of 2001 walk-only trip making, however, all minorities were estimated to have lower propensities for both utilitarian walking and recreational/exercise walking than non-Hispanic whites. In other words, it was estimated that if faced with equivalent transportation and income trade-offs, minority groups inclusive of all ages would walk less. The researchers concluded that the discrepancy in the case of utilitarian trips reveals that factors like lower car ownership, lesser income, and residential area characteristics are what leads to the observed higher incidence of utilitarian walking by minorities. They also speculate that what appears to be lower propensities to walk could, to the extent that minorities are segregated into less safe neighborhoods, be a reaction to neighborhood crime (Agrawal and Schimek, 2007).

Walking in connection with transit trips is, in any case, strongly associated with minority status by any available measure (Kuzmyak et al., 2011). For the most part, either in bivariate or multivariate analysis, the individual minority groups are estimated to be two to three times more likely to engage in 30 minutes or more a day of transit-associated walking than non-Hispanic whites (Besser and Dannenberg, 2005).

The 2002 national survey of pedestrian and bicyclist attitudes and behaviors found non-Hispanic blacks least likely to have walked for any reason during the last 30 days (75 percent walked compared to roughly 79 percent for other groups). The same was true for bicycling, but there was also more variability among all groups investigated (non-Hispanic whites, 28 percent cycled; non-

Hispanic blacks, 22 percent; non-Hispanic other, 25 percent; Hispanic, 29 percent) (NHTSA and BTS, 2002). As previously highlighted, this type of survey overweights the sample of recreational NMT trip making. In terms of the journey to work, as measured in the 2007 ACS, there appear to be few notable differentials by ethnicity. The largest were observed in walking to work by persons of Asian ethnicity (7 percent of walk commutes versus 4 percent of the U.S. population) and in bicycling to work by persons of Hispanic ethnicity (22 percent of bicycle commutes versus 15 percent of the population). None of the other similarly measured differentials exceeded 1 percent except for non-Hispanic whites, where the larger percentages involved showed this group taking 64 percent of the walk commutes and 61 percent of the bicycle commutes compared to representing 66 percent of the surveyed population (Alliance for Biking & Walking, 2010).

Other Factors and Factor Combinations

Other separate factors and factor combinations influence the choice to walk or bicycle, but do not fit neatly into a typology limited to environmental, trip, and user factors. This subsection looks at four: security and safety, university affiliation, factor combinations involving trip purpose, and attitudes and modal biases.

Security and Safety

Safety is a potentially significant but poorly understood travel choice factor for both pedestrian and bicycle trips. Concerns about personal safety from crime and street traffic safety are believed to impose some degree of deterrence on the use of non-motorized modes. Two commissioned literature reviews in 2004, however, failed to find evidence of any strong correlation between safety and NMT travel choice. Several possible reasons were suggested, primarily related to limitations in study design (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). Issues of safety and security not only may affect choices adults make concerning their own travel, they also fairly obviously impact the decisions parents and guardians make about how their children should travel to and from school and around their neighborhood.

Among pedestrian environment factors, concerns about safety and security have been identified in at least one study as outranking comfort, convenience, attractiveness, system coherence, and system continuity combined (Khisty, 1994). Other factor ranking findings are provided below. For bicyclists, issues of both traffic safety and bicycle theft are important forms of disutility (Everett, 1990). In an apparent contradiction, safety-related attitudinal questions asked in the Nonmotorized Transportation Pilot Program Evaluation Study found concern about crime affecting daytime walking to be least prevalent of any pedestrian safety concern, yet “free from crime” was the safety-related attribute ranked highest for likelihood to increase the respondents’ walking. Also ranked important, for both walking and cycling, were “free from fast-moving traffic” and certain other traffic safety issues (Krizek et al., 2007).

Personal Security. Behavioral Risk Factor Surveillance System (BRFSS) researchers, using data from five states, were the first to estimate rigorous quantitative relationships between physical inactivity and a perception of neighborhood dangerousness. The elderly, and racial/ethnic minorities, were found to be the most sensitive to perceived danger. (Children were not studied.) Physical inactivity for persons aged 65 and older ranged from 63 percent for those who reported their neighborhood was “not at all safe” down to 39 percent for “extremely safe.” Inactivity percentages for racial/ethnic minorities were 45 percent for adults reporting “not at all safe” neighborhoods down to 30 percent for “extremely safe” neighborhoods. Male non-elderly adults and persons with more than a high school education showed little sensitivity. Physical inactivity was defined as no reported physical activity or exercise, which would include walking, within the previous month (Centers for Disease Control and Prevention, 1999).

Since then, a number of additional studies have identified physical inactivity as being related to neighborhood danger perceptions for adults, and the same association has been found for children. However, numerous other studies have found no relationship. A study of Boston public housing residents, specific to walking activity, used pedometers for quantitative measurement of response to neighborhood safety perceptions. No association was found with daytime safety perceptions for either males or females, or with nighttime safety perceptions for males. Women who reported feeling unsafe at night, however, averaged only 4,302 steps per day as compared to 5,178 for women who felt safe at night (Bennett et al., 2007). Other studies specifically focused on subpopulations of older adults, women, and children have tended to show significant positive correlation between sedentary behavior and real or perceived dangers to personal safety. The relationships appear to be strongest for women, particularly minority women (Committee on Physical Activity, Health, Transportation, and Land Use, 2005).

Pedestrian trip generation modeling done using the 2001 NHTS Baltimore add-on travel data sample, augmented with Census- and GIS-derived household and urban form variables, identified a physical negative factor for walking that may well be a surrogate for high crime areas. Higher proportions of vacant household units, measured at the Census-block level, were estimated to be significantly related to lower rates of walking activity (Targa and Clifton, 2004).

Traffic Safety. Presence of traffic control devices and perceptions that traffic moves at safe speeds were the second- and third-highest positive factors in survey-respondent rankings of high importance in route choice, as noted earlier in discussing "Walk Route Choice" by pedestrians accessing rail transit stations. Only "Shortest route" outranked these factors in a list of 11 choices. When asked to volunteer route choice factors earlier in the survey, 28 percent mentioned safety, as compared to 64 percent mentioning shortest/fastest and 9 percent or less mentioning any other consideration (Weinstein et al., 2007).

Fear of traffic dangers associated with non-motorized travel has received particular attention in the case of bicycling. Bicyclists who regularly cycle in traffic are not as concerned as non-riders, but this greater confidence could result from more cycling by less fearful cyclists (self-selection) as much as it could result from cycling experience (cause and effect). Multiple surveys have shown many people to be averse to bicycling because of traffic or lack of safe bikeways. For example, 58 percent of bike owners in Philadelphia and 55 percent of adults in Portland, Oregon responded accordingly in surveys (David Evans and Associates, 1992). As part of the much newer GPS-and-network-analysis study in Portland, cyclists apparently more concerned with cycling safety than others were identified with a survey question concerning the relative safety of driving and bicycling. Persons so identified gave added importance to riding on a bike lane or off-road trail. Cyclists in the study ranked the importance of avoiding "street with lots of traffic" second only to minimizing distance. Higher-than-average concern with traffic avoidance was recorded for women and infrequent cyclists (Dill and Gliebe, 2008).

A review of several U.S. and Australian studies concluded that female cyclists have different perceptions of road safety relative to males, irrespective of experience levels. Findings were reported of a higher aversion to risk among female cyclists, paired with a higher likelihood of being discouraged from bicycling when required to share space with vehicular traffic. The accompanying original research, staged in six small western cities in the United States, involved a survey of perceptions and bicycling activity (12.6 percent overall survey response rate) together with multivariate analysis. It found women to report a significantly lower "comfort score" than men for all types of road/bicycle facilities except quiet streets, which scored highest and essentially the same for both sexes. As male and female comfort levels decreased across facility types, the percentage by which women were less comfortable than men increased until stabilizing at –17 percent. Table 16-80 lists the facility types examined and the corresponding scores obtained, in order of progression from highest score and least difference between women and men to lowest score and greatest difference. The researchers hypothesized that quiet streets offer female bicyclists good visibility to assuage personal safety concerns together with vehicular volumes low enough to mitigate traffic safety unease (Emond, Tang, and Handy, 2009).

Table 16-80 Male Versus Female Bicycling Comfort Scores by Facility Type

Facility Type	Male Score	Female Score	Pct. Difference
Quiet street	2.92	2.91	0%
Off-road shared use path	2.85	2.74	-4%
Two-lane local street with bike lane	2.84	2.70	-5%
Two-lane local street without bike lane	2.59	2.38	-8%
Four-lane street with bike lane	1.97	1.65	-17%
Four-lane street without bike lane	1.63	1.36	-17%

Note: Scores are means calculated on a three-point scale: 1 = "uncomfortable and I wouldn't ride on it" 2 = "uncomfortable but I'd ride there anyway" 3 = "comfortable."

Source: Emond, Tang, and Handy (2009).

Traffic counts/observations conducted in connection with bicycle safety enhancements to Burrard Bridge in Vancouver, BC, provide empirical support of the thesis that female cyclists are the more concerned with traffic safety and will respond positively to improvements. After cyclists crossing Burrard Bridge were provided with a barrier-protected exclusive lane (outbound) and a full sidewalk reserved for cyclists (inbound), use by cyclists increased 26 percent. Broken down by gender, the increases were 23 percent for men and 31 percent for women (City of Vancouver, 2009a). Not only perceived safety and comfort but also actual safety were increased, with a 75 percent reduction in bicycle crashes requiring hospital emergency room visits (Mustel Group Market Research, 2009, City of Vancouver, 2010). (For additional information see "Response by Type of NMT Strategy"—"Pedestrian/Bicycle Systems and Interconnections"—"River Bridges and Other Linkages"—"Other River Bridges.")

The frequently mentioned, aggregate data, cross-sectional analysis of journey-to-work cycling in 90 of the 100 largest U.S. cities included a safety variable in the bicycling-rate analysis. Data limitations forced use of statewide bicyclist fatality averages as the measure. Even so, the safety variable was significant and indicated a bicycle commuting rate that was higher by 2.3 percent for each 10 percent by which the fatality rate was lower (Buehler and Pucher, 2011, Kuzmyak et al., 2011).

Traffic safety concerns are, to a degree, addressable through infrastructure, operational, and institutional initiatives. Traffic engineering techniques available for safety enhancements are largely beyond the scope of this "Traveler Response" Handbook, but are summarized and cross-referenced in the "Related Information and Impacts" section under "Safety Information and Comparisons." The subsections under "Response by Type of NMT Strategy" on "NMT Policies and Programs" and "Walking/Bicycling Promotion and Information" contain relevant information on institutional initiatives such as the Safe Routes to School programs. Bicycle security can be addressed through parking security provisions. Trip-maker response to bicycle parking provisions is covered under "Point-of-Destination Facilities" within the "Response by Type of NMT Strategy" section.

A better understanding of the traffic dangers which exist can help put things in perspective. It makes no sense, for example, to restrain children from walking independently based solely on generalized crash rates affected heavily by adult-pedestrian alcohol intoxication. Bicycling does tend to be somewhat less safe than auto travel with an adult driver, and walking may be marginally so, but the only wildly unsafe travel mode relative to others is the motorcycle. The statistics of crash analysis are such that rate comparisons among modes can vary substantially depending on the measure of exposure used. A major focus of the "Safety Information and Comparisons" subsection of the "Related Information and Impacts" section is examination of crash statistics from more than one perspective in an effort to provide a balanced overview of traffic safety as pertains to walking and bicycling choices.

University Affiliation

University affiliation produces a special combination of environmental, user, and attitudinal factors that heightens campus and citywide non-motorized mode shares. Overall, "college towns" have higher levels of bicycle commuting than non-university locales, especially when relatively large campuses are involved. Davis, California, Boulder, Colorado, and Madison, Wisconsin, are among the most cited examples with high levels of bicycle usage. Although each have significant bicycle infrastructure and bicycle-friendly development in place, the level of cycling is such that it most likely cannot be solely attributed to these accommodations. Perhaps students and university staff are joined in choice of the bicycle mode by other townspeople with no formal university affiliation, simply because of the visible acceptability of the mode. Nevertheless, many college towns without the cycling infrastructure do not experience equivalent cycling. It is a combination of factors responsible (Goldsmith, 1992, Victoria Transport Policy Institute, 2007).

It certainly helps that locales with universities have a large population of young, healthy individuals living close by who may dress informally. In addition, most campuses limit or charge for parking and are otherwise congested to the point where the bicycle often has a time advantage over other modes. Trips are generally short and many schools are located with relatively bicycle-friendly surrounding streets, generally perceived as "safe" even if there are no dedicated bicycle facilities. Automobile ownership is low and bicycle ownership is high among students, and the culture and area motorists tend to be supportive of their use (Goldsmith, 1992, Everett, 1990).

A majority of national studies making use of aggregate city or regional data to attempt isolation of factors linked with higher levels of bicycling have found elevated presence of college students to be associated with more commuter cycling within a city. (None of these studies examined travel purposes not fitting the U.S. Census definition of the "journey to work.") The first such study to go beyond descriptive analysis was an early 1990s effort by Baltes employing commute mode data from the 1990 U.S. Census. Regression analysis covering a wide range of socio-demographic, travel time, and workplace factors isolated the proportion of college students as one of three or four key factors (Kuzmyak et al., 2011).

Later in the decade a similar approach, expanded to include bicycle facility extent and weather data, found higher ratios of college students to be one of three primary variables strongly and positively related to more commuter cycling. The other two were bikeway miles per 100,000 population and fewer rain days/year (Nelson and Allen, 1997). A subsequent regression analysis, utilizing U.S. Census 2000 Supplemental Survey travel data, did not incorporate the percentage of college students within the population into the final research models. The 43 cities covered represented a more uniform assemblage, with no small cities and no college towns (Dill and Carr, 2003). Finally, drawing on augmented 2006–2008 3-year average ACS cycling data covering 90 of the 100 largest U.S. cities, cross-sectional analysis identified student ratios as one of a half-dozen significant explanatory variables and one of those exhibiting a positive relationship (Buehler and Pucher, 2011) (See "Bicycle Lane System Coverage" within the "Bicycle Lanes and Routes" subsection of the "Response by Type of NMT Strategy" section for more on these three studies.)

At the beginning of this "Underlying Traveler Response Factors" section, a potential three-step hierarchy of transportation decisionmaking was introduced, consisting of "initial barriers," "trip barriers," and "destination barriers." In a college town such as Davis, Boulder, or Madison, clearly all of these barriers are relatively low. The infrastructure and institutional climate enables both students and non-students to be drawn to bicycling for a large percentage of their travel needs. Davis may be unique among contemporary U.S. cities in acceptance and use of cycling for meeting daily transportation needs, but college town and university district bicycle usage is often sufficient to engender a "virtuous circle." Infrastructure and operational improvements are supported not just by promise of increased NMT activity, but also by readily evident day-to-day current volumes of bicyclists. The improvements, in turn, engender additional bicycling and other active transportation.

Factor Combinations Involving Trip Purpose

In the preceding "factors" discussions, and elsewhere in this chapter, there are some presentations and speculations about the role of trip purpose in the response or relationship to other factors and to facility improvements. For example, research using 2001 NHTS data found persons in the higher income categories about 40 percent less likely to make utilitarian walk-only trips than persons in the lowest income category, but almost 25 percent more likely to walk for recreation and exercise (Agrawal and Schimek, 2007). A similar relationship has been suggested for bicycling but not established (Alliance for Biking & Walking, 2010). In the aggregate, bicycling appears roughly uniform across incomes (Kuzmyak et al., 2011), but the aggregation may obscure information important to planning and equity determinations.

Such interrelationships are among the least studied of pedestrian and bicycle choice factors. In using data covering all or multiple trip purposes, the possibility that trip purpose aggregation masks important relationships must constantly be kept in mind.

Cross-classifications by trip purpose of self-reported mode and route choice influences have produced quite informative insights. One such case is the discovery that self-reported exercise and enjoyment motivational factors were almost as important to commuters as to non-commuters in their choice to use a new pedestrian/bicycle-only river crossing in Brisbane (Abrahams, 2002). A more comprehensive matching of path choice factors by trip destination purpose is provided by the Portland, Oregon, bicyclist route choice research. Participants were asked to rank, in order of importance, seven factors that influenced their choice of route. These were then separately tallied for each of four categories of trip destination purposes. The results, provided in Table 16-81, provide instructive similarities and certain key differences. Route choice factor rankings were virtually identical for the two categories encompassing purely utilitarian travel, with a one-point ranking difference showing up only in the factors ranked last or next-to-last. Distance minimization slipped from first place for utilitarian trips to second place for social/recreational trips and sixth place for exercise. Traffic avoidance rose from second place importance ranking in the case of utilitarian trips to first place ranking for social/recreational and exercise activity (Kuzmyak et al., 2011).

Table 16-81 Importance Ranking of Factors affecting Bicycle Route Choice for Different Destination Purposes, Portland, Oregon

	Destination Purpose			
Route Choice Factor	Work, Work-Related, School	Shopping, Dining, Per–sonal Business	Social and Recreational	Exercise
Minimize distance	1	1	2	6
Avoid traffic	2	2	1	1
Use on-road bike lane	3	3	3	2
Reduce intersection delays	4	4	5	5
Take a signed route	5	5	4	4
Use off-road bike path	6	7	7	3
Avoid hills	7	6	6	7

Source: Derived from Dill and Gliebe (2008) by Kuzmyak et al. (2011).

Attitudes and Modal Biases

Effects of attitudes and modal biases on travel choices are subject to much debate. To whatever extent they exist, they are related. Modal biases are logically a function of both attitudes and experiences. The subject of attitudes is introduced, in a context relevant to NMT choice, within Chapter 15, "Land Use and Site Design." In particular, see "Attitudes and Predispositions" within that chapter's "Underlying Traveler Response Factors" section.

Modal biases are frequently cited as having a role in travel choices. Although habit may play a part in transportation decisionmaking, most modal biases are probably explained by reactions to specific attributes of travel mode options. For example, in attitude surveys some people make clear that they do not like the bus and will not ride a bus. However, in most cases the problem relates to a dislike of actual or perceived attributes of bus riding, such as time spent waiting, the type of waiting environment, harassment or crime concerns, unpleasant noise or odors, and so on, rather than some inherent dislike of buses per se. Many people make clear that they like to travel in private vehicles for a variety of reasons. They may perceive that private vehicles offer a more protected environment than other modes, and they appreciate having individual control over such factors as climate, radio, route, speed, destination, and people encountered enroute. For "modal biases" that deter use of active transportation modes to be properly addressed through public policy actions or marketing, inherent characteristics, perceptions, barriers to use, and other issues must be understood.

Some have suggested that it is personal motivation rather than physical or rational factors that controls the decision to undertake active transportation (David Evans and Associates, 1992). A mode-judgment experiment examining the role of habit in active-transportation decisionmaking found subjects who normally used bicycles for transportation to be at least somewhat more likely to choose to bicycle in various hypothetical situations than those who did not as frequently use bicycles. Perhaps more crucially, the habitual riders demonstrably streamlined their decision process and used fewer attributes of the circumstances to determine their course of action (Aarts, Verplanken, and van Knippenberg, 1997). The implication is that mode choice is "sticky" and that, in addition to addressing the decision-driving attributes, significant forces of habit and predisposition must be overcome to make a change.

Since a majority of U.S. commuters and other trip-makers are motorists, there is a fair amount of collective inertia to overcome. A 1981 FHWA study asked respondents which mode they preferred to use to make trips of various purposes and also which mode they actually used. For commuting, 72 percent of the people preferred using an automobile, but 75 percent actually did. Of the remainder, 14 percent preferred walking and 7 percent preferred bicycling, although only 11 percent actually walked and only 3 percent actually bicycled. These responses were viewed as being related to the package of attributes generally associated with each mode rather than the specific attributes underlying a specific circumstance. Thus the results were seen as highlighting the significant inertia surrounding use of the automobile (David Evans and Associates, 1992). Another interpretation might be that the actual-choice responses reflect the realities faced in actual trips, including both facility adequacies and inadequacies.

A model of behavioral change, originally developed in the context of smoking cessation campaigns, identifies five stages relevant for overcoming inertia and inducing shifts to active transportation (Rose and Marfurt, 2007):

1. Pre-contemplation (not yet thinking about changing).
2. Contemplation (consciously contemplating change).
3. Preparation (preparing to make the change).
4. Action (taking action to change).
5. Maintenance (sustaining the change).

Voluntary travel behavior change (VTBC) (see "Individualized Marketing" within "Response by Type of NMT Strategy"—"Walking/Bicycling Promotion and Information") raises interesting questions concerning the role of attitudes. Individualized marketing in the interests of VTBC is designed to raise awareness, improve information availability, and offer support for people trying alternatives to driving (Brög and Ker, 2008). These thrusts serve to address inertia and the behavioral stages listed above.

Improving information is most relevant to the contemplation and especially the preparation stages. The role of information availability is perhaps best illustrated by this approximated response of a Bellingham, Washington, recipient of individualized marketing: "Oh! I didn't know I could take that trail to downtown—I thought it was just for exercising!" In this instance, the information recipient was simply placed in a better position to make an informed utilitarian decision. On the other hand, VTBC is said to work also through empowerment and motivation. A key component is getting people to actually try an appropriate alternative travel mode and to reward the new behavior. This would seem to fall more in the sphere of changing attitudes, particularly when social learning based on the example of others—including early adopters—is a factor (Horst, 2010b, Brög and Ker, 2008).

Clearly environmental and user factors, facilities and services, time and cost parameters, availability of information about them, and attitudes are all important in travel behavior. There is of yet no agreement on the relative importance of "hard" versus "soft" factors, and indeed, their relative import no doubt depends on circumstances. Nevertheless, many explanatory research models—plus applied travel demand modeling experience—suggest it would be incorrect to ascribe the bulk of travel behavior outcomes to attitudes or related factors such as neighborhood choice (see next subsection). At the same time, it would be wrong to assume that the roles of inertia and attitudes are unimportant.

Attitudes, to the extent they apply, can affect adult travel behavior in two different ways: they can directly affect short-term travel choices such as choice of mode and they can affect long-term underlying mobility choices such as residential location, employment location, and vehicle ownership. The characteristics of the neighborhood chosen will in turn help define the attractiveness of alternative travel options and thereby influence short-term travel choices (Cao, Mokhtarian, and Handy, 2009, Federal Highway Administration, 1974). Implications of neighborhood choice are further explored in the next subsection.

The effect of attitudes on child travel behavior is somewhat different, since parental attitudes shape the travel of children. Parents presumably evaluate the trade-off between perceived child safety and benefits of independent movement and active transportation—an assessment likely influenced heavily by attitudes and social norms—determining whether the child is allowed to travel by walking, cycling, or public bus without adult supervision, or only with supervision, or gets chauffeured by private vehicle (Mackett et al., 2007a, Mackett et al., 2007b). (Within the earlier "Behavioral Paradigms" subsection, see "The Travel Choice Making of and for Children" discussion of attitudes as "moderating factors" in parental decisionmaking.) This decisionmaking is also significantly impacted by neighborhood characteristics (Davison and Lawson, 2006, Moudon, Stewart, and Lin, 2010); so again, choice of neighborhood has its effect.

Choice of Neighborhood/Self-Selection

Predispositions, in the form of attitudes and modal biases, may directly impact the immediate travel choice of whether or not to walk or bike or use public transit for any given trip, as discussed above. Alternatively, they may impact long-term mobility choices that will affect future short-term travel choices. This subsection examines travel demand interplay with neighborhood choice—primarily choice of pedestrian-and-bicycle-friendly neighborhoods over auto-oriented neighborhoods. Though not always thought of this way, selection of home neighborhood is a prime example of a mobility choice affecting subsequent travel choices such as using or not choosing active transportation for utilitarian trips. Neighborhood choice can also affect (or be affected by) auto ownership, which in turn is another mobility choice factor impacting travel decisions (Federal Highway Administration, 1974). Neighborhood characteristics likewise affect personal decisions concerning exercise and recreation (see "Public Health Issues and Relationships" under "Related Information and Impacts.")

Self-Selection Investigations

Research on self-selection at the Institute of Transportation Studies, University of California at Davis, has included an examination of 38 studies focusing either on self-selection or attitudinal effects along with built environment effects on travel behavior. The individual studies address a broad array of built environment descriptors covering land use and transportation features postulated to be supportive (or non-supportive) of walking, bicycling, transit use, and reduction in vehicle miles of travel (VMT). The researchers conclude: "Virtually every quantitative study . . . after controlling for self-selection . . . identified a statistically significant influence of one or more built environment measures on the travel behavior variable of interest" (Cao, Mokhtarian, and Handy, 2007 and 2009).

Table 16-82 outlines analytical approaches and empirical findings for 14 of these studies that directly addressed non-motorized travel while also explicitly examining residential self-selection and/or attitudinal effects. Some 3 to 5 of the 14 studies may be interpreted to have found self-selection or attitudinal effects more important for NMT choice decisions than built environment effects. Four to six of the studies found self-selection and built environment effects to be of roughly equivalent importance, and five found the built environment effects to be more important. Several of the studies concluded that residential preference effects were more important in NMT choices than in transit mode or auto-related choices.

Table 16-82 Summary of Findings about NMT Effects of Residential Self-Selection (SS) Relative to Direct Impacts of the Built Environment (BE)

Study	Process	Key Findings
1. Handy and Clifton – 2001	Direct questioning of some 1,400 participants in Austin, TX, [1995] with descriptive and correlational analysis of walk-to-store frequency.	Both SS and BE effects identified: Having the option to walk to store was "to some extent an effect of the desire to walk" while perceived store characteristics influenced frequency.
2. Cao, Handy, and Mokhtarian – 2006	Analysis with statistical control of walk-to-store and strolling frequencies of 1,368 individuals in Austin, TX, [1995] using negative binomial regression.	Both SS and BE effects identified: Residential preference "most important single factor explaining walk-to-store frequency" but objective and perceived area characteristics had separate influences on walk-to-store and strolling frequencies.
3. Cao, Mokhtarian, and Handy – 2005	Analysis with statistical control of nonwork trip frequencies by mode of 1,682 individuals from Northern California [2003] using seemingly unrelated regression.	Both SS and BE effects identified: SS "more likely to influence walking/biking trips than auto and transit trips," but the BE was nevertheless also found to influence all trips.
4. Chatman – 2009	Analysis with statistical control of numbers by mode of nonwork activities accessed by 1,114 adults in the San Francisco and San Diego regions [2003] using negative binomial regression.	Mode preference effects found to be less than BE effects: Both transit and walk/bike trips affected by mode preferences but the BE (as expressed in transit quality and street connectivity measures) also independently affected these alternative modes. Auto travel showed no effects.
5. Frank et al. – 2007	Analysis with statistical control of VMT and percent taking walking trips, with walkability index and residential preference variables, using linear regression and two subsamples of 2,056 and 1,466 from 2001-02 Atlanta SMARTRAQ data.	Residential preference and BE both affected driving and walking prevalence. BE effects were stronger for VMT and residential preference effects were stronger for walking. (See also the discussion to follow of residents locationally matched and mismatched with their area-type preferences.)
6. Kitamura, Mokhtarian, and Laidet – 1997	Analysis with statistical control of numbers and fractions of trips by mode across 963 households in San Francisco Bay Area [1993] using linear regression.	The attitudinal measures carried more explanatory power than the measures used for BE characteristics (see Chapter 15 — "Underlying Traveler Response Factors" — "Attitudes and Predispositions" for more).
7. Schwanen and Mokhtarian – 2005 (two papers)	Analysis with statistical control of commute trip shares and weekly miles by mode (personal vehicle, public transit, walk/jog/bike) for 1,358 workers in San Francisco Bay Area [1998] using multinomial logit and Tobit models.	Neighborhood (NBH) preference effects found to be less than BE effects: Preferences had less effect in suburban environments than differences within each preference group between suburban and traditional urban environments. (See Chapter 17 — "Underlying… Factors" — "Self-Selection of Residents" — "Self-Selection Effects on TOD Regional Travel…" for more).
8. Khattak and Rodriguez – 2005	Regression analysis with instrumental variables models of various trip-type frequencies and durations for 453 households in Chapel Hill and Carrboro, NC.	BE dominant: In contrast to 8 measures of residential preference, the BE (identified in terms of neo-traditional and suburban NBHs) "influenced most measures of travel behavior."
9. Boer et al. – 2007	Analysis, with propensity score (probability of self-selection) matching, of choice of walking in 10 metro areas in 1995 NPTS.	Both SS and BE effects identified, including land use mix, density, and parking pressure. Most BE influences became insignificant with propensity score matching.

(continued on next page)

Table 16-82 (Continued)

Study	Process	Key Findings
10. Cao – 2008	Analysis using propensity score stratification of walking frequency (2 measures) and VMT for 1,553 Northern CA residents [2003].	BE dominant: SS (residential preferences and travel attitudes) estimated to account for 14% of effect on strolling frequency, 39% for walk-to-store frequency, and 22% for VMT.
11. Bagley and Mokhtarian – 2002	Analysis with simultaneous models (structural equations) of vehicle, transit, and walk/bike miles by 515 individuals in San Francisco Bay Area [1993].	SS effects found to be more important than BE effects: "Residential location type had little separate impact on travel behavior; attitudes and lifestyles were the most important predictors of travel behavior."
12. Salon – 2006	Analysis with simultaneous models (nested logit) of residential choice, auto ownership, and walking levels for 4,382 New York City regional-travel-survey respondents.	Both SS and BE effects identified: "Self-selection accounted for 1/3 to 1/2 the total influence of the built environment" using density as the neighborhood characteristics measure.
13. Cao, Mokhtarian, and Handy – 2007	Longitudinal analysis, using a structural equations model, of changes in auto ownership, driving, and walking/biking for 547 movers in Northern California [2003].	Both SS and BE effects: "Attitudes influenced auto ownership and travel behavior" while the BE had separate effects, isolated using both objective and perceived NBH measures for previous and new residence locations.
14. Handy, Cao, and Mokhtarian – 2006	Longitudinal analysis, using an ordered probit model, of strolling and walking-to-store frequencies and of walking changes and biking changes for 1,682 individuals in Northern California [2003].	Both SS and BE effects: Cross-sectional analyses showed "influence of attitudes on walking" while "longitudinal analysis showed separate effects of BE on walking and biking behavior" based on objective and perceived NBH measures and perceived changes.

Note: Drawn from summaries of 38 studies, omitting those not directly addressing non-motorized travel or with no apparent examination of residential self-selection or attitudinal effects.

Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the *TCRP Report 95* "Traveler Response" Handbook is given — in the third column.

Source: Cao, Mokhtarian, and Handy (2007 and 2009).

Not included in Table 16-82—along with research not explicitly investigating NMT use—are studies which exclude residential choice effects by their very nature, such as before-and-after investigations and certain longitudinal studies. The impact estimates produced by these types of studies are of built-environment effects alone, or built-facility or executed-program effects alone, though such estimates have their own sets of issues such as confounding events and multiple causations. It is cross-sectional studies that inherently present the knottiest problems for isolation of residential choice influences. Cross-sectional studies tend to dominate travel behavior research addressing land use and site design, and are also found in applications such as public health research on sidewalk and other NMT facility effects.

Table 16-83 summarizes five additional studies of special interest in the consideration of residential choice even though they do not specifically address non-motorized travel overall. They focus on either private vehicle use, with alternative mode effects inferred, or on bicycle ownership and use. Two of these five studies found self-selection effects to be the more important, one found self-selection and built environment effects to be of roughly equivalent importance, and two found the built environment effects to be more important.

Most of the studies listed in Tables 16-82 and 16-83 employed some form of cross-sectional analysis as the investigative technique. Three, however, had the advantage of data on travel behavior before and after residence relocation. Two of those three studies (the 13th and 14th in Table 16-82) found self-selection and built environment effects to be of roughly equivalent importance, and one (the 3rd in Table 16-83) found the built environment effects to be of prime importance (Cao, Mokhtarian, and Handy, 2007, Krizek, 2003). In the latter instance, using a model developed on data from 7 waves of the Puget Sound Transportation Panel survey, it was estimated that the *daily household* average VMT was 5 miles more—irrespective of preferences—when households that moved were located in a representative suburban location as compared to a representative urban location (Krizek, 2003). Corresponding active transportation effects have to be inferred.

Three of the newer studies (the 9th and 10th in Table 16-82 and the 1st in Table 16-83) have explored approaches drawing upon medical treatment analysis procedures. They addressed self-selection as a treatment bias, similar to potentially greater use of a preventative medicine by health-conscious individuals. One of these found both self-selection and built-environment effects to be of comparable importance and two concluded that built environment effects were more important (Cao, Mokhtarian, and Handy, 2009, Zhou and Kockelman, 2008).

Table 16-83 Summary of Selected Research on Interrelationships among Residential Self-Selection (SS), the Built Environment (BE), Auto VMT, and Bicycle Ownership and Use

Study (Date)	Process (Limitations)	Key Findings
1. Zhou and Kockelman (2008)	Formulated SS as a sample selection bias, drawing on medical treatment statistics and utilizing Heckman's latent index model. Tested with 1,903 household sample. (Highly aggregate area-type BE indicator.)	Estimated difference of 17.0 to 20.2 daily VMT between central/CBD and suburban/rural Austin, TX, with 58% or more (up to 90%) of the difference attributable to BE (the "treatment") rather than SS (the "bias").
2. Circella, Mokhtarian, and Handy (2008)	Structural equations modeling, using survey results for 1,217 workers in 8 Northern CA communities [2003], to examine residential location, auto ownership, and VMT. (Direction of causality was found difficult to determine.)	Travel and land use attitudes strongly associated with travel and location behavior. SS confirmed for persons preferring alternative travel solutions. BE found to matter also, with higher neighborhood relative to regional accessibility favoring alternative modes.
3. Krizek (2003)	SS issues bypassed by examining VMT, person miles traveled (PMT), and tour characteristics changes by 430 households who moved during the Puget Sound Transportation Panel's 7 waves, which provide disaggregate and longitudinal travel data. (Assumed that relocations were mainly for reasons other than travel environment self-selection.)	Households alter their travel in response to differing built environments. Relocating to residences with higher neighborhood accessibility increases the number of daily tours but decreases the trips per tour, PMT, and VMT. Higher regional accessibility is also associated with decreased trips, PMT, and VMT, but with statistically insignificant effects on number of tours.
4. Pinjari, Bhat, and Hensher (2008)	Modeled residential location and activity time-use choices of 2,793 households in Alameda Co., CA, using a multinomial logit formulation that accommodates attributes both observed and unobserved and controls for SS. (Bicycle ownership levels treated as given.)	Individuals with "a preference for physically active pure recreation" and higher bicycle ownership tend to locate in neighborhoods with good bicycle facility density, nevertheless, modifying the activity-travel environment can produce small activity level changes (facility density x 10 = 17% increase).
5. Xing, Handy, and Buehler (2008)	Cross-sectional analysis, using nested logistic models, of relative influence of individual, social-environment, and physical-environment factors on bicycle ownership and use in 6 small Western U.S. cities. (13% overall survey response rate, mismatch with U.S. Census.)	Aside from socio-demographics, attitudes were dominant in explaining bicycle ownership and use. No BE effect on ownership was found. Two BE factors showed significance as bike use descriptors: perception of safety in reaching selected destinations, and transit access (for reasons not obvious).

Sources: As indicated in the first column.

Five studies have been encountered that undertook to put numbers on the proportions of built environment effects on travel behavior versus self-selection or attitudes. Table 16-84 consolidates the quantitative findings. Notably, all five of these studies indicate that built environment effects tend to substantially exceed, or at least roughly equal, self-selection and attitudinal effects. Both types of influences were, however, found in each study (Ewing and Cervero, 2010).

Table 16-84 Studies Quantifying the Relative Contributions to Travel Differences of Built Environment (BE) Versus Residential Self-Selection (SS) or Attitudinal Effects

Study (Date)	Quantitative Estimate of BE Versus SS or Attitudinal Effects
1. Salon – 2006	BE effects accounted for 1/2 to 2/3 of differences in New York City walking levels associated with density (see also Table 16-82, 12th study).
2. Cao – 2008	BE, for Northern California residents in a 2003 survey, accounted for 86% of effect on recreational walking frequency, 61% of effect on walk-to-store frequency, and 78% of effect on VMT (see also Table 16-82, 10th study).
3. Zhou and Kockelman – 2008	BE, depending on assumptions, accounted for 58% to as high as 90% of the VMT difference associated with central area versus suburban/rural housing location per the 1998-99 Austin travel survey (see also Table 16-83, 1st study).
4. Cao, Xu, and Fan – 2009	From 48% to 98% of differences in VMT identified in a Raleigh, NC, regional travel diary survey due to direct BE influences — remainder attributable to SS.
5. Bhat and Eluru – 2009	Some 87% of household VMT differences between conventional suburban and traditional urban neighborhoods, observed in a 2000 San Francisco Bay Area travel survey, found due to "true" BE effects — remainder due to housing SS.

Sources: Cao, Mokhtarian, and Handy (2009), Ewing and Cervero (2010).

Neighborhood Preference Matches and Mismatches

Two research efforts included in Table 16-82 looked beyond self-selection concerns, probing what the net effects are—with and/or without self-selection—of different types of built environments. A San Francisco Bay Area series of studies (the 6th entry in Table 16-82 and covered further in Chapter 17, "Transit Oriented Development," as noted) studied persons in different residential environments matched and mismatched with their area-type preferences. Neither suburban-oriented nor urban-oriented individuals residing in the suburbs exhibited walk/jog/bike commute mode shares averaging over 0.4 percent, but suburban-oriented individuals in an urban environment averaged a corresponding 3 percent walk/jog/bike commute share, with urban-oriented individuals similarly located averaging 5 percent. The suburban versus urban *weekly* VMT differential was 82 miles less driven for urban-located suburban-oriented individuals and 100 miles less for urban-located-and-oriented individuals (Schwanen and Mokhtarian, 2005a and b).

An Atlanta-based study of residential self-selection (the 5th entry in Table 16-82) carried out a similar analysis of matched and mismatched residents, albeit with somewhat different criteria and parameters. This analysis was supplemental to the primary statistically controlled modeling and was in essence an illustrative descriptive analysis. Samples were drawn from 2-day trip diary results (85 percent weekdays) for a subset of the regional SMARTRAQ travel survey in which neighborhood preference and walkability score data had been obtained.

Only cases in quartiles reflecting substantive preferences and walkability differentials were used in the analysis. Occurrence of one or more walk trips and VMT were both examined. For walk trips, the preference differentials were most striking, but whichever the preference category, high walkability neighborhoods had twice the incidence of persons walking than low walkability neighborhoods. Of persons preferring environments that tended to be less walkable, 3.3 percent in low walkability neighborhoods took at least one walk trip versus 7.0 percent of persons in high walkability neighborhoods. For persons desiring high walkability, 16.0 percent in low walkability neighborhoods took at least one walk trip, while 33.9 percent in high walkability neighborhoods did so. In the context of overall average driving of 33 VMT per day per individual, the low versus high walkability neighborhood VMT differential was 17 fewer miles driven for residents of highly walkable neighborhoods who were not seeking walkability and 11 miles less for residents of highly walkable neighborhoods strongly preferring high walkability (Frank et al., 2007).

Both the San Francisco and Atlanta area research efforts suggest that "What is the extent of self-selection?" is a question that does not have to be fully resolved to know that pedestrian-and-bicycle-friendly urban design achieves more walking and cycling activity and less VMT. On the other hand, in estimating the travel demand differentials associated with different neighborhood designs, self-selection effects do appear to deserve addressing. Importantly, if there is an unmet demand for more compact, mixed use, walkable neighborhoods, then increasing their supply may enable the most sustainable of all transportation-supportive housing selection outcomes: the movement into such areas of persons attuned to them, allowing the relocated residents to better "act on their preferences by walking more and driving less" (Cao, Mokhtarian, and Handy, 2009).

An impression that there is insufficient housing stock to meet demand for compact, mixed use, walkable areas is given support by studies in metropolitan Atlanta. A survey sample of 1,455 residents from the SMARTRAQ research program were queried about preferences and categorized into those preferring such "alternative development" and persons preferring the characteristics of auto-oriented neighborhoods. Those who preferred alternative development *and* had a desire to change from the land use and transportation characteristics of their current neighborhood outnumbered those preferring an auto-oriented environment *and* desiring change by over 2 to 1. This was taken as a definitive indicator of unmet demand in greater Atlanta for alternative development (Levine and Frank, 2007).

A related perspective is offered by the authors of the travel and built environment meta-analysis covered in the "Response by Type of NMT Strategy" section (see "Pedestrian/Bicycle Friendly Neighborhoods"—"Walk Elasticities for Land Use and Site Design Parameters"). Their meta-analysis used both many studies that did not control for self-selection and a smaller number of newer studies that did. It was found that elasticities of travel shifts in response to built environment characteristics that were derived from studies controlling for self-selection were either little different from or *higher* than those derived from studies not examining self-selection. As an explanation for this unexpected result, the authors hypothesize that many residents of higher density, mixed use, walk-friendly areas are indeed self-selecting and fulfilling a latent demand for active transportation and transit use brought about by insufficient supply of alternative development. They identify supporting research by others, but acknowledge that their hypothesis does not mesh with the larger body of literature that finds a degree of attenuation in built environment effects, and links it to self-selection (Ewing and Cervero, 2010). An alternative explanation could be that the studies not controlling for self-selection represent not only older but also less well specified research. As discussed under "Analytical Considerations" in the "Overview and Summary," less well executed research has been shown to be associated with less frequent findings of statistically significant differences in walking activity (Ogilvie et al., 2007).

Working with Self-Selection

A relatively recent analytical development pertaining to attitudes and "self-selection" is the use of statistical methods to control for these factors, internal to the core modeling approach, when estimating built environment effects on active transportation. This is accomplished using one of a number of forms of "joint models" or models derived from medical and epidemiological practice, including joint discrete score models, structural equations models, mutually dependent discrete choice models, sample selection models, and application of propensity scores (Cao, Mokhtarian, and Handy, 2009). The approach accepts that there likely are attitudinal and residential self-selection effects and anticipates them at the outset within the impact analysis research and model design. A number of the newer studies listed in Tables 16-82 and 16-83 illustrate movement in this direction, albeit mostly in an exploratory context.

An additional example of controlling for attitudes and self-selection, beyond those in Tables 16-82 and 16-83, uses exercise instead of travel as the metric being investigated. It is covered in the "Public Health Issues and Relationships" subsection of the "Related Information and Impacts" section (see Handy, Cao, and Mokhtarian in Table 16-123 and accompanying discussion). In the final model developed in that research, attitudes were found significant and were included. However, none of the neighborhood preferences—set forth as indicators of likely self-selection—proved to be. Thus this particular investigation found self-selection not a significant factor at all, although attitudes toward physical activity were (Handy, Cao, and Mokhtarian, 2007).

The larger body of relevant research does tend to show, however, that individual preferences are a factor deserving serious attention when seeking to encourage walking, cycling, or other active travel for either transportation and environmental or public health purposes. It would also seem that the phenomenon of neighborhood-preference matches and mismatches needs to be taken into account in context with possible undersupply of alternative development that offers compact, mixed-land-use, active-transportation-accessible, pedestrian/bicycle friendly neighborhoods. Such undersupply may nullify or reverse the attenuation of alternative-development land-use effects estimated in much of the self-selection research. This would render alternative development even more beneficial than state-of-the-art modeling incorporating self-selection effects might suggest. In other words, undersupply of alternative development may be creating pent-up demand leading to such housing being snapped up by those particular home-seekers most anxious to accommodate, to the fullest extent, pre-existing preferences for active transportation and minimization of VMT. If so, self-selection may be actually adding to public benefits where the supply of alternative development is failing to meet the demand.

RELATED INFORMATION AND IMPACTS

The first three subsections of the following collection of related NMT information cover the amounts and characteristics of pedestrian and bicycle trips at national, state, regional, and facility levels. The next two subsections examine examples of travel mode shifts with opening of new shared use NMT or bike lane facilities, and the amount of time required for usage of new facilities to stabilize or mature and thus become established. Overview NMT safety information and comparisons are then provided. They are followed by a subsection on public health issues, impacts, and relationships, concluding with an "Adult and Child Public Health Relationships Summary" of NMT facility improvement and program effects. This health impacts summary parallels the "Traveler Response Summary" offered as part of the chapter's introductory "Overview and Summary." The final two "Related Information and Impacts" subsections address traffic, energy, environmental, economic, and equity impacts.

Extent of Walking and Bicycling

Data on current non-motorized transportation (NMT) trip making are instructive both as context and in their own right. The context provided is particularly helpful for scaling the impacts of traveler and recreational responses to NMT facilities and programs in terms of their relative impact on the universe of travel or physical activity.

An important first step, however, is to have a clear understanding of NMT trip accounting peculiarities involving mode share definitions and coverage. Many standard regional and national household transportation data sources identify and count NMT travel only if it is the "prime" or primary mode, in other words, only if an NMT mode is used exclusively for the entire trip from an origin to a separate destination. Walking or bicycling for access to or egress from other modes may or may not be picked up in any particular household travel survey. Even if obtained, the NMT identification often becomes lost in the typical trip accounting process, showing up only in special tabulations.

Additional important background on these data issues is found in the "Analytical Considerations" discussion in this chapter's "Overview and Summary" section (See "Analytical Considerations"—"National and Regional Non-Motorized Transportation (NMT) Data"—"Modal Definitions for Multi-Modal Trips"). Definitions, with examples, of prime-mode share, sub-mode share, and mode of access share are provided in the introduction to the "Pedestrian/Bicycle Linkages with Transit" subsection of the "Response by Type of NMT Strategy" section.

The review that follows distinguishes between NMT as the primary or exclusive mode ("prime mode") and NMT as a feeder and distribution mode for public transit ("mode of access"). The almost complete lack of regional and national data on NMT travel for access to modes other than public transit results in global "feeder and distribution mode" data being restricted to transit access (Agrawal and Schimek, 2007). While walking to and from private vehicles is more prevalent, such walk trips tend to be quite short. They are of case-specific interest for major parking facilities and instances where safety issues are involved, and in general for urban and suburban central business districts (CBDs), business/commercial strips with on-street parking (Schneider, 2011), and campuses with remote or peripheral parking.

Out of a total of 48.6 billion primary mode and transit-linked walk trips per year in the United States in 2009, 16 percent represent walking in connection with transit use. Relative to 4.1 billion U.S. primary mode bicycle trips, not including transit-linked bike trips (Kuzmyak et al., 2011), a rough estimate developed below under "Extent of Bicycling" suggests that perhaps another 10 percent or so may represent bicycling in connection with transit use.

Eight out of ten (78.7 percent) of adult respondents to the 2002 National Survey of Pedestrian and Bicyclist Attitudes and Behaviors reported walking, running, or jogging outdoors at least once for no less than 5 minutes during the last 30 summertime days. This percentage represents approximately 164 million U.S. pedestrians age 16 years or older. The bicycling equivalent was one out of four (27.3 percent), representing approximately 57 million adults who rode a bicycle (NHTSA and BTS, 2002). These statistics are perhaps the more notable for the adults who essentially did not walk or bicycle at all.

Extent of Walking

The U.S. Census Bureau's American Community Survey (ACS) was deemed by researchers for the periodically issued Bicycling and Walking Benchmarking Report to be, within its limitations, the preferable source of large-area NMT travel data for the United States. This determination came because the survey is taken throughout the year, on a continuing basis, and has a sample size that lends itself to city-specific analysis. Its crucial limitations are that it covers only trips to and from work (commute trips), by persons 16 years of age and older, focuses only on the *usual* travel mode, and may be presumed to subsume most NMT trips linked to motorized modes within motorized-prime-mode categories such as auto or transit (Thunderhead Alliance, 2007, McGuckin and Srinivasan, 2005). Each of these limitations is disadvantageous, to some degree, when attempting to examine overall NMT use.

The 2007 ACS found that 2.8 percent of trips to and from work were made exclusively by walking (Alliance for Biking & Walking, 2010). This may be compared with the percentage of trips for all travel purposes made exclusively by walking that have been derived from the U.S. Department of Transportation's National Household Travel Survey (NHTS).[61] These walk-only mode share percentages, inclusive of weekend travel, were 8.7 percent in 2001 and 10.1 percent in 2009 (Alliance for Biking & Walking, 2010, Kuzmyak et al., 2011). The 2007 ACS-based 2.8 percent finding for the nationwide commute trip walk-only share becomes 4.8 percent if applied only to the 51 largest cities. Less dramatically, the 2001 nationwide walk percentage of 8.7 percent for all persons and travel purposes becomes 11.0 percent if the same 2001 NHTS-based calculation is restricted to U.S. metropolitan areas in which the largest cities are located (Alliance for Biking & Walking, 2010).

Year 2007 walk shares on a statewide basis, for travel to-and-from work, range from highs of 8.4 percent in Alaska and 6.3 percent in New York State down to 1.3 percent in Alabama. The 11 states with walk commute shares of 4 percent or greater are all in the north except for Hawaii. Perhaps surprisingly, none contain large metropolitan areas except for New York City and Honolulu. The 10 states with the lowest walk commute shares are all in the southeast (if broadly defined to include Oklahoma and Texas) and together constitute the U.S. states with walk commute mode shares below 2 percent. Walk-to-work shares for the three cities at the top, Boston, Washington, DC, and New York City, range from 10.3 to 13.3 percent. Oddly, Boston has the highest and New York has the lowest of these shares (Alliance for Biking & Walking, 2010), undoubtedly an artifact of Boston's tightly drawn municipal boundary and the inclusion of all of New York City's boroughs within its city limits.

The prevalence of walking is higher the shorter the trip. In the 2001 NHTS adults (18 or more years of age) making trips of 1 mile or less were found to have a 27 percent walk mode share, over 3 times the 8.7 percent walk mode share for all persons, purposes, and trip lengths. The walk mode share for children (5 to 15 years of age) making school trips of 1 mile or less was 36 percent (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). For related information on walk trip length distributions, and associated characteristics and influences, see "Characteristics of Walking and Bicycling Overall"—"Trip Distance and Duration" below, and also "Trip Factors"—"Walk Trip Distance, Time, and Route Characteristics"—"Walk Trip Speeds and Lengths" in the "Underlying Traveler Response Factors" section.

The NHTS is a particularly useful national source, not only because it covers travel for all purposes by persons of all ages, but also because it has data on both walk-only trips and transit-access walk trips that are at least partially internally consistent. NHTS surveys have collected their information on trips primarily from trip diaries covering all modes of travel (Agrawal and Schimek, 2007, Liss et al., 2003). The 2001 survey diaries covered a sample of 64,000 households[62] and the 2009 survey diaries covered a sample of 150,000 households (Kuzmyak et al., 2011). Table 16-85 provides an overall compilation of walk trip totals, proportions, distance, and duration from the 2001 and 2009 surveys.

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[61] Throughout discussions of NHTS results, 2009 data are used when the particular calculations and assessments were available in consistent or preferred format without need for original research, and 2001 information is used where they were not, or for comparison. Over this period, walk-only mode shares grew 13 percent, while bicycle shares grew somewhat less. In many instances it is not yet known to what extent relative relationships may have shifted. In examples examined (such as proportion of walk trips involving transit access/egress, which rounds to 16 percent in both 2001 and 2009) shifts appear to be minor.

[62] Almost 63 percent of the 2001 NHTS sample was composed of "add-on" surveys arranged to provide larger sample sizes for nine regional study areas (Alliance for Biking & Walking, 2010). Differential expansion factors allow representation of national data (Liss et al., 2003), but the underlying national sample was smaller than implied by the total.

Table 16-85 Number, Proportion, Distance, and Duration of U.S. Walk Trips in 2001, 2009

	Walk Only		Walk to/from Transit		Total Walk Trips	
Walk Trip Parameter	**2001**	**2009**	**2001**	**2009**	**2001**	**2009**
Trips per Year (Billions)	35.4 B	41.0 B	6.9 B	7.6 B [a]	42.3 B	48.6 B
Trips per Person per Year	128	145	25	27	153	172
Share of All Trips	8.7%	10.1%	1.7%	1.7%	10.4%	11.8%
Mean Distance	0.62 mi.	0.70 mi.	n/a	n/a	n/a	n/a
Median Distance	0.25 mi.	n/a	n/a	n/a	n/a	n/a
Mean Travel Time	16.4 min.	14.9 min.	13.8 min. [b]	n/a	16.0 min. [c]	n/a
Median Travel Time	10.0 min.	n/a	n/a	n/a	n/a	n/a

Notes: [a] Calculations of 2009 walk to/from transit trips include only those transit trips for which walking was the travel mode for both access and egress (Kuzmyak et al., 2011). The walk to and the walk from transit service together register as only 1 walk trip in this tabulation.

[b] Revised calculation supplied by the corresponding author of the paper. Computed as the sum of averages of 6.34 minutes spent walking to transit and 7.44 minutes spent walking from transit to the final destination (Schimek, 2008). Since some transit access/egress does not utilize the walk access mode, the access plus egress mean would be slightly lower if computed on the basis of the average transit trip, but probably more or less the same if computed in the manner of the 2009 travel times (see Note A).

[c] Weighted average calculation by Handbook authors.

Sources: Derivation from 2001 NHTS by Agrawal and Schimek (2007), modified per Schimek (2008), and from the 2009 NHTS by Kuzmyak et al. (2011).

Three survey and analysis protocols affecting trip data in Table 16-85 are important to understand, especially given that the protocols differ from historic metropolitan trip-based survey and analysis procedures. For walking in connection with a trip via transit, the walk access to transit and the walk egress from transit are conflated into a single one-way walk trip (the walk component of a "transit trip"). For walking from and back to home for recreation or exercise (a "circular" trip), the activity is included and is broken into two trips, one out to the farthest point from home and one back (Agrawal and Schimek, 2007, Kuzmyak et al., 2011). Lastly, the trip data cover all 7 days of the week, weekdays and weekend days (McGuckin and Srinivasan, 2005).

The 42.3 billion U.S. annual walk trips identified for 2001 in Table 16-85 represent 153 walk trips per person per year, or 10.4 percent of all person trips. Of these, 35.4 billion were walk-only and 6.9 billion were walks associated with transit use. Mean and median distances of walk-only trips were 0.62 and 0.25 miles, respectively, while corresponding mean and median travel times were 10.0 and 16.4 minutes, respectively (Agrawal and Schimek, 2007). The large differences between the means and medians indicate trip length distributions skewed toward short trips but including significant numbers of fairly long trips.

Between the 2001 and 2009 NHTS surveys, the absolute number of U.S. annual walk trips increased by 15 percent to 48.6 billion. Walk trips per person increased by 12 percent to 172, and the walk trip share of all trips increased by 13 percent to 11.8 percent. Only the share of walk to/from transit trips relative to all trips stayed the same, at 1.7 percent (Kuzmyak et al., 2011). This is the first increase in overall U.S. walking activity in over 30 years demonstrated with comparisons thought to be sound (see Table 16-87 including Note A). It is quite likely the first increase, excepting possible short-term 1970s gas-crisis responses, since the gasoline rationing of World War II. Other 2001 versus 2009 comparisons are displayed in Table 16-85. Details on distance and duration distributions are provided below in the "Characteristics of Walking and Cycling Overall" subsection.

There is, however, one category of walk trips known to have continued to diminish in terms of mode share between 2001 and 2009. This category is that of schoolchildren, age 5 to 18, traveling to and from school. (Data are presented in Table 16-91, with accompanying discussion, at the end of the upcoming "Extent of Bicycling" presentation.)

All purposes of travel are represented in the combined weekday and weekend-day statistics of Table 16-85. If walk-only trips are divided into utilitarian trips and recreation/exercise trips, using 2001 data for completeness, the latter (mean trip length 1.0 mile) are found to average twice as long as utilitarian trips (mean trip length 0.5 miles). Recreation/exercise trips account for roughly 1/4 of all trips, but given their longer length, equate to about 1/2 the U.S. national distance walked. Mean travel times of people walking to and from transit in connection with an average single transit trip were 13.8 minutes, only 16 percent less than the mean for walk-only trips (Agrawal and Schimek, 2007, Schimek, 2008, McGuckin and Srinivasan, 2005).[63]

The NHTS has questions about number of walk and bicycle trips per week that are separate from the survey day trip inquiries (Clifton and Krizek, 2004). The results for walking are presented in Table 16-86. They show that the majority of walk trips by U.S. residents are actually made by roughly 1/4 of the population. Of the people queried in the 2001 NHTS, 84 percent reported no walk trips in their daily routine. Table 16-86 indicates that 35 percent reported no walk trips at all in the preceding week in 2001, dropping to 32 percent in 2009. The median number of walk trips shifted from two per week to three in round numbers. The mean based on survey-day responses increased from 2.9 per week in 2001 to 3.3 per week in 2009. Some 91 percent averaged only one walk trip or less per day during the week in 2001, dropping to 86 percent in 2009 (Weinstein and Schimek, 2005, Kuzmyak et al., 2011).

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[63] CDC research (Besser and Dannenberg, 2005) can be used to derive, on the basis of two transit trips per transit user per day (Agrawal and Schimek, 2007), a mean walk time per transit trip of 12.2 minutes. See Note B to Table 16-85 for a likely explanation of much or all of the difference.

Table 16-86 Number of Walk Trips Reported for the Preceding Week, 2001 and 2009

	2001 NHTS		2009 NHTS	
Walk Trips per Week	Percent of Persons	Cumulative Percentage	Percent of Persons	Cumulative Percentage
0	35%	35%	32%	32%
1	7	41	6	38
2	11	52	10	48
3	11	63	10	58
4	7	70	6	64
5	7	77	8	72
6	3	80	3	75
7	11	91	11	86
8+	9	100	13	100

Source: Derived from 2001 NHTS by Agrawal and Schimek (2007) and from 2009 NHTS by Kuzmyak et al. (2011).

Inspection of Table 16-86 shows that the percentages of people reporting zero trips up through four trips per week all decreased by roughly 10 percent between 2001 and 2009. The percentage reporting six trips per week stayed the same, while the percentages reporting five, seven, and eight or more trips a week all increased. This provides substantiation, from a separate NHTS trip-recall line of questioning, that walking did increase between 2001 and 2009 in the United States.

Table 16-87 illustrates the steadily downward U.S. trend of walk-only trips, as a percentage of total trips, in the latter part of the 20th Century. It also illustrates, along with both Tables 16-85 and 16-86, the modest reversal of this trend in the first decade of the 21st Century. Table 16-87 covers walk mode shares over time for all trip purposes combined and for the work commute alone. Bicycle-only shares are included and, because most transit trips involve substantive walking (and some involve bicycling), transit shares are also listed. These data are assembled from the Nationwide Personal Transportation Study (NPTS), the predecessor survey to the NHTS, along with the 2001 NHTS itself and also the U.S. Census decennial surveys and American Community Survey for 2009.

Table 16-87 NMT Mode Shares for All Trip Purposes and Work Purpose Trips, 1969–2001

Travel Mode	1969/70	1977	1980	1983	1990	1995	2000/01	2009
All trip purposes								
Bicycle	n/a	0.7%	—	0.8%	0.7%	0.9%	0.9%	1.0%
Walk-only	n/a	9.3	—	8.5	7.2	5.4	8.6 [a]	10.1 [b]
Transit [c]	3.2%	2.6	—	2.2	2.0	1.8	1.6	1.9
Work purpose trips								
Bicycle	n/a	—	0.5%	—	0.4%	—	0.4%	0.6%
Walk-only	7.4%	—	5.6	—	3.9	—	2.9	2.9
Transit	8.9	—	6.4	—	5.3	—	4.7	5.0

Notes: All-trip-purposes shares are from the NPTS/NHTS. Work-purpose shares are from the U.S. Decennial Census except for 2009, which are from the American Community Survey (ACS). In multi-year columns, the odd-numbered year pertains to NPTS/NHTS all-purpose shares and the even-numbered year pertains to U.S. Census work-purpose shares.

[a] The 1995-2001 NPTS/NHTS increase in all-trip-purposes walk-only shares relates primarily to survey methodology changes, designed to capture previously unreported walk trips (Hu and Reuscher, 2004). The work-purpose data from the U.S. Census provide a better indicator of trends in the 1990-2000 decade.

[b] Taken from Table 2-1 of Kuzmyak et al. (2011).

[c] Transit mode shares are included as an approximate indicator for the substantive walking that occurs in connection with most transit travel. The 1969 NPTS-derived transit share is adjusted for comparability, compensating for lack of NMT trips in the original survey.

Sources: NPTS results for 1969, 1977, 1983, 1990, and 1995; NHTS results for 2001; U.S. Census results for 1970, 1980, 1990, and 2000 as reported in Pucher and Renne (2003); NHTS results for 2009 as reported in Kuzmyak et al. (2011); and U.S. Census Bureau ACS 2009 (2011), with 1969 transit share adjustment by the Handbook authors.

There is a methodological enhancement, and thus inconsistency, between the NPTS and NHTS surveys that must be taken into account. Survey protocol changes were made for the 2001 NHTS survey that were designed to capture previously unreported walk trips. It is felt that these changes, and not a shift in trends, were the primary cause of the 2001 increase in reported walk mode share (Hu and Reuscher, 2004). The work-purpose data from the U.S. Census probably provides a better indicator of 1990 to 2000 trends, indicating continued decline in walking up to that point.

The 2009 ACS results, methodologically similar to the U.S. Decennial Census with a margin of error of ±0.1 percent, indicate a 2000 to 2009 increase in bicycling to work, stability in walking to work, and an increase in transit use with its associated walking (U.S. Census Bureau, 2011). These work commute outcomes are not in conflict with the NHTS all-trip-purposes results for the 8 years, but suggest that the increase observed in overall walk-only trips may mainly be the result of more walking for non-work utilitarian purposes and/or recreation and exercise.

A metropolitan area perspective is provided by the National Capital region. Weekday trip mode shares increased in the Washington, DC, metropolitan area as a whole—between 1994 and 2007/08—by 1.6 percentage points for walk-only (from 7.8 to 9.3 percent), 0.2 percentage points for bicycle (from 0.5 to 0.7 percent), and 0.7 percentage points for transit (from 5.6 to 6.3 percent) (Griffiths, 2010).

Metropolitan area research from the other coast provides a start at answering the question of how much walking occurs as a result of parked-car egress and access, along with other short walks within trip destination areas that may or may not be picked up in surveys like the NHTS. The research obtained completed face-to-face interviews with about 1,000 patrons of 20 retail pharmacy stores located throughout the midsection of the San Francisco Bay Area. The stores were in San Francisco proper, the San Mateo County portion of Silicon Valley, Contra Costa County, Berkeley, Oakland, and suburban Alameda County. Complete details were obtained on all trips within the home-to-home tour that included the pharmacy. No time limit was placed in the tour definition on intermediate stops, such that—for example—a tour including a pharmacy stop on the way home from work would include all travel between home and work, from and to the work location, and between work and home.

The primary modes used for the whole tour averaged, among tours, 21.3 percent walk, 2.2 percent bike, 9.9 percent transit, and 66.6 percent auto (Schneider, 2011). For comparison, the 2009 NHTS obtained NMT shares for the San Francisco-Oakland-San Jose Metropolitan Statistical Area (MSA) of 14.3 percent walk, 1.9 percent bicycle, and 3.0 percent walk to/from transit (Kuzmyak et al., 2011). This is a reasonable degree of consistency considering the relatively auto-oriented nature of MSA areas not covered by the pharmacy surveys, along with other basic differences.

In contrast to the 21.3 percent walk primary-mode share for tours intercepted at pharmacies, 51.9 percent of these same tours involved walking between stops or along a street at some time during the tour. Walking under one roof between stops was not counted, and neither was walking between a parked car and the adjacent dwelling or destination building. The primary mode used on trips within shopping districts and corridors was, respectively, 65.2 and 72.8 percent walk. Total distance by mode for the entire tour averaged 4.5 percent walk. Total travel distance internal to shopping districts and corridors was, respectively, 54.6 and 67.5 percent walk (Schneider, 2011). These findings, while not differentiating in the aggregate between transit access, auto access, and purely walking trips, begin to give measure to the larger role of walking relative to the narrow perspective imposed by primary-mode analytical protocols.

Extent of Bicycling

Bicycling, as observed in the United States of the late 20th and early 21st Centuries, "accounts for a minute percentage of Americans' overall trips" (MacLachlan and Badgett, 1995) and, for adults at least, has been characterized as a "fringe mode" and "rare behavior" (Krizek and Johnson, 2006). The 2009 ACS found that 0.6 percent of trips to and from work were made exclusively by cycling (U.S. Census Bureau, 2011). The comparable figure for all purposes of weekday and weekend travel, by persons of any age, is 1.0 percent for trips made exclusively by cycling as derived from the 2009 NHTS. Other bicycle trip statistics for 2009 corresponding to the walk trip statistics of Table 16-85 are 4.1 billion bike trips per year, 14.5 bike trips per person per year, 2.3 miles mean bicycle trip distance, and 19.4 minutes mean travel time (Kuzmyak at al., 2011).

Trend data on bicycling assembled from the NPTS and NHTS do not exhibit the methodological inconsistencies associated with the 2001 changes to walk trip surveying methodology. Together, the NHTS and NPTS indicate that U.S. nationwide bicycling mode shares have been relatively stable over one-third of a century, with perhaps a very slight increase from about 0.7 percent in 1977 to 1.0 percent in 2009. Bicycling mode shares over time for all trip purposes and for the work commute were included above in Table 16-87.

Despite the consistency over time of the NPTS/NHTS national data for bicycling, there is cause to be cautious in working with these small percentages, especially when comparing across surveys with different types of methods. For example, a study commissioned by Los Angeles County found

2.4 percent of *all* trips in that county to be by bicycle, while the 2001 NHTS-based estimate was 1.0 percent. Three 21st Century Los Angeles County *commute* mode share estimates are virtually identical, however: 0.61 percent from the 2000 U.S. Census and 0.59 percent from the 2005 ACS (Thunderhead Alliance, 2007), remaining essentially the same in the 2007 ACS. A second example is even more notable. The 2001 NHTS-based bicycle-share estimate for *all* city and county of San Francisco trips was 0.93 percent. A city-commissioned study with "a larger sample size and more robust methods" found an all-trip-purpose bicycling mode share of 6 percent. The 2000 Census identified a 1.98 percent *work*-trip mode share while the 2007 ACS found a 2.52 percent share (Alliance for Biking & Walking, 2010).

There is apparently less difference between all-purpose bicycle usage rates for the nation as a whole compared to large metropolitan areas than is the case for walking. The nationwide 2001 cycling percentage of 0.90 percent for all travel purposes shifts only to 0.94 percent if the NHTS-based calculation is limited to U.S. metropolitan areas in which the 50 largest cities are located. However, the 2007 ACS-based 0.5 percent commute trip cycling share nationwide becomes 0.8 percent when restricted to the 51 largest cities. Cycling shares on a statewide basis for 2007 travel to and from work range from highs of 1.9 percent in Oregon and 1.4 percent in Montana to 0.1 percent in Alabama, Arkansas, and Tennessee. The 12 states with bicycle commute shares of 0.7 percent or greater are all in the west, including all continental states bordering on the Pacific and other individual states as far east as Wisconsin. The 12 states with the lowest bicycle commute shares, all 0.2 percent or less, are in the southeast if extended to include Texas and West Virginia. One additional state, Rhode Island, is in the 0.2 percent category (Alliance for Biking & Walking, 2010).

In the 2001 NHTS, adults (18 or more years of age) making trips of 5 miles or less had an 0.6 percent bicycle mode share. The bicycle mode share for children (5 to 15 years of age) making school trips of 2 miles or less was 1.5 percent (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). The fact that the adult 5-mile-or-less share is below the bicycle share for all persons, purposes, and trip lengths is almost certainly the result of inclusion of children in the global statistic and/or analytical issues such as the small bicycle trip sample size. It is amply demonstrated on the basis of trip length distributions that bicycle use must fall off faster with increasing trip length than is the case for trip making overall. Information on bicycle trip lengths is found below under "Characteristics of Walking and Bicycling Overall"—"Trip Distance and Duration" and also in the "Underlying Traveler Response Factors" section (see "Trip Factors"—"Bicycle Trip Distance, Time, and Route Characteristics"—"Bicycle Trip Speeds and Lengths").

Although NHTS data are theoretically available to make an adjustment to include bicycling as a mode of access to public transit, the small sample size would be an issue. The national data presented here do not include as bicycle trips those bike trips made in conjunction with transit use. Tables 16-88 and 16-89 together provide summarized 1996–98 survey data covering bicycling shares for access to and egress from public transit routes in 14 U.S. cities, shown along with comparable information for walk access/egress and other access/egress modes. The overall bicycle access/egress shares, averaging from 0.6 to 1.4 percent depending on the end of the trip in question (McCollom Management Consulting, Inc., 1999), suggest that inclusion of transit access/egress cycling would increase the estimate of 0.9 percent of all 2001 U.S. trips being by bicycle to a total of 1.0 percent at most (see Table 16-87 above). This crude circa 2000 estimate, made starting with the 4.7 percent transit share presented in Table 16-87 for 2001 and applying bicycle access shares from Tables 16-88 and 16-89, can also be taken to suggest that bicycle trips taken in conjunction with transit amounted to on the order of 1/10 of 1 percent of all U.S. trip making. An update to 2009 would increase these percentages by a tiny fraction, but the result would still be a small proportion when viewed globally.

Table 16-88 Access Mode Share Percentages from Home to Bus and Rail Routes (and Return) for 14 U.S. Systems, 1996–1998

Access Mode	All 14 Systems	Systems Classified by Size			Multi-Modal Systems	
		Small	Medium	Large	Bus	Rail
Bicycle	0.6%	0.3%	0.8%	0.3%	0.3%	0.8%
Walk	67.0	84.8	61.9	62.6	74.0	47.7
Auto Driver	9.6	2.0	10.7	13.5	4.0	20.5
Auto Passenger	3.4	1.6	3.9	4.2	2.5	5.5
Bus/Train	19.3	11.3	22.7	19.5	19.1	25.2

Notes: Small-sized systems (0 to 500,000 service area 1997 population) include Grand Rapids, MI, Kenosha, WI, and Lincoln, NB.

Medium-sized systems (500,000 to 1,500,000 service area 1997 population) include Austin, TX, Buffalo, NY, Portland, OR, and Sacramento, CA.

Large-sized systems (1,500,000 or more service area 1997 population) include Chicago, IL (Chicago Transit Authority bus and HRT only), and Pittsburgh, PA.

Multi-modal (bus and urban rail) systems include Buffalo, Chicago, Pittsburgh, Portland, and Sacramento. Results shown are for the bus or rail components as indicated.

Auto passenger includes passenger drop-off and passengers in cars parked.

Bus/Train represents surveyed riders who started on another transit route and transferred to the route being surveyed.

Source: McCollom Management Consulting, Inc. (1999).

Table 16-89 Non-Home Egress/Access Mode Percentages for the Bus and Rail Routes of 14 U.S. Systems, 1996–1998

Egress/Access Mode	All 14 Systems	Systems Classified by Size			Multi-Modal Systems	
		Small	Medium	Large	Bus	Rail
Bicycle	1.4%	3.5%	1.1%	0.4%	0.5%	1.0%
Walk	73.0	78.0	70.4	73.9	72.3	69.9
Auto Driver	2.6	1.1	3.3	2.5	1.5	4.9
Auto Passenger	2.7	2.9	2.7	2.5	2.6	2.6
Bus/Train	20.3	14.5	22.5	20.8	23.2	21.5

Notes: Notes same as Table 16-88 except Bus/Train represents surveyed riders who completed their trip on another transit route and transferred from the route being surveyed.

Source: McCollom Management Consulting, Inc. (1999).

Walking in connection with transit service occurs in greater magnitudes. Tables 16-88 and 16-89 indicate that—across 14 systems—67 percent of transit route riders starting from (or returning to) home reached (or left) the transit route on which they were surveyed by walking. At non-home ends of trips, 73 percent of transit egress or access was by walking (McCollom Management Consulting, Inc., 1999). If one subtracts out transfer passengers who reported their access or egress mode as being bus or train, and normalizes the remaining access/egress percentages, it can be seen that on a system basis 83 percent of riders of the 14 systems starting from home walked to the transit system, and 92 percent of system riders leaving or accessing the system away from the home used the walk mode. (Corresponding figures for bicycling are 0.7 percent and 1.8 percent.) This walk access/egress information undergirds the findings in the preceding "Extent of Walking" discussion concerning the importance of transit riding to understanding of the total amount of walking in the United States.

The overall frequency of bicycling among the U.S. public has been explored in a number of surveys. Those conducted over the past 15 years show that in general, as the defined time frame increases, so does the number of people who report cycling during that time period. There is extensive variation across geographic areas. The 2001 NHTS found a range of 0.2 to 2.4 percent of persons bicycling during their survey day across the various Metropolitan Statistical Areas covered, with a range of 4.5 to 12.7 percent cycling sometime during a week. Rodale Press surveys in 1992 and 1995 found 16.6 to 21.2 percent to have cycled during a month, compared to 27 percent over the summer of 2002 as determined by BTS, and 37 to 46 percent over a full year as found by Rodale. Minnesota DOT in 2003 found that 1/2 the population in their state never cycled (Krizek et al., 2007). Table 16-90 categorizes 2009 NHTS respondents nationwide by the number of bicycle trips taken per week. Of all respondents, 13 percent were found to have bicycled at least once in the preceding week (Kuzmyak et al., 2011).

Table 16-90 Number of Bicycle Trips Reported for the Preceding Week, 2009 NHTS

Bike Trips per Week	Percent of Persons	Cumulative Percentage	Bike Trips per Week	Percent of Persons	Cumulative Percentage
0	87%	87%	5	1%	98%
1	4%	91%	6	0.4%	98%
2	3%	93%	7	1%	99%
3	2%	95%	8+	0.8%	100%
4	1%	97%			

Source: Derived from 2009 NHTS by Kuzmyak et al. (2011).

Looking specifically at school children from age 5 to 18, bicycling to school as a percentage mode share has stayed close to the range of 1/2 to 1 percent established in 1977 and 1983, the first two survey years it was separately measured. Data in Table 16-91 demonstrate that the major shift has been in walking for school access, which declined from 22.5 percent in 1977 to 9.5 percent in 2009. Even more dramatic is the change from 1969 to 2009, which can be measured only in total walking and bicycling access to school. That percentage, for children, plummeted from over 40 percent in 1969 to 10 percent in 2009, a huge concern for public health practitioners and a significant contributor to school-area congestion and automotive pollution (Moudon, Stewart, and Lin, 2010, Kuzmyak et al., 2011).

Table 16-91 NMT Percent Mode Shares for Child Transportation to School, 1969–2009

Travel Mode	1969	1977	1983	1990	1995	2001	2009
Bicycle	n/a	1.0%	0.5%	1.0%	1.1%	0.8%	0.7%
Walk	n/a	22.5	14.5	18.2	10.6	12.1	9.5
Total NMT	40.7%	23.5%	15.0%	19.2%	11.7%	12.9%	10.2%

Notes: Includes children ages 5 to 18.

Source: NPTS results for 1969, 1977, 1983, 1990, and 1995, and NHTS results for 2001, as reported in Moudon, Stewart, and Lin (2010). NHTS results for 2009 as reported in Kuzmyak et al. (2011).

Characteristics of Walking and Cycling Overall

A number of tabulations of pedestrian and bicycle trip and trip-maker characteristics were presented in the "Underlying Traveler Response Factors" section, in support of examining influences on NMT choices. In addressing "Characteristics of Walking and Cycling Overall," these tabulations will be referred to as appropriate. A summary perspective is provided here, along with additional data displays. The focus of this overall-characteristics subsection is on describing the nature of walking and cycling, primarily in the United States, along with presenting related insights and information potentially useful in NMT evaluation and design. The focus of the earlier "Underlying Traveler Response Factors" section is on how the manifestations of walking and cycling, such as NMT trip generation, mode choice, route choice, and time-of-day choice, are affected by the characteristics of the environment, the trips, and the trip makers.

Trip Distance and Duration

Lengths of walking and bicycling trips are governed by the location of activities and the interplay of the corresponding travel desires with the locations of NMT facilities. Also having important roles are the purposes of the desired trips and the character and quality of the NMT facilities available.

Trip distance and duration *findings* also vary according to the research design. Information derived from the NHTS conforms with many aspects of standard metropolitan transportation planning practice, the bulk of the data being derived from daily trip diaries which accept "no trips" (NMT or otherwise) as a legitimate survey response. As previously indicated, 84 percent of the 2001 NHTS survey respondents reported no walk trips on their survey day. The acceptance and recordation of no NMT trips, after probing to make sure none were overlooked, means that the results should parallel what one would expect on a typical day in the United States. In contrast, surveys that ask about the most recent walk or bike trip—while they may provide needed information on infrequent trip making—overweight and thus overemphasize infrequent trips. Results may thus be skewed, as characteristics of infrequent trips may be different from trips made on a frequent, regular basis.

Table 16-92, derived from the 2009 NHTS, provides a rough but presumably reliable overall picture of walk trip distance and duration distributions in the United States. The results are somewhat lumpy, as a result of self-reported survey limitations. Trip durations tend to be self-reported in round numbers, thus the disproportionate percentages of trips in the 5, 10, 15 and 30 minute categories. The walk trips in this tabulation exclude transit access trips. The mean walk-only distance calculated was 0.70 miles, but the median was 4 blocks (about 0.45 miles), indicating a skewing of the mean by a lesser number of fairly long trips. Similarly, the mean travel time was 14.9 minutes, with a median value of 10 minutes. Some 23 percent of walk-only trips were a mile or more in length, while 13 percent were 30 minutes or more in duration (Kuzmyak et al., 2011).

Table 16-92 Distribution of U.S. 2009 Walk-Only Trips by Distance and Duration

Walk Trip Distance			Walk Trip Duration		
Blocks/Miles [a]	Frequency (percent)	Cumulative Frequency	Time	Frequency (percent)	Cumulative Frequency
			< 5 min.	16%	16%
≤1 block	16%	16%	5 min.	16	32
2 blocks	17	33	6-9 min.	6	39
3 blocks	7	40	10 min.	16	54
4 blocks	15	55	11-14 min.	4	58
5-8 blocks	22	77	15 min.	16	74
1 mile	11	88	16-29 min.	13	87
1.1 to 2 miles	9	97	30 min.	6	93
> 2 miles	3	100	> 30 min.	7	100

Notes: [a] It is assumed that 9 blocks are equal to 1 mile.

Source: Derived from 2009 NHTS by Kuzmyak et al. (2011).

A Centers for Disease Control and Prevention (CDC) analysis of the 2001 NHTS made from the public health perspective found that Americans who used public transit spent a median time of 19 minutes daily walking to and from transit. This statistic is a total for all transit access and egress during the day (Besser and Dannenberg, 2005), most frequently (but not always) four walk segments daily (Agrawal and Schimek, 2007). If one treats walk access to and walk egress from a single transit trip as one walk trip, as commonly done in analysis of NHTS data, the median transit-linked walk time becomes 9.5 minutes. Additional discussion of this CDC research is provided further on under "Public Health Issues and Relationships" (see "Baseline Walking and Bicycling Activity" and also Table 16-123).

Table 16-93, the bicycle equivalent of Table 16-92, draws bicycle trip distance and duration distributions from the 2009 NHTS. It has the same limitations as described for Table 16-92. The mean bicycle-only distance calculated was 2.3 miles, but the median was 1 mile. As with walking, this differential indicates a skewing of the mean by a lesser number of long trips, only more so in the case of bicycling. The mean bicycle travel time was 19.4 minutes, with a median value of 15 minutes. Of all bicycle trips, 12 percent were 30 minutes or more in duration, virtually the same as for walking, but 26 percent were 2 miles or more in length (Kuzmyak et al., 2011). The typical bicycle trip takes 30 to 50 percent more time than its walk-trip counterpart, but covers 2.2 to 3.3 times as much ground. The greater disparity between the mean and median for distance than for time suggests wide variation in bicycling speeds.

Table 16-93 Distribution of U.S. 2009 Bicycle-Only Trips by Distance and Duration

Bicycle Trip Distance			Bicycle Trip Duration		
Blocks/Miles [a]	Frequency (percent)	Cumulative Frequency	Time	Frequency (percent)	Cumulative Frequency
			< 5 min.	9%	9%
≤1 block	9%	9%	5 min.	13	22
2 blocks	10	19	6-9 min.	6	28
3 blocks	5	24	10 min.	16	44
4 blocks	7	31	11-14 min.	3	47
5-8 blocks	15	46	15 min.	18	65
1 mile	11	57	16-29 min.	14	78
1.1 to 2 miles	17	74	30 min.	9	88
> 2 miles	26	100	> 30 min.	12	100

Notes: [a] It is assumed that 9 blocks are equal to 1 mile.

Source: Derived from 2009 NHTS by Kuzmyak et al. (2011).

Reporting of the 2002 summer survey performed by NHTSA and BTS also provides comparative walk and bike trip distance data, but from a different perspective. This survey utilized a variant of the "most recent trip" inquiry methodology in that it recorded active transportation data for the day (within the last 30 days) of most recent walking or bicycling activity. It also differed from the NHTS by defining a trip from home and return "with no real destination" and no stops as a single trip, not separate trips to and from a farthest point (NHTSA and BTS, 2002). Both of these survey differences are thought to increase reported trip distances, and certainly affect means and related computations in some way. In any case, Table 16-94 presents the summertime trip length distributions obtained.

This tabulation serves to again illustrate the larger geographic market potentially served by bicycling as compared to walking. It also again illustrates the preponderance of trips that are short, relative to the "most recent day" survey means of 1.2 miles for walk trips and 3.9 miles for bike trips. The "most recent day" median walking distance was slightly over 0.5 miles, while the comparable median cycling distance was somewhat under 2.0 miles (NHTSA and BTS, 2002). Comparison of the "most recent day" mean and median walk and bicycle trip distances with those from Tables 16-92 and 16-93 does indicate that the recorded trip lengths, particularly the means, are indeed longer than obtained from trip diary surveys using the NHTS protocol.

Table 16-94 Attitudinal Survey 2002 Trip Lengths On Most Recent Day Walked/Biked

	Walk Trips		Bicycle Trips	
Trip Distance Range	Frequency (percent)	Cumulative Frequency	Frequency (percent)	Cumulative Frequency
0.25 miles or less	26.9%	26.9%	—	—
0.26 to 0.5 miles	19.6	46.5	—	—
0.5 to 1.0 miles	20.7	67.2	—	—
Subtotal, 1.0 miles or less	67.2%	67.2%	38.6%	38.6%
1.1 to 2.0 miles	18.0%	85.2%	18.5%	57.1%
2.1 to 5.0 miles	—	—	23.8	80.9
5.1 to 10.0 miles	—	—	11.8	92.7
More than 10.0 miles	—	—	7.3	100.0
Subtotal, more than 2.0 miles	14.8%	100.0%	42.9%	100.0%

Note: See discussion in text above of methodological limitations.

Source: NHTSA and BTS (2002) with elaboration by the Handbook authors.

Trip Purposes

Utilitarian walking and bicycling trips are, overall, usually made for the same reasons as motorized utilitarian trips. Common utilitarian purposes include going to work, shop, or school (and returning home), or to obtain medical/dental care, conduct personal business, eat a meal, or visit an entertainment venue. The major differences in trip purpose distributions involve recreational or exercise purposes, which are much more prevalent among NMT trips. Recreational and exercise trips may be for reasons of enjoyment, physical fitness, or general health.

Table 16-69 of the "Underlying Traveler Response Factors" section (see "Trip Factors"—"Trip Purpose"), presents walk and bike mode shares for work and various non-work trip purposes. Such mode choice proportions, applied to overall trip-making by purpose, give absolute numbers of walk and bike trips. This allows calculation of the distribution of walk and bicycle trips among trip purposes. Such distributions may, however, be calculated directly from survey results. Table 16-95, derived from the 2009 NHTS, presents such an examination for 10 trip purposes. It covers work trips and six other utilitarian purpose categories, two recreation/exercise categories, and one miscellaneous "other" category, plus trips with unspecified purposes. "To home" trips from the trip diaries were allocated according to the travel purpose at the trip origin. The results given in Table 16-95 include not only walk and bicycle trip proportions by trip purpose category, but also a separate purpose distribution for walk trips to/from transit stops and stations. In addition, distances and durations are provided for each NMT mode and purpose, except walk to/from transit (Kuzmyak et al., 2011).

Table 16-95 Proportions, Distance, and Duration of Walk and Bike Trips by Trip Purpose

	Proportions by Purpose (percent)			Average Trip Length (miles)		Average Travel Time (minutes)	
Trip Purpose	Walk Only	Transit Access [a]	Bicycle	Walk Only	Bicycle	Walk Only	Bicycle
Utilitarian Trips							
To/from work	4.5%	29.8%	10.9%	1.0	3.8	16.2	21.2
Work-related business	1.7%	3.6%	1.8%	1.1	3.3	14.0	21.7
School/religion-related	8.6%	10.9%	6.0%	0.6	1.6	14.5	15.2
Shopping, buy goods/gas	14.7%	16.6%	9.8%	0.6	1.3	12.7	14.0
Visit friends/relatives	8.7%	7.5%	13.0%	0.6	1.0	11.7	13.9
Medical/dental	0.9%	5.4%	0.2%	0.7	2.2	16.1	26.0
Other personal business [b]	21.5%	9.4%	8.2%	0.5	1.4	11.2	15.5
Recreation/Exercise Trips							
Rest, relaxation, vacation	1.9%	0.8%	2.1%	0.8	2.4	22.5	21.0
Other social/recreational [c]	35.4%	11.0%	47.3%	0.8	2.6	18.3	22.5
Miscellaneous Trips							
Other	1.4%	3.6%	0.1%	1.2	2.3	13.1	16.0
Unspecified	0.8%	1.5%	0.8%	0.8	2.7	22.0	25.7
Trips by all Purposes	100%	100%	100%	0.7	2.3	14.9	19.4
Total Trips (millions)	40,962	7,647	4,082	40,962	4,082	40,962	4,082

Notes: [a] Walk to/from public transit stop/station (transit access/egress).

[b] Includes family/personal business, buy services, day care, grooming, pet care/dog walk, transport someone, wedding/funeral, attend civic meeting, social event, get meal/snacks.

[c] Includes social/recreational; exercise (walking, jogging, etc.); and some purposes normally considered as utilitarian, such as go out for entertainment, play sports, visit public place, social event, get/eat meal/coffee/snacks.

The NHTS covers all trips by persons of all ages (Liss et al., 2003) on all 7 days of the week, weekdays and weekend days (McGuckin and Srinivasan, 2005). The 7-day-a-week coverage lowers work trip percentages relative to those seen in weekday-only surveys and tabulations.

Sources: Derived from 2009 NHTS by Kuzmyak et al. (2011).

Of all 2009 walk-only trips, 61 percent were in trip purpose categories primarily associated with utilitarian travel, and 37 percent were in categories primarily associated with recreation or exercise.[64] Walk to/from transit trips had an even higher utilitarian travel proportion, at 83 percent, with over 6 times the percentage of work commute trips. Of transit access/egress trips, 30 percent were to and from work, 11 percent were to and from school (or school-related library trips or place-of-worship-related trips), 17 percent were for shopping, and 15 percent were for medical/dental or other personal business. Bicycle trips were the most oriented to recreation or exercise, with cycle trips being 50 percent utilitarian, 49 percent recreation or exercise, and 1 percent miscellaneous.

[64] Multiple NMT trip purposes/motivations were not addressed in the NHTS. If a survey respondent had multiple purposes/motivations for a particular walk or bike trip, it was implicitly up to him or her to choose which single purpose/motivation to report. (In the "Overview and Summary," see "Analytical Considerations"—"Trip Purpose Versus Motivation" for further exploration of NMT trip purpose identification issues.)

Mean distances were not available for walk to/from transit trips. Walk-only mean distances ranged from 0.5 to 0.7 miles for school, shopping, visiting friends and relatives, health services, and other personal business categories. Recreation/exercise walk trips averaged 0.8 miles to the farthest point reached in terms of distance from the origin. Work, work-related, and miscellaneous-other walk-only trips were in the range of 1.0 to 1.2 miles (Kuzmyak et al., 2011). Tabulations from the 2001 NHTS suggest that median walk-only trip distances run about 1/2 of mean distances for shopping, errands, personal business, and recreation/exercise trips, and 1/3 or less of mean distances for work and school trips (Agrawal and Schimek, 2007).

Bicycle trip distances run 2 to 4 times as long as walk-only trips, with mean distances ranging from 1.0 one-way miles for visiting friends and relatives to 3.8 miles for work trips, as seen in Table 16-95. There is less difference between walk and bicycle trips when viewed from the perspective of time expended, although travelers tend to allocate somewhat more time to bicycle trips. Both walk and bicycle trip time duration means lie within the 11-to-15-minute range in the case of school, shopping, visit friends and relatives, and other personal business categories. Among the longer trip time averages are 16 minutes walk and 21 minutes bike for work trips, 16 minutes walk and 26 minutes bike for medical/dental-purpose trips, and 18 minutes walk and 22 minutes bike to the farthest point reached during recreation/exercise trips (Kuzmyak et al., 2011).

User Characteristics

Prevalence of walking and cycling trips, like motorized trips, is influenced not only by the type and proximity of activities and the facilities for travel, but also—and strongly so—by the socio-economic characteristics of the trip making population. Walking and bicycling rates and characteristics are influenced by gender, age, income, auto ownership, education, and ethnicity. They are also affected by individual caution, proficiency (especially for cycling), physical capability, and attitude.

Global relationships of user characteristics to NMT trip making have been examined under "User Factors" in the "Underlying Traveler Response Factors" section, illustrated with tabulations by user category, primarily on the basis of U.S. average active transportation mode shares from the 2001 or 2009 NHTS. Mode share tabulations are not quite the same as data on absolute numbers of trips, because differential trip generation rates also affect numbers of trips. For example, lower income people and the elderly tend to make fewer trips, so a relatively higher mode share exhibited by one of these groups may be damped down in terms of actual trips in the category. Such circumstances are noted, where important, in the "Underlying Traveler Response Factors" discussions. In the "User Factors" subtopic, the primary tables and discussions of interest to a global understanding of user characteristics are the following:

- **Gender:** Table 16-72 under "Gender," and the accompanying development of indications that the lesser bicycling of females in the United States is balanced by more walking.
- **Age:** Table 16-74 under "Age," and the discussions of NMT activity decline with the onset of adulthood and then aging, aside from increased walking for recreation and exercise by seniors, and the magnitude of walking and bicycling in childhood.
- **Income:** Tables 16-75 and 16-76 under "Income," respectively providing both NMT mode shares by income and income distributions by mode, along with the indication that while walk-only trip activity and bicycle trip activity vary only moderately with income, walk-transit trip making is much more prevalent in low income households.

- **Auto Ownership:** Table 16-78 under "Automobile Ownership," and the demonstration that active transportation use is several times higher in households without cars.

- **Education:** Table 16-79 under "Education," and accompanying analyses indicating that while the least educated have the highest NMT mode shares, once factors such as housing patterns (including densities and neighborhood walkability) and auto ownership are accounted for, the proclivity to walk for exercise *and* utilitarian purposes increases with education.

In addition, the "Underlying Traveler Response Factors" section also addresses the user characteristics/factors of ethnicity (see "User Factors"—"Ethnicity"), caution and proficiency (see "Other Factors and Factor Combinations"—"Security and Safety"), and attitude (see "Other Factors and Factor Combinations"—"Attitudes and Modal Biases"). The facility-specific "Facility Usage and User Characteristics" coverage in the next subsection provides further insight, but as always, must be used with caution when making extrapolations from individual sites to other or larger areas and applications. As will be demonstrated, there is considerable variation among areas, facility types, and particular locations.

Facility Usage and User Characteristics

The tables and discussion that follow offer a selection of the information encountered on NMT facility traffic and usage patterns, and also on characteristics of facility travel purposes and of the facility users themselves. This is presented in a manner as specific to individual types of facilities as possible. The approach is in contrast to pedestrian and bicyclist characteristics data located in the earlier "Underlying Traveler Response Factors" section, which is focused more on national or other broad-based perspectives.

There is also facility usage and user characteristics information located in the facility-specific subsections of the "Response by Type of NMT Strategy" section, and in individual case studies. That information is primarily from "after" studies done following facility implementation. Users of this chapter interested in facility-specific data should check both the following presentation and the applicable "Response by Type of NMT Strategy" and "Case Studies" topics.

Frequency of Facility Usage by Facility Type

Analysis of usage distribution among motorized transportation facilities, such as freeways versus arterials, is typically based on traffic and passenger count data. Count information on NMT usage of different transportation facilities is, however, totally inadequate for estimating usage distribution among NMT facility types. Such analyses must be based on reports by pedestrians and bicyclists on how they themselves have traveled.

The 2002 national survey on pedestrian and bicyclist attitudes and behaviors provides one such source of information. Its reporting of facility types used is based on the most recent walk or bike trip in 30 days by survey respondents. The type of facility identified is that most used during the trip (NHTSA and BTS, 2002). Table 16-96 presents the results.

Table 16-96 Facilities Used for Most Recent Walk/Bike Trip per Attitudinal Survey 2002

Facility Type	"Most Used" for Walk Trips	"Most Used" for Bike Trips
Sidewalks	45%	14%
Paved roads, not on shoulders	25	48
Shoulders of paved roads	8	13
Bicycle lanes on roads	—	5
Bicycle paths/walking paths/trails	6	13
Unpaved roads	8	5
Grass or fields	5	—
Other	3	2
Total (all facility types)	100%	100%

Source: NHTSA and BTS (2002).

The information in Table 16-96 indicates that 51 percent of walk trips take place on facilities specifically constructed for pedestrian or other NMT use—sidewalks and paths/trails. Another 41 percent of walk trips take place on roads. For pedestrians, roads would normally be considered an inferior facility type, even though local streets are undoubtedly heavily represented in the "Paved roads, not on shoulders" category.

Facility appropriateness is harder to identify in such a straightforward manner in the case of bicycle trips. Appropriate on-street bicycle routes and facilities are, for adults at least, likely safer than riding on most sidewalks. (This finding is explored further in the upcoming "Safety Information and Comparisons" subsection.) Table 16-97 supplements the bicycle facility use information of Table 16-96 by introducing results for five U.S. urban areas from the Nonmotorized Transportation Pilot Program Evaluation Study. Covered are "reference trips" selected for each survey respondent by the interviewer. With multiple responses allowed, the five-area total sums to 140 percent. A rough normalization can be obtained, by dividing through by 1.4, for comparison with Table 16-96. The distribution becomes remarkably similar when this is done, except that bike lane use appears to be over twice as prevalent in the five-area sample. This exercise suggests that a little over one-half of bicycling occurs on the more ideal facilities—local streets, bike lanes, and bike paths. In more global terms, barely over one-half of walk trips and bike trips occur on facilities that may be readily presumed suitable.

Table 16-97 Facilities Used for Bicycle "Reference Trip" in Pilot Program 2006 Baseline Survey

Facility Type	Columbia, Missouri	Marin Co., California	Minneapolis, Minnesota	Sheboygan, Wisconsin	Spokane, Washington	Five-Area Total
Sidewalk	28%	16%	15%	10%	20%	18%
Local street	42	49	48	41	46	45
Busy street	28	25	28	30	26	28
Bike lane	11	27	18	14	14	17
Bike path	13	27	32	10	18	19
Rural road	4	14	0	13	10	8
Other	8	2	0	4	10	5
Sample Size	*72*	*51*	*60*	*70*	*50*	*303*

Note: Multiple responses allowed in Pilot Program survey. Columns total to more than 100%.

Source: Krizek et al. (2007).

Neither of the facility-use distributions presented above separately identifies use of bicycle boulevards. This reflects the small number of such facilities nationwide and the fairly recent recognition, beyond a few "early adopter" localities, of this facility type as more than a niche application. Portland, Oregon, has a number of bicycle boulevards. Table 16-67, in the "Underlying Traveler Response Factors" section (See "Trip Factors"—"Bicycle Trip Distance, Time, and Route Characteristics"—"Bicycle Route Choice") provides trip mileage distributions among Portland's facility types for bicycle-only *utilitarian* trips, based on GPS-based survey measurements. Adding in exercise and "loop" bicycle trips, the distribution becomes 22 percent on arterials with no bike lane, 27 percent on low traffic streets with no bike lane or bicycle boulevard provisions, 26 percent on streets with bike lanes (550 miles available), 9 percent on bicycle boulevards (30 miles available), 14 percent on off-road, shared use trails (130 miles available), and 2 percent other (Dill and Gliebe, 2008). The percentage of bicycle miles of travel attracted to bicycle boulevards in Portland is remarkably high relative to the comparatively small survey-year extent of such facilities.

Sidewalks and Streets in Suburbs and City Neighborhoods

Typical Suburban- and City-Neighborhood Pedestrian and Bicycle Volumes. Given the prevalence of low to moderate pedestrian volumes on neighborhood sidewalks, volume information is generally obtained only at points where land use or activity concentrations cause a buildup. Table 16-98 provides illustrative circa 2002 pedestrian intersection volumes at a wide variety of San Francisco Bay Area locations selected by local authorities for their importance on account of critical location within the NMT infrastructure, crash history, or other concerns. Three out of nine counties are selected for presentation here. They are Napa County, predominantly rural with many vineyards, but also containing small towns and expanding exurban development; Santa Clara County, the heart of Silicon Valley and mostly suburban in nature; and San Francisco City and County, the most dense of the three primary urban centers of the region.

The counts were taken on Tuesdays, Wednesdays, and Thursdays only, from 7:00 to 9:00 AM and 4:00 to 6:00 PM. They have been expanded by a factor of 2.5 to give a very approximate estimate of daily volumes. This factor was developed by analogy with recent Bay Area 24-hour vehicle counts and was intended for bicycle count expansion (Wilbur Smith Associates, 2003). The Handbook authors have taken the liberty of applying the factor to the pedestrian counts as well to give a rough feel for daily NMT activity.

Intersection counts such as these, in the case of four-legged intersections (which constitute the vast majority), represent approximately twice the average pedestrian or bicycle volume on the individual intersecting streets, and four times the average individual sidewalk volume in the case of pedestrians (assuming there are sidewalks on both sides of both streets). It is interesting to note that, with one exception, all of the suburban intersections with daily NMT volume estimates exceeding 1,000 are located in the heart of traditional rural or railroad-suburb downtowns with 19th or early 20th century roots. Thus they technically violate the "outside CBDs" restriction. The one exception—California Avenue and Escuela Street in Mountain View—is central to an area of low-rise apartments, with ethnic gathering spots, just beyond the tighter early 20th Century residential street grid.

At roughly 2,700 daily pedestrian and bicycle crossings, the pedestrian volumes at the Mountain View site are about one-third the volumes at the San Francisco neighborhood intersection of Geary and Divisadero Streets, also covered in Table 16-98. Exploration of this circumstance is instructive. While the neighborhood residential densities are likely roughly similar, the Geary and Divisadero intersection features a greater mix of land uses plus intersecting high-frequency bus routes. Both of these characteristics are generally deemed indicators of higher pedestrian volume likelihood.

Pedestrian activity effects of mixed land use have been addressed in the "Response by Type of NMT Strategy" section (see "Pedestrian/Bicycle Friendly Neighborhoods") and in Chapter 15, "Land Use and Site Design," there under "Response by Type of Strategy"—"Diversity (Land Use Mix)"—"Accessibility, Entropy, and Other Measures" and also "Land Use Mix and Transit Use."

Table 16-98 Illustrative Intersection Pedestrian and Bicycle Volumes from Selected San Francisco Bay Area Counties

Jurisdiction	Intersection	Area Type and Adjacent Land Use	Intersection Legs with Sidewalks	7 to 9 AM		4 to 6 PM		~ 2002 Daily Intersection NMT Volume
				Peds	Bikes	Peds	Bikes	
Napa County *(Two surveyed rural intersections [Oakville and unincorporated County] are omitted, having no sidewalks or pedestrian traffic)*								
Am. Canyon	SR 29 @ American Canyon	Suburban: shopping center, vacant land	2 out of 4	5	2	4	6	40
Calistoga	Lincoln St. (SR 29) @ Washington	Suburban: retail, eateries	4 out of 4	263	9	738	38	2,600
County	Dry Creek @ Orchard	Rural: vineyards, fields	0 out of 3	15	6	0	25	100
Napa	Lincoln Ave. @ Jefferson St.	Suburban: high sch., gas, retail, vacant	4 out of 4	65	27	56	39	500
Napa	1st @ School Rd.	Suburban: retail, bank, city hall	3 out of 3	133	10	382	41	1,400
St. Helena	Main (SR 29) @ Adams	Suburban: retail, ofc., bank, gas/auto	4 out of 4	106	5	365	25	1,300
Yountville	Finnell @ Yountville	Rural: town hall, homes, vineyard	3 out of 3	96	9	39	29	400
Santa Clara County *(Silicon Valley proper: Three surveyed intersections — in the East Bay [Milpitas] and South County [Morgan Hill, Gilroy] — are omitted)*								
Campbell	Bascom @ Hamilton	Suburban: retail, gas	4 out of 4	30	64	71	59	600
Cupertino	Stevens Creek Blvd. @ De Anza	Suburban: bank, civic center, gas	4 out of 4	67	23	108	41	600
Mtn. View	California St. @ Escuela Ave.	Suburban: residential apartments	4 out of 4	589	104	307	92	2,700
Palo Alto	Foothill Expwy. @ Page Mill	Suburban: fields, office building	4 out of 4	1	63	8	82	400
Palo Alto	University @ Emerson	Suburban: retail, restaurant	4 out of 4	295	80	557	42	2,400
San Jose	San Fernando @ 7th	Urban: CBD (details n/a)	3 out of 3	631	20	674	39	3,400
San Jose	Santa Clara @ Montgomery	Urban: arena, parking lots	3 out of 3	114	18	111	32	700
Santa Clara	El Camino Real @ Railroad	Suburban: storage, police, auto rental, etc.	4 out of 4	34	20	45	23	300
Santa Clara	Homestead Rd. @ Kiely Blvd.	Suburban: retail, gas	4 out of 4	107	23	121	27	700
San Francisco City/County *(The surveyed intersections do not include any in the core financial/retail district north of or along Market Street)*								
San Francisco	3rd St. @ Howard	Urban: convention ctr., theatre, hotel, ofc.	4 out of 4	2,227	n/a	2,698	n/a	12,000 (ped only)
San Francisco	Embarcadero @ Washington	Urban: urban waterfront (details n/a)	3 out of 3	318	115	516	181	2,800
San Francisco	Seventh @ Folsom	Urban: CBD fringe (details n/a)	4 out of 4	810	207	789	151	4,900
San Francisco	Geary @ Divisadero	Urban: apartments, retail, garage, chapel	4 out of 4	1,157	n/a	1,436	n/a	6,500 (ped only)
San Francisco	Ocean @ Geneva	Urban: college, residential, gas, firehouse	4 out of 4	266	n/a	323	n/a	1,500 (ped only)

Notes: The Handbook authors have taken the liberty of applying the study's bicycle expansion factor (peak periods *x* 2.5 = daily) to both bicycles and pedestrians, in order to provide rough, order-of-magnitude approximations of the daily NMT intersection volumes.

Source: Wilbur Smith Associates (2003), daily volumes and missing urban land-use/sidewalk data estimated/supplied by Handbook authors.

The San Francisco Bay Area intersection count data, as can be seen in Table 16-98, includes both pedestrians and bicycles. The counts were structured as if all bicycles would be on the street (Wilbur Smith Associates, 2003), but there may have been some cyclists approaching the intersections using a sidewalk.[65]

Suburban and City-Neighborhood Pedestrian and Bicyclist Trip Purposes. A study in Texas produced more limited volume examples but offers the advantage of some information on walking and bicycling trip purposes in such areas. Eight suburban and neighborhood locations, mostly

65 In some jurisdictions riding a bicycle on the sidewalk is prohibited.

intersections, were selected for study on the basis of having supportive bicycle and pedestrian facilities. Two each were in College Station, Austin, Houston, and Dallas. Looking first at College Station and Austin, three streets had bike lanes and attracted weekday 12-hour bicycling volumes of 73 to 161 bicycles, averaging 115. The three cross streets in these locations carried seven to 314 bicycles, averaging 110. Overall bicycle trip purposes obtained for the three intersections in a rudimentary survey were 14 percent recreation, 53 percent work, 28 percent school, and 5 percent personal, shopping, and other. Pedestrian volume along the six streets ranged from two to 92 persons, averaging 41. Overall trip purposes for walkers at the three intersections were 25 percent recreation, 20 percent work, 25 percent school, 20 percent personal, and 10 percent other. The fourth location, Loop 360 in Austin, was an outlier both statistically and geographically. Survey responders among the 62 counted cyclists all reported recreational activity. No survey returns were obtained from the six pedestrians.

Each of the four locations in Houston and Dallas featured a trail, either stand-alone or in conjunction with a street or arterial. Weekday 12-hour bicycle volumes on the four trail corridors ranged from 111 to 346, averaging 205. The two intersecting streets which were counted had only 17 bicycles total, so the bicycle trip purpose information for these four sites is nearly trails-only. Overall bicycle trip purposes were 53 percent recreation, 44 percent work, and 3 percent personal and other. Pedestrian volumes along the four trails, including joggers, ranged from 67 to 626, averaging 235. On the two cross streets, pedestrian counts were 26 and 108. Overall pedestrian trip purposes were 65 percent recreation, 4 percent work, 6 percent personal, and almost 25 percent other (Hottenstein, Turner, and Shunk, 1997). The recreation trip purpose was thus in the majority for these Houston and Dallas trail-dominated sites, but in the minority for the College Station and Austin intersections where roadways with bicycle lanes along with undifferentiated mostly-two-lane cross streets both played major roles. On the other hand, the trail recreational trip proportions identified in this particular study are generally lower than found in trail studies that include weekend usage, several of which are examined below under "Off-Road Shared Use Paths."

Mixed-Use Suburban and City-Neighborhood Pedestrian Volume Variations. One set of the very limited published or presented data on non-CBD sidewalk volume temporal patterns covers monthly variations on University Avenue in San Diego. This east-west arterial, on the opposite side of Balboa Park from the downtown, is a non-radial, cross-town facility. Mixed-use development fronting the sidewalk at the count location reflects extensive small-shop commercial use. Morning peak-hour pedestrian volume, circa 2008, was in the 76 to 225 range (Jones, 2009). Percentages of annual volume by month are provided in Table 16-99. No strong seasonal pattern stands out, with May the highest month at 10.2 percent of yearly volume, and September the lowest with 6.2 percent. San Diego is of course known for its year-round moderate and relatively dry climate.

Table 16-99 Monthly Variation, University Avenue Sidewalk, San Diego

Month	Percent	Month	Percent	Month	Percent	Month	Percent
January	8.0%	April	8.0%	July	9.6%	October	8.2%
February	8.2	May	10.2	August	7.4	November	8.2
March	8.8	June	9.0	September	6.2	December	8.2

Note: Basis for November percentage is 2007-08 average, December is 2007, all other months are 2008; all percentages are normalized to 100% for 12 months.

Source: Jones (2009), with percentage values scaled from the presentation graphic and normalized by the Handbook authors.

A suburban CBD weekday hourly variation example is provided in the "Case Studies" section (see Table 16-128). As indicated there, it is not known whether the substantial differences in peaking among counts were caused by land use differences on opposite sides of the studied arterial crosswalks, pre- and post-Christmas shopping pattern differentials, count protocol differences, or some combination of these factors. The 13-hour counts, two per east-west crosswalk at one intersection, ranged from 400 to 2,100 pedestrians per crosswalk. Peak hour volumes ranged from 80 to 280, with individual crosswalk highest-peak hours starting at times ranging from noon to 5:00 PM. (See "More—Volume Variability" in the "Special Mini-Studies in Montgomery County, Maryland" case study.)

Sidewalks and Other Provisions in Major Central Business Districts

Central Business District Pedestrian Volume Characteristics. City centers, and other major activity centers with large employment, are environments associated with substantially higher volumes of pedestrian trips. Major proportions of person-trips within metropolitan CBDs are made by pedestrians. Circa 1970 it was estimated that 55 percent of morning peak period person trips in Midtown Manhattan were by pedestrians, with the figure increasing up to 70 percent during the noontime and afternoon peaks (Pushkarev and Zupan, 1975). The trips are usually short, typically less than a few blocks. They mainly reflect movements from parking and transit terminals to places of work, between stores (and offices) in the retail core, and other building-to-building trips—often for eat-meal purposes. Many walk trips in high-density areas are trips that would be made by automobile in environments where activities are more dispersed (Levinson, 1972).

Pedestrian travel within central areas is highly concentrated in the retail and commercial cores. Major internal travel movements take place between relatively few areas, usually within the retail shopping area. Pedestrian flows typically correlate closely with land value profiles. The decline in land values as one moves out from major intersections mirrors the patterns of people walking along the street (Berry, 1967).

Pedestrian volumes are far more localized than transit or automobile passenger flows. Data collected in a series of comprehensive CBD pedestrian surveys circa the 1970s may be dated insofar as absolute values are concerned, but still illustrate the degree of localization very clearly. For example, while 10-hour sidewalk volumes along State Street in Chicago's Loop between Madison and Washington Streets at one time exceeded 50,000 persons, sidewalk volumes were only 11,000 persons between Lake Street and Wacker Drive three blocks up the street, and below 7,000 persons 5 blocks to the west on Franklin Street. Daily crosswalk volumes exceeded 20,000 persons in Seattle's core area but dropped to 3,000 persons within two blocks beyond the core.

Midday pedestrian traffic volumes on Fifth Avenue in New York of about 50,000 per hour were paralleled by volumes averaging 10,000 along the Avenue of the Americas and 5,000 persons per hour on Eighth Avenue, 2,000 feet to the west. Fifth Avenue noontime and evening peak pedestrian volumes declined rapidly north of 57th Street. The peak-hour pedestrian volumes along Washington, Summer, and Tremont Streets in the heart of Boston proper approached 6,000 persons near major subway entrances but dropped to fewer than 2,000 persons within a few blocks. Along Wilshire Boulevard in Beverly Hills, 6-hour pedestrian volumes dropped from 3,000 to 300 within a few blocks. Similar phenomena were recorded in Philadelphia and Dallas (Pushkarev and Zupan, 1971, Wilbur Smith and Associates, 1970, Levinson, 1982).

Lunchtime 3-hour counts taken in 2002 in Columbus, Ohio, illustrate the same pedestrian volume concentration phenomenon, but in a medium-size city. Counts from 11:00 AM to 2:00 PM on two individual sidewalk sections immediately alongside the State House showed 500 and 800 pedestrians. Across from the State House and within 1/2 block, eight sidewalk counts along office and commercial frontage ranged from 1,200 to 2,700 pedestrians each, averaging 2,100 pedestrians. Further away, up to three blocks, eight additional lunchtime sidewalk counts ranged from 400 to 1,400, averaging 900. Once beyond 1/2 block of the State House, the drop-off to the north, east, and south appeared to diminish. (No counts were made beyond 1/2 block to the west.)

Three 11-hour counts, all within 1/2 block of the State House at prime locations, ranged from 6,100 to 6,900 pedestrians, averaging 6,500. At these locations, the 3-hour midday pedestrian traffic averaged 38 percent of the corresponding 11 hour volumes. Downtown Columbus, in 2002, had 475 stores with $761 million in annual sales, 75,000 office workers, 20,000 transit rider arrivals daily, and some 30,000 students about 1/2-mile to the east (Capital Crossroads, 2003).

Table 16-100 displays a selection of 11-hour two-way counts made in central Minneapolis in 2002, showing the variations by hour in levels of sidewalk and Skyway pedestrian activity. The sidewalk counts were taken along the Nicollet Transit Mall. Note that on the east-side sidewalk, the counts one block apart during the busy noon hour differ by a factor of two, underscoring the points made earlier about the very localized nature of pedestrian traffic flows. The 8th to 9th Street block was the busiest on the mall in 2002, with a combined east and west side volume of 23,600 pedestrians. The pedestrian volume was up 69 percent over the prior year as the result of store openings (Bruce, 2002a and c).

The Nicollet Mall sidewalk counts show a minor influence of commute hours, but a strong relationship to noon-hour activity, and also what may be presumed is a reflection of afternoon shopping activity. The Skyway count made just west of the Nicollet Mall exhibits a similar pattern, but with commute flow influences barely discernible. This is to be expected, as the sidewalks serve persons leaving or accessing their bus stops, while the Skyways are one storey removed. Caution should be applied in comparing the sidewalk and Skyway counts, as the sidewalk counts were on warm, sunny, September days and the Skyway counts were on cool late October days with mixed weather.

The last-listed count in Table 16-100 is for a Skyway toward the northwest perimeter of the Skyway system, close to I-394 parking and transit facilities. The pedestrian commute flow can be clearly seen in the hourly flow distribution. All these 11-hour Minneapolis counts are averages for 2 days except for the last 2 hours of this last-listed Skyway segment. The counts on the omitted day were affected by a special event between 4:00 and 6:00 PM. Compared to the data shown, the special event increased the 4:00 to 5:00 PM tally by 34 percent and the 5:00 to 6:00 PM tally by 48 percent, providing a classic example of the importance of special events and other exogenous circumstances in the understanding and recording of NMT flows (Bruce, 2002a).

Table 16-101 provides aggregated hour-of-day distributions for pedestrians and for bicyclists entering and leaving the Minneapolis CBD, separately by direction of flow. These data are from the 2003 Cordon Count. The CBD cordon counts are taken periodically on or about September 10th and obtain a 12-hour tally of vehicles and people entering and leaving the core area broken down by 15-minute intervals and travel mode. The pedestrian hour-of-day distributions are quite different from those of any other travel mode, exhibiting a major midday peak, even though measured along the periphery of the CBD. The bicycle hour-of-day distributions are roughly similar to the distributions for all travel modes combined when examined on an hourly basis. Bicycles exhibit a sharper "peak-of-the-peak," however, with 5.1 percent of the inbound flow between 7:45 and 8:00 AM, and 5.9 percent of the outbound flow between 5:00 and 5:15 PM (SRF Consulting Group, Inc., 2003).

Additional Minneapolis NMT count information is provided in the "50 Years of Downtown NMT Facility Provisions—Minneapolis" case study. Also, Table 16-8 in the "Pedestrian Zones, Malls, and Skywalks" subsection (see "Pedestrian Skywalks"—"Skywalk Impacts on Walking") illustrates the interplay of noontime Twin Cities Skyway use versus use of parallel crosswalks. Observed Skyway volumes slumped in summer and rose in winter, volumes on the parallel crosswalks did the opposite, and the total of the two stayed within plus or minus 10 percent throughout all 12 months of the year (Heglund, 1980). This outcome suggests that, with a weather-protected option provided, even a rigorous northern climate such as found in Minneapolis and St. Paul can have overall business-area walking levels unaffected by season.

Table 16-100 Weekday Hour-of-Day Patterns of Pedestrian Traffic on Nicollet Transit Mall and Skyways of Minneapolis, 2002

Hour Beginning:	7 AM	8	9	10	11	12 PM	1	2	3	4	5 PM	Total
Nicollet Mall, 6th-7th Sts., East side	386	320	193	204	655	982	587	491	420	509	470	5215
Tues. 9/10/02 and Tues. 9/17/02	**7.4%**	**6.1%**	**3.7%**	**3.9%**	**12.6%**	**18.8%**	**11.2%**	**9.4%**	**8.1%**	**9.8%**	**9.0%**	**100%**
Nicollet Mall, 6th-7th Sts., West side	435	366	241	290	888	1231	807	674	733	1082	1013	7757
Wed. 9/4/02 and Tues. 9/17/02	**5.6%**	**4.7%**	**3.1%**	**3.7%**	**11.4%**	**15.9%**	**10.4%**	**8.7%**	**9.5%**	**13.9%**	**13.1%**	**100%**
Nicollet Mall, 8th-9th Sts., East side	535	457	489	513	1085	1984	1294	832	624	771	728	9310
Wed. 9/4/02 and Tues. 9/17/02	**5.7%**	**4.9%**	**5.3%**	**5.5%**	**11.7%**	**21.3%**	**13.9%**	**8.9%**	**6.7%**	**8.3%**	**7.8%**	**100%**
Skyway, 9th St., West of Nicollet	614	962	693	941	2151	3299	1864	1172	945	981	825	14445
Tues. 10/22/02 and Thu. 10/31/02	**4.3%**	**6.7%**	**4.8%**	**6.5%**	**14.9%**	**22.8%**	**12.9%**	**8.1%**	**6.5%**	**6.8%**	**5.7%**	**100%**
Skyway, 1st Ave., South of 6th St.	700	710	293	139	229	228	240	223	321	640 [a]	777 [a]	4497
Wed. 10/23/02 and Thu. 10/30/02	**15.6%**	**15.8%**	**6.5%**	**3.1%**	**5.1%**	**5.1%**	**5.3%**	**5.0%**	**7.1%**	**14.2%**	**17.3%**	**100%**

Notes: All counts are 2-day averages unless footnoted. [a] (Count is 10/23/02 only). Percentages are calculated on the basis of 11-hour totals.

Source: Bruce (2002a and c).

Table 16-101 Weekday Hour-of-Day Patterns of Pedestrian and Bicycle Traffic Entering and Leaving Minneapolis CBD, 2003

Hour Beginning:	6:30 AM	7:30	8:30	9:30	10:30	11:30	12:30 PM	1:30	2:30	3:30	4:30	5:30 PM	Total
Pedestrians, Inbound	1554	2788	1763	1308	1149	1952	2020	1307	1210	1200	1313	882	18446
Percentage by Hour	**8.4%**	**15.1%**	**9.6%**	**7.1%**	**6.2%**	**10.6%**	**11.0%**	**7.1%**	**6.6%**	**6.5%**	**7.1%**	**4.8%**	**100%**
Pedestrians, Outbound	600	1109	906	932	933	1613	1905	1314	1355	1766	2665	1711	16809
Percentage by Hour	**3.6%**	**6.6%**	**5.4%**	**5.5%**	**5.6%**	**9.6%**	**11.3%**	**7.8%**	**8.1%**	**10.5%**	**15.8%**	**10.2%**	**100%**
Bicyclists, Inbound	170	331	247	173	141	138	158	149	172	187	192	161	2219
Percentage by Hour	**7.7%**	**14.9%**	**11.1%**	**7.8%**	**6.4%**	**6.2%**	**7.1%**	**6.7%**	**7.8%**	**8.4%**	**8.6%**	**7.3%**	**100%**
Bicyclists, Outbound	91	116	114	110	118	115	120	166	204	272	411	267	2104
Percentage by Hour	**4.3%**	**5.5%**	**5.4%**	**5.2%**	**5.6%**	**5.5%**	**5.7%**	**7.9%**	**9.7%**	**12.9%**	**19.5%**	**12.7%**	**100%**

Notes: Sum of cordon counts taken at 32 non-ramp stations on September 10, 2003. Percentages are calculated on the basis of 12-hour totals.

Source: SRF Consulting Group, Inc. (2003), with hourly-on-the-half-hour sums of 15-min. counts, and percentages, by the Handbook authors.

Central Business District Pedestrian Trip Purposes and Modal Linkages. Pedestrian trip purposes reported in comprehensive studies conducted in 1970 in downtown Seattle are shown in Table 16-102. Although the numerical values in this dated information should be treated with caution, the relationships remain instructive. Work and commercial or personal business trips accounted for over one-half of the pedestrian trip total. Shopping activity accounted for 30 percent of all pedestrian trips even though shopping trips comprised only an estimated 15 percent of all CBD person-trip destinations made by all modes of travel (Wilbur Smith and Associates, 1970).

Table 16-102 Reported Purposes of Seattle CBD Pedestrian Trips, 7:00 AM–7:00 PM, 1970

Purpose	Percent	Purpose	Percent
Work	24.1%	Shopping	30.8%
Commercial Business	12.3	Eat-Drink	5.8
Personal Business	17.6	Social-Recreational	2.4
Sales and Service	2.2	Other	4.8

Note: Downtown Seattle has had extensive office tower development since collection of this data.

Source: Wilbur Smith and Associates (1970).

There are, of course, major variations in CBD pedestrian trip purposes by time of day. During the AM peak period, most trips originate at home and manifest themselves as walk trips between a parking place or transit stop and a place of CBD employment. The reverse predominates in the PM peak. At noontime, in strong contrast, the main pedestrian movements are between offices and places such as restaurants.

To support a circa 1970 Midtown Manhattan circulation study two Regional Plan Association office building surveys were supplemented with nearly 4,400 interviews conducted at 22 sites representing six different land uses. The results confirmed the midday importance of walk trips to and from offices. Between 12:00 Noon and 2:00 PM destinations of walk trips from offices were restaurants (53 percent), other offices (21 percent), retail establishments (9 percent), residences (5 percent), and various other land uses (12 percent) (Lemer, Bellomo, and Liff, 1972).

Trip purpose information tends to mask the importance of linkages with other travel modes as a major component of CBD walking activity. In addition, survey data identifying the extent to which observed pedestrians are making trips in connection with use of some other primary mode, as compared to utilizing the walk mode exclusively, is quite limited. Such data as do exist indicate that parking space-to-building or transit stop-to-building walk trips are usually more prevalent than walk trips between buildings. In downtown Seattle circa 1970, for example, 56 percent of all 7:00 AM to 7:00 PM weekday pedestrian trips were to or from transportation facilities and 44 percent were inter-building trips. The transportation facility percentage was comprised of 39 percent automobile parking and 17 percent transit stops and terminals (Wilbur Smith and Associates, 1970).

What is evident from such relationships is that the locations of parking facilities and transit terminals are necessarily a major influence on the patterns and volumes of walking trips within a CBD. While major changes in Seattle's transportation system may have altered the percentages somewhat, the order of magnitude relationships would still be valid for any typical large-city core area.

A 21st Century summertime off-peak weekday and Saturday survey in Toronto on Bloor Street sidewalks between the Bathurst Street and Spadina Avenue subway stations did determine what the usual mode of travel to the area was for pedestrians interviewed. It was 46 percent walk, 12 percent bicycle, 32 percent public transit, and 10 percent motor vehicle (Sztabinski, 2009). A similar survey in New York City's SoHo district, on Prince Street sidewalks between Broadway and 6th Avenue, found that modes utilized by the interviewees to arrive in the area that day were 29 percent walk, 5 percent bicycle, 54 percent rail transit, 2 percent bus, 9 percent taxi or livery service, and 9 percent private motor vehicle (Schaller Consulting, 2006).

These two surveys only indirectly address the question of whether the observed walk trips were walk-only or multimodal. Also important is that central Toronto and Lower Manhattan are areas of intensive public transit service. Obviously a survey of this type in an area not similarly served would produce different results.

Two quite different circa-1980 perspectives on the proportion of persons using downtown sidewalks for accessing and egressing bus service come from on-street pedestrian malls in Portland, Oregon, and Minneapolis, Minnesota. In Portland, pedestrian volumes on a pair of one-way, transit-mall streets were estimated to be 75 percent bus riders (Dueker, Pendleton, and Luder, 1982). In Minneapolis, most pedestrians interviewed on Nicollet transit mall sidewalks in 1977 were there for shopping (57 percent), pleasure (42 percent), or because of their work (24 percent). Only 16 percent were there because it was their bus stop location (5 percent were on the sidewalks for other reasons—multiple answers were allowed) (Edminster and Koffman, 1979). Background on these transit malls is found in the "Response by Type of NMT Strategy" section (see "Pedestrian Zones, Malls, and Skywalks"—"Pedestrian Zones and Malls"—"Transit Malls") and also in the "50 Years of Downtown NMT Facility Provisions—Minneapolis" case study.

On-Street Bicycle Facilities

Perhaps the least well represented of NMT facility types among published bicycle volume compilations are on-street bicycle facilities. The "after" counts of before-and-after studies of bike lanes and bicycle boulevards provide a source, however. A number of such counts are presented or cross-referenced in the "Bicycle Lanes and Routes" subsection, within the "Response by Type of NMT Strategy" section (see "Bicycle Lane Implementation"—"Before-and-After Counts and Surveys" and also "Bicycle Lane Variations, Bicycle Boulevards, and Other Signed Bicycle Routes"—"Bicycle Boulevards").

Reported 1-hour bicycle volumes in California after bicycle lane implementation range from just over 80 on Fell Street in San Francisco (one-way, PM peak, bicycles in lane only) (Chaney, 2005) to an average of a little over 500 on Anderson Road in Davis (two-way, an average of one AM and two PM peak hours, all bicycles anywhere on the street or sidewalk) (Lott, Tardiff, and Lott, 1979). An issue with "after" counts of before-and-after studies is that there may be substantial subsequent growth. St. Kilda Road in Melbourne, Australia, was carrying about 75 bicyclists in the AM peak hour a year after bike lane implementation, but that number had grown to some 500 bicyclists 10 years after opening (Davies, 2007).

In terms of all-day counts, Oriental Boulevard in Brooklyn was, 1 year after bicycle lane installation, carrying just over 100 bicycles and other human-powered wheeled vehicles in 11 weekday hours (Chaney, 2005). Six bicycle lanes in downtown Toronto had annual average weekday bicycle volumes ranging from 570 to 1,900, an overall average of 1,230 bicycles, roughly 2 years after implementation (Macbeth, 1999).

Extrapolated 24-hour bicycle volumes on the various bicycle-boulevard-like segments of the Bikeway system in Vancouver, BC, Canada, ranged from about 40 to almost 1,100 daily (Chaney, 2005). Bicycle volumes on the Bryant Street bicycle boulevard in Palo Alto, California, fall in the mid to upper part of this range (Ciccarelli, 2010), but the Vancouver range is exceeded by the 2008 volume of 1,900 bicycles reported for the Lincoln-Harrison bicycle boulevard in Portland, Oregon (Alta Planning + Design, 2009a).

Counts assembled in 1997 for the Palo Alto, California, Bicycle Transportation Plan help illuminate, in terms of bicycle volumes handled, where on-street routes and facilities fit in the total spectrum of urban bicycle facilities. Palo Alto is a university town with a long-standing bicycle-friendly reputation, but is also part of the larger Silicon Valley environment. The 1990s population of Palo Alto was on the order of 60,000 residents. The 1990 U.S. Census journey-to-work Palo Alto bicycle share was 5.8 percent, compared to 1.4 percent for Santa Clara County as a whole and 0.4 percent for the nation. Taken together, the bicycle counts suggest that all types of facilities, on-street and off-street, have a significant role to play, and that location is a crucial factor in determining bicycle facility volumes. A brief summary of the counts illustrates the point:

- The highest bicycle usage—making allowances for count duration—was reflected in an 8-hour count of 830 bicycles at the intersection of the Bryant Street bicycle boulevard and an arterial with bicycle lanes, both on-street facilities in the heart of the city.[66]

- Two other counts in the 800 to 900 range, actually higher but obtained in 12-hour counts, were at grade separations serving arterials with and without bicycle lanes and piercing barriers separating Stanford University from much of the city.

- Four 8- and 12-hour bicycle counts in the 400 to 600 range included two exclusive bicycle/pedestrian bridges over creeks (one at the end of the bicycle boulevard and one serving a mix of bicycle lanes, routes, and paths); one arterial intersection adjacent to Stanford with bike lanes on one leg; and one intersection of bike lanes and a path.

- Ten counts in the 200 to 400 bicycle range included one grade separation, seven intersections of streets and arterials with and without bicycle lanes or signed routes, and two exclusive bridges over creeks, one serving a bicycle route and the other a path.

- Finally, the two lowest volumes were both on bicycle lanes bordering the baylands at the edge of the city (City of Palo Alto, 2001).

Thus the highest and lowest Palo Alto bicycle volumes were encountered on designated on-street bike facilities, with about every imaginable facility-type combination in between.

As noted elsewhere, trip purpose information for bicyclists utilizing bicycle lanes is extremely scarce. A 7:00 to 9:00 AM weekday bike lane survey in the Seattle CBD found 97 percent of survey respondents to be making a work, school, or other utilitarian trip (Niemeier, Rutherford, and Ishimaru, 1995b). The Texas surveys summarized under "Suburban and City-Neighborhood Pedestrian and Bicyclist Trip Purposes" found 84 percent of College Station and Austin bicycle trips to have work and other utilitarian purposes, over a 12-hour weekday period, among a population of cyclists roughly evenly split between users of urban streets with bike lanes and users of undifferentiated streets (Hottenstein, Turner, and Shunk, 1997).

There is presently little basis on which to extrapolate what the trip purpose mix for bicycle boulevards might be. The apparent attractiveness of such facilities for less experienced bicyclists and females (Dill and Gliebe, 2008) supports speculation that the purpose distributions would lie between the mixes attracted by bicycle lanes and off-road shared use paths. Volunteer responders to an on-line survey, among residents fronting on the SE Salmon Street bicycle boulevard in Portland, Oregon, reported their

[66] An independent report of a 1997 8-hour count on Bryant Street gives 385 bicycles (Ciccarelli, 2010). This suggests that intersection counts reported in the Bicycle Transportation Plan (City of Palo Alto, 2001) are totals for all movements in the intersection, on all streets and bicycle facilities involved.

three top bicycling destinations (on or off the bicycle boulevard) were social/recreational (82 percent), shopping/errands (61 percent), and work (59 percent) (VanZerr, 2010).

Off-Road Shared Use Paths

The most extensive and readily available store of contemporary NMT volume characteristics and facility user information is that pertaining to off-road, shared use paths. Even so, its comprehensiveness and consistency don't begin to approach that for motorized travel modes and facilities. The National Bicycle and Pedestrian Documentation Project, for example, was just initiated in 2002 and as of early 2009 remained a volunteer effort with no source of funding and no resources for quality assurance or control (Jones, 2009). A selection of off-road shared use path volume and facility user characteristics information is presented here.

Path Volume and Usage Patterns. Table 16-103 illustrates the monthly patterns of traffic observed on San Diego and Indianapolis paths, and gives Indianapolis temperatures for perspective. These data are placed in context of season and climate with six other paths and path groupings in the "Underlying Traveler Response Factors" section (See "Environmental Factors"—"Natural Environment"—"Combined Walk and Bike Seasonal Effects" and Table 16-63). The Gilman Bike Path in San Diego is in a freeway and active-railroad transportation corridor in the suburbs, the Strand Bike Path interconnects beachfront urbanization and parkland (Jones, 2009), the Monon Trail is a rail trail through the heart of Indianapolis (Indiana University, 2001), and the other Indianapolis trails are an assortment of rail trails, riverside trails, and a canal towpath.[67]

Day of week volumes and percentage distributions are provided for the same two San Diego paths in Table 16-104, along with percentage distributions for the Terry Hershey Park Trail in Houston. The Houston facility is a riparian greenway trail. Of particular interest are the separate volume and percentage distributions for pedestrians and bicyclists on San Diego's Strand Bike Path. In this one instance, pedestrian traffic is much more variable day-by-day than bicycle traffic. On Saturday, the peak day, the volume of 620 bicycles was 2.8 times the volume of 220 pedestrians. On Wednesday, the low traffic day, the volume of 390 bicycles was 9.8 times the count of 40 pedestrians (Jones, 2009).

Table 16-105 presents weekday combined volume distributions by hour of day for nine mostly urban/suburban paths, and weekend volumes for eight, utilizing nine- and eight-path averages. In the weekday data, two outliers tend to balance out, and the average is a good representation of the dominant pattern of extended morning peak, noontime peak, and more sizeable afternoon/evening peak. Showing Manhattan separated out serves to display a slightly different pattern with an earlier morning peak and a particularly sharp peak at 6:00 to 7:00 PM, a phenomenon seen—with variations in the timing—on a little over half the paths. In the weekend data, the non-urban recreational trail and the Bosque Trail in Albuquerque are both outliers, with heavy morning usage disproportionate to light afternoon usage. Together they tend to warp the average. Manhattan separated out serves to represent the majority of the paths better than does the eight-path weekend-day average.

[67] Trail descriptions in this discussion rely both on the cited sources and on supplemental trail web-search results.

Table 16-103 Monthly Patterns of Traffic on Shared Use Paths for All Users Combined (Pct. by Month of Annual Traffic)

U.S. Location/Description	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Southwest (San Diego, CA)												
Gilman Bike Path	4.8%	5.2%	7.0%	7.2%	9.0%	7.6%	15.8%	12.8%	10.0%	6.0%	7.2%	7.4%
Strand Bike Path	6.2	6.4	9.4	8.8	8.8	10.2	14.4	7.0	7.6	8.2	7.0	6.0
Midwest (Indianapolis, IN)												
30 Indianapolis locations	2.0	3.6	4.6	9.8	11.0	13.0	14.8	15.8	13.0	6.6	3.8	2.0
4 locations - Monon Trail	3.6	3.4	5.8	12.0	11.2	12.6	13.0	12.6	10.6	6.8	4.6	3.8
Indianapolis temperature (°F)	*36°*	*36°*	*38°*	*58°*	*64°*	*70°*	*74°*	*76°*	*66°*	*56°*	*50°*	*38°*

Notes: Basis for San Diego November percentages is 2007-08 averages, December is 2007, all other months are 2008; all San Diego percentages are normalized to 100% for 12 months. No years given for Indianapolis counts.

Source: Jones (2009), with percentage values scaled from presentation graphics, and normalized (San Diego only), by the Handbook authors.

Table 16-104 Day of Week Patterns of Traffic on Shared Use Paths (All-User Daily Volumes and Percent by Day of Weekly Use)

U.S. Location/Description	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	7-Day Volume
Southwest (San Diego, CA)								
Gilman Path, Week of 7/23/07	320 (10%)	420 (13%)	410 (13%)	430 (13%)	380 (12%)	690 (21%)	590 (18%)	3,240 (100%)
Gilman Path, Week of 7/30/07	310 (8%)	440 (12%)	500 (13%)	460 (12%)	620 (16%)	760 (20%)	730 (19%)	3,820 (100%)
Strand Bike Path, Pedestrians	60 (8%)	70 (9%)	40 (5%)	70 (9%)	130 (17%)	220 (29%)	180 (23%)	770 (100%)
Strand Bike Path, Bicyclists	400 (12%)	420 (13%)	390 (12%)	410 (12%)	460 (14%)	620 (19%)	600 (18%)	3,300 (100%)
South Central (Houston, TX)								
Terry Hershey Park Trail	16%	11%	12%	11%	15%	18%	17%	100%

Notes: All users combined, except as noted otherwise. No dates given for Strand Bike Path or Terry Hershey Park Trail counts.

Source: Jones (2009), with scaling from presentation graphics, and calculation of percentages (San Diego only), by the Handbook authors.

Wednesday, June 13, 2007, hourly variation data for two San Diego paths (not previously introduced) exhibit quite different pedestrian and bicyclist activity patterns over a 24-hour period. Walkers and cyclists were separately identified using active infrared counting technology (Jones, 2009). The results dramatically illustrate how much NMT facility usage characteristics can vary by sub-regional location and orientation.

One of these two paths, the Rose Canyon Bicycle Path, serves a low density area with few destinations of its own and has a commuter orientation. Significant pedestrian activity (more than two per hour) was limited to the 7:00 AM to 11:00 AM period, with essentially no activity in the heat of the afternoon. The 21 pedestrians counted all day, 6 percent of path traffic overall, had secondary peak hours starting at 7:00 AM (14 percent) and 7:00 PM (10 percent) that may or may not have been related to commuting activity. The main peak for walkers was 10:00 to 11:00 AM (24 percent). Significant bicyclist activity occurred between 5:00 AM and 9:00 PM. Bicycle traffic, at 327 cyclists, was 94 percent of the path traffic total of 348. A morning peak occurred between 7:00 and 9:00 AM (12 percent each hour) while the evening peak was sharper, concentrated between 5:00 and 6:00 PM (12 percent).

A major contrast is provided by the second path, the Mission Beach Bicycle Path, an urban waterfront facility that is recreational in focus with many destinations. Here the pedestrian traffic of about 870 walkers was 43 percent of the counted path traffic total of roughly 2,020. Significant pedestrian activity occurred between 6:00 AM and 10:00 PM. The morning pedestrian peak hour started at 7:00 AM (10 percent), followed by a secondary noon hour peak (7 percent) and a broad afternoon and evening peak with its apogee at 5:00 to 6:00 PM (12 percent). Significant bicycling activity ran from 5:00 AM to midnight and the 24-hour total was about 1,160 cyclists, 57 percent of path traffic. The traditional morning peak hour was minor, starting at 7:00 AM (6 percent). The more dominant morning peak hour started at 11:00 AM (9 percent), and after dropping by barely more than 1/3, the bicycle traffic peaked again at 6:00 PM (9 percent) (Jones, 2009).

Additional trail count information along with data on peak-hour timing and percentages are given for six Indiana trails in the case study "Six Urban, Suburban, and Semi-Rural Trails—Indiana Trails Study" found near the end of this chapter. (Table 16-135 describes the trails and Table 16-136 gives the count and peaking information.) The Monon trail of Indianapolis exhibited the sharpest all-user peak of any encountered in the literature, 17.9 percent between 6:00 and 7:00 PM weekdays in September, 2000, and 19.4 percent between 5:00 and 6:00 PM in October when the days were shorter (Indiana University, 2001).

Path User Mode Distributions. Table 16-106 gives proportions walking, running or jogging, cycling, or in-line skating, based on trail traffic observations or survey results for six different paths or groups of paths. For a majority of the paths, information was also obtained on other or associated activities, as listed in the "Other" column. The Hennepin County (Minneapolis area) survey obtained frequency of use information. With that data they found that 2 percent of summertime trail users reported extensive on-trail skiing activity, obviously in the winter, with another 12 percent reporting occasional skiing (Hennepin County, 2005).

Table 16-105 Weekday/Weekend Hour-of-Day Patterns of Traffic on Shared Use Paths (All-User Pct. by Hr. of 16-Hour Use)

Hour Beginning:	6 AM	7	8	9	10	11	12 PM	1	2	3	4	5	6	7	8	9 PM
Weekday Hourly Patterns																
Nine U.S.-location average	$2^{\underline{5}}$%	5%	7%	$7^{\underline{5}}$%	7%	$6^{\underline{5}}$%	$7^{\underline{5}}$%	$4^{\underline{5}}$%	5%	$6^{\underline{5}}$%	8%	11%	$10^{\underline{5}}$%	$6^{\underline{5}}$%	3%	2%
Manhattan separated out	4	8	$8^{\underline{5}}$	$5^{\underline{5}}$	6	$5^{\underline{5}}$	6	3	5	$6^{\underline{5}}$	$7^{\underline{5}}$	$9^{\underline{5}}$	12	8	3	2
Weekend Hourly Patterns																
Eight U.S.-location average	$0^{\underline{5}}$	$2^{\underline{5}}$	7	9	10	10	9	$6^{\underline{5}}$	7	$7^{\underline{5}}$	8	8	6	4	3	2
Manhattan separated out	$0^{\underline{5}}$	$1^{\underline{5}}$	$5^{\underline{5}}$	$8^{\underline{5}}$	$9^{\underline{5}}$	$9^{\underline{5}}$	$9^{\underline{5}}$	$6^{\underline{5}}$	$7^{\underline{5}}$	$8^{\underline{5}}$	$8^{\underline{5}}$	$8^{\underline{5}}$	$6^{\underline{5}}$	$4^{\underline{5}}$	3	2

Notes: Nine-location weekday average included one each from the five New York City boroughs, one from Licking County in Ohio (July), the Monon Trail in Indianapolis (October), the Terry Hershey Park Trail in Houston (May-Oct.), and a recreational area trail with no urban anchor (Outerbanks in North Carolina). Eight-location weekend average included the New York City boroughs, the Bosque Trail in Albuquerque, the Terry Hershey Trail (May-Oct.), and the Outerbanks trail. No dates given other than the months indicated.

Source: Jones (2009), with percentage values scaled from presentation graphics by the Handbook authors.

Table 16-106 Shared Use Path Traffic Proportions by Type of Activity (Weekday and Weekend Combined)

U.S. Location/Description	Walkers	Run/Joggers	Cyclists	In-line Skaters	Other
3 Hennepin Co. (Minneapolis) trails, urb./sub.	6%	3%	84%	7%	0.2% (also see text re. skiing)
4 Rhode Island trails, suburban/towns/rural	32	7	49	12	—
Capital Crescent Trail (MD-DC), inner suburban	34	15	41	7	3% infants in strollers
W&OD Trail, Northern Virginia, sub./exurban	16	16	66	3	(2% with pets, 1% with strollers)
3 Texas Trails, Houston, Austin, urban/sub.	32	29	38	1	0.1% other
Iron Horse Trail, S. F. East Bay, exurban	27	9	51	13% incl. other	0.1% equestrians (W&OD also)

Notes: Trails are predominantly rail-trails except for alignments via riparian greenways in Houston and Austin, Texas. Traffic proportions were obtained from classification counts except for use of short-form on-trail surveys in Hennepin County, Rhode Island, and Texas.

Source: Hennepin County (2005), Gonzales et al. (2004), Maryland-National Capital Park and Planning Commission (2001), Bowker et al. (2004), Shafer et al. (1999), East Bay Regional Park District (1998).

The path traffic distributions in Table 16-106 were obtained from classification counts and surveys that were apparently all taken at on-trail intercept points. As discussed in the "Overview and Summary" (see "Analytical Considerations") and in the "Indiana Trails" case study, this analytical approach produces a "traffic" rather than a "user-visit" perspective. It under-emphasizes trail use for shorter trips such as walk trips, trips for non-work utilitarian purposes, and probably trips by women, younger children, and elders, while over-emphasizing longer trips (more likely to be intercepted) such as seen with adult bicycling. (The Mission Beach Bicycle Path discussed above is the type of situation where it can be readily imagined that a tally of *users,* in contrast to *traffic,* would show pedestrian activity dominance rather than a bicyclist majority.)

Only the six-trail "Indiana Trails Study" described in the next-to-last case study obtained a true user perspective by observing and surveying persons as they entered or exited the trails in the course of beginning or ending their trail visits. In addition, the three-trail Hennepin County survey may have come closer than others, by very explicitly allowing only one survey response per person.

Even with the methodological precaution, the Hennepin County trail traffic was reported to consist of a quite high 85 percent cyclists (Hennepin County, 2005). NMT mode share counts made during fieldwork seem to validate this high proportion. The other trails and trail groupings listed in Table 16-106 had trail traffic cyclist percentages ranging from 66 down to 38 percent. In contrast, *users* of the six studied Indiana trails exhibited cyclist percentages that, aside from 77 percent on one of two semi-rural trails, ranged from 40 down to 23 percent (see Table 16-138). Walkers exceeded 50 percent of Indiana trail users on both the Indianapolis Monon Trail (51 percent) and the Greenfield Pennsy Trail (54 percent) (Indiana University, 2001), while among all 13 trails encompassed by Table 16-106, walking as a component of path traffic exceeded 50 percent only on the Blackstone Valley bike path (51 percent walk) in Rhode Island (Gonzales et al., 2004) and the Shoal Creek Trail (52 percent walk) in Austin, Texas (Shafer et al., 1999).

Two sets of survey results are available for the Monon Trail in Indianapolis, one obtained with an interview survey of user visits (persons entering and exiting the trail) and the other obtained as a survey of traffic (persons observed at points on the trail itself). This makes for an instructive comparison, set forth in Table 16-107 for four activity-types and also gender. Some caution is needed in evaluating the Table 16-107 results differentials, in that the user survey was in 2000 and the traffic observations were in 2004, the user survey was in July-August and the traffic observations were in June–July, the 7-1/2 mile trail of 2000 had been extended by 2004 (Indiana University, 2001, Lindsey et al., 2006), and the trail locations used may not have been entirely comparable. However, the differences seen in results are sufficiently sizable, and in the expected direction, that survey timing or survey station location "noise" falls short as a credible explanation. The higher male proportion, the much higher bicycle proportion, and the lower proportions of other trail activities, including a much lower proportion of walking, can all be clearly seen in the main-line trail traffic observations as compared to the trail user-visit interview results.

Table 16-107 Comparison of Monon Trail 2000 User-Visit Interview Survey Results and 2004 Traffic Survey Observations for Activity Type and Gender

Monon Trail Survey Type	Walk	Run	Bicycle	Skate/Other	Male	Female
2000 Trail User-Visit Survey	51%	13%	23%	13%	46%	54%
2004 Trail Traffic Observations	19	11	61	10	57	43

Note: The 2000 user visit survey data is from statistically controlled interviews of users beginning or ending trail use, not the mail back survey (Indiana University, 2001).

Sources: Indiana University (2001), Lindsey et al. (2006).

Trail activity mix may vary over time. This is demonstrated and discussed in the case of the Burke-Gilman/Sammamish River (B-G/SR) Trails in greater Seattle, in connection with Table 16-17 within the "Response by Type of NMT Strategy" section (see "Shared Use, Off-Road Paths and Trails"—"Shared Use Path Implementation"—"Seattle Urban/Suburban Trails").

Path Mode-of-Access Distributions. Substantial off-road shared use path facilities and other NMT features attractive in their own right, such as major NMT bridge facilities, generate facility-access trips that typically include motorized access along with NMT access modes. Auto access is sometimes appreciable enough that parking availability becomes a concern and may actually influence patterns of use (Lindsey et al., 2006). Table 16-108 presents mode of access shares over time for the B-G/SR Trails, and also for four additional U.S. trails or groups of trails. All of these data are from surveys of persons on the trail itself (user traffic) and thus likely over-represent the characteristics of longer trips. Note the decline in auto access from 1985 on the B-G/SR Trails. In the previously cross-referenced "Seattle Urban/Suburban Trails" discussion, it is hypothesized that this decline may be the result of expanding alternative trail options, available for recreation and exercise, afforded by a growing trail system.

In the "Indiana Trails" case study, data provide trail mode of access from a user-visit perspective for six Indiana trails (see Table 16-138). Not much studied is the obvious relationship between choice of shared-use path access mode and distance from home to a path. On the Monon Trail in Indianapolis, just under 1/2 of trail users reported a 0-1 mile distance to the trail (the next questionnaire choice being 2-4 miles), and just under one-half reported use of NMT modes for trail access, as compared to driving to the trail. The 85th percentile trail user lived 5-8 miles from the trail (Indiana University, 2001).

Table 16-108 Mode-of-Path-Access Proportions for Shared Use Paths, All Facility Users

Location/Timing	Walk/Run	Bicycle	Skate	Bus/Metro	Auto	Other
B-G/SR Tuesday, 1985 [a]	11.8%	54.2%	n/a	n/a	34.0%	0.0%
B-G/SR Tuesday, 1990	20.9	58.0	n/a	n/a	20.8	0.2
B-G/SR Tuesday, 1995	12.6	62.2	n/a	1.5% [b]	21.9	1.8
B-G/SR Saturday, 1985	3.3	58.7	n/a	n/a	38.0	0.0
B-G/SR Saturday, 1990	13.2	53.5	n/a	n/a	32.8	0.6
B-G/SR Saturday, 1995	11.0	52.1	n/a	2.5% [b]	31.7	1.7
3 Minneapolis area trails [c]	8%	75%	3%	n/a	13%	n/a
4 Rhode Island trails [d]	14.8	25.1	1.2	n/a	58.1	0.8%
W&OD Trail, No. VA	15	38	n/a	2%	44	1
3 Houston/Austin trails	43.4 [e]	33.3	0.5	0.3	21.8	0.6

Notes: [a] B-G/SR stands for the combined Burke-Gilman/Sammamish River Trails, in northeast urban and suburban greater Seattle. All counts were on or close to May 20 (Moritz, 2005b). Data for 2000 are not shown because of a large non-response to the trail-access question.

[b] On Tuesday: Comprised of 1.0% bike-on-bus, 0.5% bus/foot. On Saturday: 1.9% bike-on-bus, 0.6% bus/foot. In 2000, these proportions had roughly doubled *on average*, while in-line skating, recorded for the first time, accounted for less than 1/2 of 1% of all access.

[c] See Table 16-106 for descriptions of the last four listed trails.

[d] Short-form on-trail survey results. Results from long-form mail-back survey were similar.

[e] Composed of 24.5% walk and 18.9% run/jog.

Sources: Moritz (2005b), Hennepin County (2005), Gonzales et al. (2004), Bowker et al. (2004), Shafer et al. (1999)

Path and Trail Purposes of Use. Table 16-109 provides trip purpose information for the five paths or groups of paths among those listed in Table 16-106 that surveyed this information. The Minneapolis-area Hennepin County trails exhibit the highest commute share, at 10 percent, even with the "Other" purpose having been inflated by inclusion of "Multiple [purpose] Responses" (Hennepin County, 2005). The other notable deviation from the typical is seen with the San Francisco East Bay's Iron Horse Trail, which on its former railroad alignment, passes through or close to both historic-small-town business and modern shopping centers. As covered in Note G of the table, "Retail" and "Restaurant" trips together comprise an unusually high 16 percent of reported trip purposes (East Bay Regional Park District, 1998). The other three trails have more typical primary purpose distributions, insofar as can be seen from the data, joining examples such as the six Indiana trails covered in the "Indiana Trails" case study (see Table 16-138).

Table 16-109 Purpose of Use of Shared Use Paths (Weekday and Weekend Combined)

U.S. Location/Description	Exercise	Recreation	Commute	Other
3 Hennepin Co. (Minneapolis) trails, urb./sub.	60%	8% [a]	10%	22% [b]
4 Rhode Island trails, suburban/towns/rural [c]	76	42	4	2
W&OD Trail, Northern Virginia, sub./exurban	7 [d]	84 [d]	6	3
3 Texas Trails, Houston, Austin, urban/sub.	90 [e]	—	4	6
Iron Horse Trail, S. F. East Bay, exurban	—	64 [f]	1	35 [g]

Notes: Information obtained from intercept surveys and interviews.

[a] Consists of 4% "Enjoy Scenery," 3% "Socialize," and 1% "Walk Pet."

[b] Consists of 6% "Shop/Errands," 3% "Meet Family/Friends," 1% "School," 10% "Other/ Multiple Responses," and 2% "No Response."

[c] Multiple responses were allowed in response to the Rhode Island trip purpose question.

[d] The survey combined "Fitness" with "Recreation" (84%). "Training" (7%) has been placed in the "Exercise" column.

[e] "Exercise" and "Recreation" were not explicitly identified. The 90% value entered in the "Exercise" column consists of 76% home-based out-and-back (a.k.a. "loop" or "round") trips and 14% work-based out-and-back trips.

[f] "Exercise" was not a survey form option. Trips taken for exercise were typically assigned by respondents to the "Recreation" category, but in some cases interviewers determined that "individuals had actual destinations and had chosen to use the trail because of the opportunity for exercise."

[g] Consists of 9% "Retail," 8% "Restaurant," 6% "Friends," 4% "Park/Recreational Facility," 3% "Another Town," 3% "School," 1% "Other," and less than 1% "BART" (rail transit).

Source: Hennepin County (2005), Gonzales et al. (2004), Bowker et al. (2004), Shafer et al. (1999), East Bay Regional Park District (1998).

One other item of special interest that comes from the surveys reported on in Table 16-109 pertains to the three Texas trails. Almost all of the 14 percent three-trail work-based out-and-back trips noted in table Note E took place on Houston's Buffalo Bayou Trail, representing 42 percent of the users of that one trail. This trail, with employment sites nearby, was found to have become "a very popular midday and after work jogging circuit." Indeed, 9 percent of the users of this trail were accompanied by business associates (Shafer et al., 1999).

Travel purpose distributions can shift over time, as illustrated by time series data for the Seattle-area Burke-Gilman/Sammamish River Trail. On that trail the weekday work/school commute proportion has grown from 10 percent in 1985 to over 30 percent in 2005 (Moritz, 2005a and b). A full discussion of this instance is presented in connection with Table 16-18 in the "Shared Use, Off-Road Paths and Trails" subsection of the "Response by Type of NMT Strategy" section (see "Shared Use Path Implementation"—"Seattle Urban/Suburban Trails").

Path and Trail User Characteristics. Individual trail traffic gender distributions are reasonably consistent with national data for all types of facilities, with only Virginia's W&OD Trail exhibiting a non-conforming result. In Hennepin County, Minnesota, 62 percent of trail traffic was found to be male, and 37 percent female (Hennepin County, 2005), a distribution one might expect given the bicycle-use dominance of the three Minneapolis area trails studied. The split was closer on the four Rhode Island trails, 56 percent male and 44 percent female overall, with 54 percent female on the Blackstone Valley bike path where use for walking dominated. A similar relationship among trails was found on the three Texas facilities, with females at 48 percent on the Shoal Creek Trail where walking dominated, while the three-trail average essentially matched the Hennepin County experience with a 63/37 split of males versus females (Gonzales et al., 2004, Shafer et al., 1999). Both trails in the suburbs of Washington, DC, had fairly even gender distributions. The split was 53/47 for the Capital Crescent Trail in Maryland and 47/53 for the W&OD trail in Virginia, with the tilt toward use by females on the W&OD trail found despite the low 16 percent-walker trail-traffic mix (Maryland-National Capital Park and Planning Commission, 2001, Bowker et al., 2004).

Data from the Indiana studies, the only instance encountered of truly surveying users as compared to trail traffic, shows close gender splits on all except the rural, bicycle-dominated Cardinal Greenway rail-trail radiating out from Muncie. (See Table 16-136 in the "Indiana Trails" case study.)

Path users include persons of all ages, but results from the two studies that reported age by even increments—the Hennepin County survey and the W&OD trail evaluation—suggest that the most extensive use of trails is made by middle-aged adults in the 45-54 age bracket (more than 1/4 of all users). Adults in the 35-44 age bracket are next most prevalent, followed by adults in the 25 to 34 age bracket (Hennepin County, 2005, Bowker et al., 2004). Different age-bracket survey specifications make it difficult to generalize, but it appears that seniors—surveyor identified or reporting age 65 and above—compose only 6 to 15 percent of trail traffic on the Hennepin County, Rhode Island, Capital Crescent, W&OD, Iron Horse, and Indiana trails listed in Table 16-106 (or covered in Table 16-137) (Hennepin County, 2005, Gonzales et al., 2004, Maryland-National Capital Park and Planning Commission, 2001, Bowker et al., 2004, East Bay Regional Park District, 1998, Indiana University, 2001). The corresponding average is about 8 percent seniors.

Children and adolescents are even less consistently identified, if covered at all. Two trails used a "less than 15" definition for the younger set and two trails included children and most or all teenagers. Into the "less than 15" category, the Rhode Island study placed 19 percent of trail traffic and the Capital Crescent survey placed 8 percent (Gonzales et al., 2004, Maryland-National Capital Park and Planning Commission, 2001). Into the broader category, the Hennepin County survey placed 3 percent and the Iron Horse Trail study placed about 20 percent (Hennepin County, 2005, East Bay Regional Park District, 1998). The average for younger users was thus about 12 percent of total traffic. The relative use of paths by children and young adults appears to be less than the relative use of the walking and bicycling modes nationwide by the same age groups. The opposite appears to hold for those of middle age.[68]

Much as middle-aged groups are heavily represented among path users, with a tilt toward older middle-aged users, so are middle-income groups with a tilt toward upper incomes. The proportions of Indiana trail survey respondents reporting household incomes between $40,000 and $80,000 annually in year 2000 dollars were in a tight range between 45 and 51 percent for 6 urban, suburban, and semi-rural trails. Higher income respondents comprised 16 to 21 percent except for 33 percent in Indianapolis, and lower income respondents made up 33 to 39 percent of respondents except for 22 percent in Indianapolis (Indiana University, 2001). (See Table 16-137 in the "Indiana Trails" case study.)

Fewer middle-income and more upper-income survey respondents were encountered on 3 Texas trails, with 22 percent reporting annual incomes below $40,000 annually, 33 percent between

[68] This and similar comparisons with U.S. national data to follow are drawn on the basis of national perspectives offered in the "Underlying Traveler Response Factors" section. See the applicable discussions and tables within the "User Factors" subsection.

$40,000 and $80,000, and about 45 percent reporting higher incomes (Shafer et al., 1999). Still higher incomes were reported by respondents to the W&OD Trail survey in upper-income Northern Virginia suburbs of Washington, DC. There the survey sample exhibited an average household annual income of $98,600 and almost 25 percent reported an income in excess of $120,000 (Bowker et al., 2004). Clearly path user makeup reflects the communities through which a trail passes. It also appears that trail users tend to fall more in the middle-income and/or upper-income categories than U.S. pedestrians and bicyclists in general.

Paths appear to attract educated users, although the proportion with college degrees varies markedly according to path location. Indiana trail surveys in Greenfield and Portage found about 1/3 of trail users to be college graduates, while trails in the other 4 Indiana areas studied had over 1/2 of users holding college degrees. Almost 80 percent of Monon Trail users in Indianapolis reported college degrees (Indiana University, 2001). Responders to the mail-back surveys on the 3 studied Texas trails had college degrees in 85 percent of all cases, over 1/2 accompanied by advanced degrees (Shafer et al., 1999). These findings are consistent with national-level research results indicating that propensity to walk, especially for exercise and recreational purposes, is highly correlated with educational attainment (Agrawal and Schimek, 2007). National bicycling versus education relationships are not as well studied.

All path studies that have investigated path user racial composition and ethnicity report low proportions of minorities on the paths, but the Hennepin County study makes special note of it. Their surveys—backed up by surveyor observations—found non-white persons to represent less that 20 percent of Midtown Corridor trail users, even though people of color are in the majority in adjoining Minneapolis neighborhoods. Overall responses for the 3 trails surveyed indicated a distribution of 92 percent white, 5 percent non-white, and 3 percent no race identified (Hennepin County, 2005). Survey responses for the W&OD trail in Northern Virginia came 85 percent from whites, 2 percent from blacks, 4 percent from Hispanics, 6 percent from persons of Asian ethnicity, and 1 percent from Native Americans, with the question unanswered by 2 percent (Bowker et al., 2004). Corresponding data from the 3 Houston and Austin trails was 87 percent white, 3 percent black, 6 percent Hispanic, and 3 percent other, on average (Shafer et al., 1999).

Surveyor-recorded racial makeup information on Indiana Trails ranged from 86 percent white, 10 percent black, and 4 percent Hispanic in Ft. Wayne to 98 percent white, 1 percent black, and 1 percent Hispanic in Greenfield. The potential for survey bias was highlighted by survey responses that came back 94 and 100 percent white, respectively, for the trails in these two cities. Similar discrepancies were noted in all areas (see Table 16-137 in the “Indiana Trails” case study), despite high survey mail-back rates (Indiana University, 2001). There are a number of possible reasons besides path use propensity differentials for the low numbers of minorities reported on paths, as well as for other phenomena such as somewhat low usage by lower-income persons. Possible explanations include not only survey response biases but also lesser mileage of paths in crowded urban environments.

Travel Behavior Shifts

Improvements to pedestrian and bicycle infrastructure have been shown in preceding sections to attract additional facility usage in most cases. When pedestrians or bicyclists are attracted (or repelled) by improvements (or degradations), shifts among travel modes take place along with some occurrences of new or redirected trips (or trips forgone). Two more or less fully developed empirical investigations of such effects have been encountered, both from cities in Australia. Both studies focus on peak-period weekday travel. They illustrate phenomena and relationships not readily discernible from “before and after” volumes and modal percentages, as instructive as those may be.

Prior or Alternative Modes of New Facility Users

Radial Off-Road Paths in Melbourne. The Melbourne evaluation of substitute modes of path users provides the more straightforward example of travel behavior shift research findings, because the results are not complicated by multi-mode trip recombinations. Its reliance on path bicyclist perceptions of travel alternatives makes it perhaps less robust, however, than if actual prior-activity data had been practicable to obtain. The survey utilized 12 intercept locations with count-based controls. An impressive 77 percent survey response rate was achieved for the one in seven sample of bicyclists using Melbourne off-road paths radial to the CBD. The path orientation and the 7:00 to 10:00 AM Monday timing of the survey resulted in a low proportion of recreational trips. Trip purposes were determined to be work (85 percent), university (3 percent), school (2 percent), recreation, (8 percent), and other (2 percent) (Rose, 2007). The work trip dominance must be considered in interpreting the results.

Respondents were asked, in the self-administered questionnaire, about how their travel behavior would be different if the path they were riding on had not been built. Table 16-110 summarizes the responses. The very small proportion who indicated they would not make the trip without the bicycle facility (1 percent), and the modest proportion indicating they would alter their destination (4 percent), represent responses constrained by the fact that work and school trips (90 percent of the total) cannot readily be adjusted in that manner. Nevertheless, the reporting that some of these responses would occur is highly instructive. The researchers postulate that the size of the proportion responding that they would continue to bicycle without destination change (75 percent) might be smaller if the responders were fully aware of the limitations of alternative routes (Rose, 2007). Nevertheless, a 20 percent mode shift in itself is not insubstantial. The implication is that the bicycle facilities have led to 25 percent more peak period cycling in Melbourne's radial corridors (or 26 percent accounting for new trips) than would be occurring without the paths.

Table 16-110 Melbourne Cyclist Responses on Their Travel Behavior Had Their Path Not Been Built

Travel Selection Had Bicycle Facility Not Been Built	Percent	Combined Categories
Would still cycle, changing route only	75%	Continue to bicycle
Would still cycle, but to a different destination	4	79%
Would change mode to car driver	7	Change travel mode
Would change mode to car passenger	1	20%
Would change mode to public transportation	12	Forgo trip
Would not make the trip	1	1%

Source: Rose (2007).

Goodwill Pedestrian and Bicycle Bridge in Brisbane. The Brisbane example is more unique, but it importantly demonstrates the extent and complexities of travel shifts that can occur under specific sets of circumstances. The preceding "Facility Usage and User Characteristics" discussion notes that the CBD locations of parking facilities and transit terminals are a major influence on the patterns and volumes of walking trips within a downtown. The Goodwill Bridge experience demonstrates that placing a major new NMT link-up in amongst parking facilities, transit terminals, and the CBD destinations they could or do serve can produce a major perturbation of the pedestrian (and bicycle) trip patterns and volumes.

The Goodwill Bridge experience is first introduced in this chapter under "Pedestrian/Bicycle Systems and Interconnections" (see "River Bridges and Other Linkages"). A full description is provided there. In brief, the Goodwill pedestrian/bicycle bridge crossing of the Brisbane River was opened in October, 2001. It for the first time provided an NMT connection between the south end of the CBD—and adjoining university—to South Bank residential and mixed-use areas, cheaper automobile parking, an additional south-of-river commuter railroad station, and key express bus stops. The post-graduate student research that reported on the induced travel behavior shifts explicitly obtained information on bridge user travel behavior before and after the new facility was in place, albeit relying on survey respondent recall of prior travel choices (Abrahams, 2002). It also obtained other insightful bridge user information already reported on in the earlier discussion.

The Goodwill Bridge analysis did not investigate travel behavior shifts other than changes in mode. Possible attraction of new trips and changes in trip destination choice were not inquired about in the survey. It appeared that persons whose circumstances in the prior condition did not fit with the options presented in the survey's previous travel mode question, tourists included, tended to answer "other."

The survey anticipated that the prior trips of some bridge users would involve more than one mode, and allowed survey respondents to give multiple answers concerning prior modes. The analysis then used the responses, and also information solicited on prior use of the upstream Victoria Bridge, to divide users who had originally walked or bicycled and who had retained that same NMT mode (shifting routes to the Goodwill Bridge) from those who had changed their travel mode in response to the new bridge. The first section of Table 16-111 shows the results of that analysis for commuters. The second Table 16-111 note does the same for non-commuters. Overall, 58 percent of Goodwill Bridge users were continuing to use their previous NMT mode, including 40 percent previously crossing on the Victoria Bridge, and 42 percent were persons who had changed mode. Among user subgroups, 52 percent of commuter pedestrians walking the bridge had changed modes, 19 percent of commuter bicyclists were likewise mode-changers, 34 percent of non-commuter walkers were mode-changers, and 26 percent of non-commuter cyclists had changed their NMT mode compared to their pre-bridge trips (Abrahams, 2002).[69]

Mode changers who reported only one prior mode were separated out for further analysis, though only in the case of commuters, providing the single-prior-mode information for commuter mode changers used to develop the second section of Table 16-111. Note that the table is constructed so that mode-changer subcategories nominally total to 100 percent, requiring inclusion of an entry for mode changers whose prior trip had involved more than one mode. The prior means of travel for Goodwill Bridge commuters involved more than one mode for 17 percent of walkers and the same for cyclists. The number of two-or-more mode trips did not increase much when bridge use was introduced in the case of bicycle commuters, but it tripled in the case of pedestrian commuters.[70] The previously cross-referenced "River Bridges and Other Linkages" discussion provides additional detail and context concerning the multimodal activity observed after bridge opening.

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[69] Goodwill Bridge trip diversion and mode shift estimates presented here reflect adjustment by the Handbook authors for differential pedestrian versus bicyclist survey response rates. The researcher reported survey response rates of 25 percent for walkers and 50 percent for cyclists (Abrahams, 2002). Despite the derivation of these rates without benefit of survey control counts, when these percentages are used to normalize the split between walkers and cyclists, the results are highly reasonable. (The result is 82 percent walkers and 18 percent cyclists, compared to weekday all-day cyclist percentages from counts taken 3 months previous—shown in Table 16-23—that range from 16 to 22 percent bike and have a weighted average of 19 percent.) Consequently, the Handbook authors elected to normalize the pedestrian and bicyclist results on the basis of the response rates given, for purposes of reporting trip diversions and mode shifts.

[70] The determination as to what constituted a separate mode requiring identification on the survey response was effectively left up to each responder. This approach probably led to some fuzziness in the handling of walk trips linked to motorized modes, which may in turn have affected the reliability with which the gain in trips of more than one mode can be calculated.

Table 16-111 Goodwill Bridge Mode Change Record for Commuter Walkers and Cyclists

Mode Retention Versus Change	Percent of Commuters Within Category: Bridge Commuter Walkers	Percent of Commuters Within Category: Bridge Commuter Cyclists
Prior and current mode same	48%	81%
Prior mode different (Mode Changer)	52	19
Prior Mode of Mode Changers	**Percent of Mode Changers Within Category: Bridge Commuter Walkers**	**Percent of Mode Changers Within Category: Bridge Commuter Cyclists**
Train only	23%	17%
Bus only	26	33
Ferry only	6	0
Taxi only	0	0
Car only	20	6
Walk only	—	22
Bike only	3	—
Other (single mode)	6	6
More than one mode	17	17

Notes: Adult and late-teen school trips were designated as commuter trips. (Bridge users under 18 were not surveyed.)

For Goodwill Bridge non-commuter walkers, 66% had the same prior and current mode and 34% were mode changers. For non-commuter cyclists, 74% had the same prior and current mode and 26% were mode changers.

Source: Abrahams (2002), with elaboration by the Handbook authors.

Table 16-112 augments Table 16-111 by displaying and giving percentages for the full array of prior modes reported by Goodwill Bridge Mode Changers. As can be seen in both tables, commuter rail, bus, and auto are together prominent in the prior mode arrays. Because of the gain in trips of more than one mode, it is likely that a number of the mode changes affected only the downtown and cross-river end of the trips involved. For example, a commuter who had driven into the Brisbane CBD might now drive only to less expensive parking in the South Bank, and walk the remainder of the distance via the Goodwill Bridge. Given the peculiarities of train station placement, the rough equivalent could be happening for trips via rail as well (Abrahams, 2002).

Table 16-112 Prior Mode Use Reported by Mode Changers (Multiple Responses Allowed)

Prior Modes Reported	Commuter Walkers	Commuter Cyclists	Non-Commuters
Train	27%	22%	7%
Bus	42	33	22
Ferry	7	11	3
Taxi	2	0	3
Car	31	11	45
Walk	—	33	6
Bike	7	—	3
Other	7	11	16

Note: See Table 16-111 (including notes) for proportions of surveyed bridge users who had retained their same mode and were thus not classified as "Mode Changers."

Source: Abrahams (2002), with elaboration by the Handbook authors.

Mode Shares "Before and After"

Mode shares obtained before and after infrastructure improvements provide less precise insights on shifts than actual prior mode data, because they do not give explicit information on what users of a new mode were doing previously, except possibly by inference. Such data are nevertheless quite useful, and in some instances increases in use of particular modes together with decreases for others provide a basis for judging what users attracted to newly enhanced modes were doing previously. Information of this type is provided, if available, in the "Response by Type of NMT Strategy" section.

A fully comprehensive presentation of before and after mode shares is exemplified by Table 16-6, in the "Pedestrian Zones, Malls, and Skywalks" subsection (see "Pedestrian Zones" under "Pedestrian Zones and Malls"). This example presents study area and overall CBD mode shares for all primary modes before and after Downtown Crossing pedestrian zone implementation in Boston. Another such tabulation, this one illustrating mode shifts over time in response to a city-wide bicycle and pedestrian facility and transit enhancement program for the entire city of Boulder, Colorado, is found in Table 16-44 of the subsection "NMT Policies and Programs" (see "New World Program Examples"—"Denver, Colorado"). Given that individual pedestrian and bicycle programs are often too incremental to produce discernible areawide changes in other travel modes, these types of before and after mode share presentations are somewhat rare, making travel behavior shift evaluations of the types accomplished in Melbourne and Brisbane all the more valuable.

Time to Establish Facility Use

Transportation options that have been in place for some time reflect usage that is "stabilized," "matured," or "established." Similarly, usage forecasts are typically prepared with travel demand estimation models and techniques keyed to travel behavior that reflects established travel choices and patterns. Experience from motorized transportation shows, however, that usage of a new facility or service will have to build up to stabilized levels of usage over time. Prospective users have to find out about the new travel option and its advantages to their particular situation. The opportune time for initiating use may not come at once. The result is lower usage during the initial months of option availability (Pratt and MWCOG, 1987). The same need for time to establish use applies to pedestrian and bicycle facilities. Lower initial use may be incorrectly interpreted as a sign of poor investment or design, or failure.

Motorized Transportation and NMT Experience Compared

Documented time-series volume-of-usage data for new facilities is scarce, so it is useful to examine what is available for NMT in the context of motorized transportation findings. Table 16-113 summarizes examples of motorized transportation experience, with emphasis on movement of people as contrasted to vehicular traffic. The last three rows present available NMT experience. The experience is expressed, in addition to "Months to Stabilize," in terms of the percentage of stabilized usage that is observed in the first month or so after opening, the first year, and the second year. Note that "established," "stabilized," or "matured" should not in this context be taken to necessarily infer a flat usage plateau with long-term permanence. It may be the reaching of a steady growth that parallels secular trends, such as population growth. The established pattern may also be disrupted by events such as fuel price changes, facility expansion, or competition from a new facility. The "Months to Stabilize" figures in Table 16-113 are developed based on visual examination of trend data and are identified on the basis of the *first* substantial period of stabilized ridership if there is more than one such period.

Table 16-113 Motorized and NMT Facility Usage Maturation Experience

Service or Facility	Use as a Percentage of Stabilized Use: Initial Use	1st Year Use	2nd Year Use	Months to Stabilize
VRE, Northern Virginia, Manassas and Fredericksburg commuter rail lines	56%	80%	106%	8
Washington Metrorail Yellow and Red (NW mid and outer segments) Lines	42%	66%	94%	20
Prince William County, VA, OmniLink demand responsive bus lines (5 lines)	17%	51%	89%	26
1960s Los Angeles and Long Island jobs-access bus routes (1 route each)	28%	54%	84%	27
Houston North, Katy, Northwest, and Southwest HOV lanes	30%	60%	80%	48
Melbourne St. Kilda Road bike lanes	n/a	16%	19%	84
Seattle Burke-Gilman/Sammamish River Trails (Tuesday data)	n/a	37%	n/a	90
Seattle Burke-Gilman/Sammamish River Trails (Saturday data)	n/a	78%	n/a	90

Notes: Available data for Washington Metrorail Orange Line (east), one additional Los Angeles jobs-access bus route, one additional Long Island jobs-access bus route, and four additional Houston and Dallas HOV lanes are not included either because of almost immediate stabilization (2 cases) or because of lack of stabilization during the study period (5 cases).

All percentages and numbers of months (except Washington Metrorail) are approximations by the Handbook authors based on graphed (transit) or tabulated (NMT) time series data. Means for each type of motorized transportation are simple averages. The OmniLink values are based on the total ridership on five routes, two of which did not open until the 5th month.

The 1960s jobs access bus route percentages are based not on use per se, but instead on the inverse of deficit per passenger (as a surrogate).

Sources: Washington Metrorail – Pratt and MWCOG (1987), Virginia Railway Express (VRE) – Parsons Brinckerhoff et al. (1994), and TCRP Report 95 figures and tables as follows: OmniLink (Prince William County, VA) – Chapter 6, "Demand Responsive/ADA," Figure 6-5; 1960s jobs access bus routes – Chapter 10, "Bus Routing and Coverage," Figure 10-1; Houston HOV lanes – Chapter 2, "HOV Facilities," Figure 2-4; Melbourne St. Kilda bike lane – Table 16-114 (below); Seattle Burke-Gilman/Sammamish River Trails – Table 16-17 (see "Response by Type of NMT Strategy" — "Shared Use, Off-Road Paths and Trails" — "Shared Use Path Implementation" — "Seattle Urban/Suburban Trails").

The motorized transportation and NMT facility usage outcomes presented in Table 16-113 are displayed in order of increasing numbers of months required after opening for stabilization of usage to occur. The ordering is very instructive. First are averages for two commuter rail line implementations and for three new sections of Metro (heavy rail transit). Both systems are in the metropolitan Washington, DC, area. Ridership on these urban rail lines stabilized in about 2 years or less—considerably less in the commuter rail examples (Pratt and MWCOG, 1987, Parsons Brinckerhoff et al., 1994). In the case of new urban rail lines, many riders have already been using public transportation, and for them the switch to rail is highly sensitive to travel time and convenience. Cost differentials and socio-economic factors play just a minor role (Pratt, 1971). Those shifting from auto commuting are making a more substantial change, but have the added impetus of parking cost savings at the destination, consequential in the Washington, DC, examples and most areas with rail systems. Attitudes toward new rail systems tend to be positive or neutral and their use is not generally looked upon askance. The shift to urban rail use is thus comparatively fluid, reflected in the relatively short 6- to 26-month usage maturation times observed on the five individual lines.

Next in Table 16-113 are a demand responsive bus system in outer Washington suburbs of Northern Virginia and bus routes designed to connect outlying jobs with urban pockets of unemployment in Los Angeles and on Long Island. In these examples, there were no previous viable transit connections, so all riders had to have made substantial travel adjustments. In addition, users of the jobs-access bus routes had to secure employment at the newly accessible locations. These various accommodations lead to less fluid travel changes, and usage stabilization on the three systems/lines assessed required 1-1/2 to 3 years. (See "Service Development and Time Lag" in the "Related Information and Impacts" section of Chapter 6 and "Traveler Response Time Lag" in the corresponding section of Chapter 10).

The final motorized transportation entry in Table 16-113 is for usage by bus riders and carpool passengers of HOV lanes in the Houston area. Here much more was involved than simply travel mode shifts alone. For potential bus passengers to even be in a position to consider use, bus routes via the HOV lanes had to be established, involving time-consuming steps for the transit agency. Carpool and vanpool users of the HOV lanes had to make ridesharing arrangements in order to affect mode shift decisions. HOV lane implementations thus offer an example of facility usage growth in the presence of barriers that must be overcome before shifts can occur. The individual HOV lanes studied had widely varying rates of usage maturation ranging from 2 to over 6 years. Although the initial use percentage averages are not out of line with the urban bus averages included in Table 16-113, the average time span before stabilization for the four HOV facilities covered was higher, on the order of 4 full years. (See "Time to Establish Ridership and Use" in the "Related Information and Impacts" section of Chapter 2, "HOV Facilities," for further information).

The small amount of data available for NMT facilities indicates that movement toward a stabilized usage level is even slower than the average for HOV lanes. The weekday time series data for the St. Kilda Road Bike Lanes in Melbourne, Australia, and the Burke-Gilman/Sammamish River Trails in Seattle, Washington, suggest a very gradual response to bicycle or bicycle and pedestrian facility availability. The better part of a decade is apparently required to reach stabilized usage levels. Barriers which must be overcome to make use of NMT facilities for utilitarian travel, most common on weekdays, have been discussed in the "Underlying Traveler Response Factors" section. They range from potential user safety concerns to workplace dress codes (Goldsmith, 1992). Confounding externalities, such as facility extensions and end-to-end conjoining of the two pathways in the case of the Seattle trails, may also be lengthening the time for usage stabilization. In any case, the choice to use NMT facilities is clearly a "sticky" one, not fluid, typically taking substantial elapsed time.

The weekend data from the Seattle trails, also entered in Table 16-113, hint that usage buildup for weekend walking and bicycling may be less gradual, although the observed 7-1/2 year time to reach fully stabilized usage is the same for the observed Saturdays as for the observed Tuesdays. Weekend usage is more heavily oriented toward exercise and recreation. A significant portion of the walking and bicycling involved may simply reflect a shift in exercise or recreation venue, likely combined with increased activity, with smaller components representing outright initiation of exercise or change in mode of exercise or active recreation. Further examination of the St. Kilda Road Bike Lanes and the Burke-Gilman/Sammamish River Trails experiences is provided or cross-referenced below.

Melbourne St. Kilda Road Bike Lanes

An AM peak hour count of St. Kilda Road bicyclists has been made almost every year since 1 year prior to the 1993 opening of bicycle lanes on this major traffic route oriented to Melbourne City. Bicyclist injuries per year have also been tracked for St. Kilda Road. Table 16-114 provides these data and also a "hazard ratio" calculation carried out as described in Note A of the table. The bicyclist count data are the basis for the St. Kilda Road Bike Lane facility usage maturation entry in Table 16-113.

Table 16-114 Melbourne St. Kilda Road Bike Lane Volumes and Injury Rates over Time

Year	Injuries per Year	Cyclists in AM Peak	Hazard Ratio [a]
1991 (before)	4	n/a	—
1992 (before)	3	42	1.0
1993 (lanes opened)	11	66	2.3
1994	5	76	0.9
1995	7	n/a	—
1996	10	130	1.1
1997	9	154	0.8
1998	10	160	0.9
1999	11	n/a	—
Early 2000	17	416	0.6
Late 2000	11	382	0.4
2002	19	318	0.8
2003	7	511	0.2
2004/2005 [b]	7	459	0.2

Note: [a] This hazard ratio, computed by the Handbook authors from data in the preceding columns, is reported injuries per year divided by the counted number of bicyclists in the AM peak and normalized to a value of 1.0 for the 1992 "before-bike-lanes" condition.

[b] 2004 injuries (cyclists n/a) and 2005 AM peak cyclists (injuries n/a).

Source: Davies (2007) with elaboration (see Note A).

AM peak bicycle volumes grew nearly sevenfold in the first 12 years of St. Kilda Road bicycle lane operation, from 66 in 1993 to 459 in 2005. The process has been very gradual, however, as discussed already. Possible reasons for the substantial jump in usage between 1994 and 1996 are not provided or speculated on in the available documentation. Of special interest is the stabilization of reported bicyclist injuries even as bike lane usage continued to dramatically expand. This beneficial effect has been attributed to the bicycle lane installation. A review of experience with the Australian state of Queensland's Main Roads cycling policy concludes, "The evidence [that in Table 16-114] broadly suggests that creation of a complete cycle network through implementation of the Main Roads cycling policy will have a positive impact on cycling mode share and safety" (Davies, 2007).

The hazard ratio in the final column of Table 16-114 is designed to better illustrate the safety trend. After an apparent doubling of hazard in the first year of bike lane installation, the hazard per bicyclist quickly dropped back to the before-bike-lanes level. Then, 5 years out from opening of the lanes, it dropped further over time as lane usage increased. These data not only seem to demonstrate the long-term safety benefit of the bike lanes, but also can be interpreted to support the "safety in numbers" hypothesis examined in the upcoming "Safety Information and Comparisons" subsection.

Seattle Burke-Gilman/Sammamish River Trails

The Seattle Burke-Gilman/Sammamish River Trails, like the St. Kilda Road bike lanes, did not reach an apparently stabilized level of usage until 7 or so years after facility implementation. Usage evolution has been quite complex and has been made more difficult to assess by a number of confounding NMT facility changes. The Burke-Gilman Trail component was extended subsequent to the initial 1980 count. Five years following the point selected as representing the reaching of stabilized usage for purposes of Table 16-113, the Burke-Gilman and Sammamish River Trails were joined. Usage recorded in the following 5-year count was up markedly, higher than seen 5 and 10 years afterward. Early use of the trails was 90 percent for recreation and exercise, but the work/school commute and other utilitarian purpose proportions have grown, sharply at first, and steadily thereafter. These and other usage observations based on time-series data are detailed and interpreted in the "Response by Type of NMT Strategy" section (see "Shared Use, Off-Road Paths and Trails"—"Shared Use Path Implementation"—"Seattle Urban/Suburban Trails").

Safety Information and Comparisons

There is a substantial body of pedestrian- and bicycle-oriented references, manuals, toolkits, instructional materials, and research on causes of traffic crashes and preventative or remedial facility designs and modifications to employ in response (Nabors, et al., 2007, Nabors, et al., 2008, Harkey and Zegeer, 2004, Campbell et al., 2004). Safety issues are not a central focus of this "Traveler Response to Transportation System Changes" Handbook. Nevertheless, it is difficult to avoid the subject when addressing walking and cycling, since many actual or potential non-motorized travelers cite perceived safety as a major factor in their active transportation decisionmaking. In addition there is concern that crash outcomes may detract from the health benefits of walking and cycling.

Accordingly, while this "Pedestrian and Bicycle Facilities" chapter hews to the "Traveler Response" Handbook practice of leaving facility design analyses and recommendations to other publications, this subsection does highlight safety information bearing on the overall risk of walking and cycling and the suitability of pedestrian and bicycle provisions. Selected NMT safety indicators and relationships are provided. Available comparisons with other developed countries and among facility types that contribute to the total picture of program and facility effectiveness are presented. Discussion of what is known about the effects of perceived safety on NMT travel choices is, however, found within the earlier "Underlying Traveler Response Factors" section (see "Other Factors and Factor Combinations"—"Security and Safety"). Effects on NMT travel choices of personal safety concerns about physical attacks and crime are addressed in that same subsection.

Pedestrian and Bicyclist Safety Highlights

Pedestrian and cyclist crash, injury, and mortality rates are at levels that may be viewed as a glass half full or a glass half empty. The rates are low enough that they should not be used to dissuade people from walking or cycling for active transportation or exercise and enjoyment. They are high enough to provide strong impetus for safety improvements. The crash data summarizations provided here are intended to help in scaling the magnitude and nature of NMT traffic safety risks.

Crash Rates from Various Perspectives. Almost all comprehensive U.S. crash rate statistics pertain only to crashes that in some way involve a motor vehicle operating on a public highway. Unless otherwise identified, all statistics presented here fall into that category. Pedestrian and bicycle crashes that do not happen on a public street or highway, or do not involve conflict between the pedestrian or cyclist and a motor vehicle, are rarely documented in conventional transportation crash statistics.

U.S. motor vehicle crashes in 2004 included 12.7 motor vehicle occupant fatalities per 100,000 population, 1.6 pedestrian fatalities per 100,000, and 0.3 bicyclist fatalities per 100,000. These are, however, measures of "population burden" rather than risk. To produce an estimate of risk requires a measure of exposure. Traffic exposure measures that have been used include distance traveled, time duration of travel, and number of trips (Beck, Dellinger, and O'Neil, 2007).

Distance traveled is the traditional traffic engineer's measure of crash exposure, although not necessarily the most appropriate for NMT. Since NMT trips are relatively slow and short, particularly in the case of walk trips, use of this measure produces the highest NMT crash rate estimates relative to other travel modes. Distance-based pedestrian fatality rates have been estimated, with 2001 data, at 140 fatalities per billion kilometers walked (22 per 100 million miles). This is over 23 times the distance-based 6 fatalities per billion kilometers rate for auto occupants. Corresponding rates for bicyclists are 72 fatalities per billion kilometers cycled (12 per 100 million miles), or 12 times the rate for auto occupants (Pucher and Dijkstra, 2003).

Use of time of travel as the exposure measure is one option, little used in the United States, for addressing the inability of a distance-traveled exposure measure to account for the large speed differentials between NMT and motorized travel. One U.S. analysis has been prepared using time of travel, drawing on 2001 Fatality Analysis Reporting System (FARS) and National Household Travel Survey (NHTS) fatal crash and travel data. It found a walking risk of 4.94 pedestrian deaths per million hours of walking as compared to 2.90 auto occupant deaths per million hours of auto travel, indicating a risk of walking 1.7 times that of traveling by auto. Bicycling fatality rates were not examined.

The research also, as one illustration of application of the technique, found—in terms of fatalities per unit of time—that walking is as safe as driving or riding in an auto during the daytime hours of 7:00 AM to 5:00 PM. The other side of the coin is, however, that walking was measured to be 5 to 8 times as risky during other hours as traveling by auto. The researcher notes that since the transportation infrastructure does not much change according to time of day, the explanation must lie in other factors such as light conditions, pedestrian and auto occupant behavior including inebriation, traffic flows, enforcement levels, and availability of emergency services (Chu, 2003).

Use of number of person trips as the exposure measure is a more common approach to NMT crash rate computations and comparisons designed to compensate for NMT versus motorized travel speed differentials. A CDC research effort utilized 1999 through 2003 FARS and National Automotive Sampling System—General Estimates System (GES) crash statistics together with person trip estimates based on the 2001 NHTS to produce the annualized fatal and non-fatal injury rates summarized in Table 16-115 for various travel modes (Beck, Dellinger, and O'Neil, 2007). Table 16-115 illustrates that on this basis making a trip by walking or cycling is 1.5 and 2.3 times as likely to result in a fatality, respectively, as taking a trip in an auto or other private passenger vehicle. Walking or bicycling is 39 and 25 times *safer* compared to riding a motorcycle, respectively, in terms of fatalities per trip.

Table 16-115 Annualized Injury Rates per 100 Million Person Trips by Mode of Travel

Mode of Travel	Fatal Injuries		Non-Fatal Injuries		Total Injuries	
	Rate per Exposure	Indexed to Auto Rate	Rate per Exposure	Indexed to Auto Rate	Rate per Exposure	Indexed to Auto Rate
Passenger Vehicle	9.2	1.0	803.0	1.0	812.2	1.0
Motorcycle	536.6	58.3	10,336.6	12.9	10,873.2	13.4
Pedestrian	13.7	1.5	215.5	0.3	229.2	0.3
Bicyclist	21.0	2.3	1,461.2	1.8	1,482.2	1.8
Bus	0.4	<0.05	160.8	0.2	161.2	0.2
Other Vehicle	28.4	3.1	1,020.6	1.3	1,049.0	1.3
Overall Rate	10.4	–	754.6	–	765.0	–

Notes: Unit of exposure is person trips in hundreds of millions (100,000,000 trips).

Based on 1999 through 2003 FARS and GES crash statistics together with trip estimates derived from expanding the 2001 NHTS.

Includes only pedestrian and bicyclist crashes involving a motor vehicle operating on (or entering/leaving) public streets or highways.

Sources: Beck, Dellinger, and O'Neil (2007), with injury totals and indexing by the Handbook authors.

The pedestrian and bicyclist crash rates per trip were also analyzed by gender and age group. Roughly speaking, males are on the order of twice as prone to crashes as females. The fatal injury rate for male cyclists stands out as being almost four times the equivalent rate for female cyclists (27.6 versus 7.2 per 100,000,000 trips). Walking and bicycling fatal-injury rates increase steadily with age. Combined fatal and non-fatal injury rates, however, peak at ages 15-24 and then decline with age. The increasing fatality rate in the face of an overall decline in the injury crash rate after age 24 is consistent with vehicle crash studies showing that fatality increase with age is primarily attributable to the greater fragility of older persons rather than decline in crash avoidance (Beck, Dellinger, and O'Neil, 2007).

Crash estimates roughly comparable to those presented for the general population in Table 16-115 have been developed by a select TRB committee for student travel during school hours, accepted as an approximation of travel to and from school. FARS and GES fatal and non-fatal injury data from 1991 through 1999 were combined to average out infrequently occurring incidents, and rates were determined on the basis of trip data from the 1995 NPTS. The estimates are "confounded by inconsistent and incomplete data," but deemed sufficient to make gross comparisons of relative risks among school travel modes. One notable issue is that while bus access pedestrian crashes (such as when crossing the street to get on a bus) are counted as bus crashes for school-bus trips, that is not the case for "other bus" (mainly transit bus) trips (Committee on School Transportation Safety, 2002). The committee's findings are summarized in Table 16-116. Walking or cycling to school, in terms of fatalities per trip, involves more risk than being driven by an adult but is safer than traveling in a vehicle driven by a teenager. Student bicyclists are more prone to crashes than student pedestrians.

Table 16-116 Annualized Injury Rates per 100 Million Schoolchild Person Trips by Mode

	Fatal Injuries		Non-Fatal Injuries		Total Injuries	
Mode of Travel	Rate per Exposure	Indexed to Adult-Driver Auto Rate	Rate per Exposure	Indexed to Adult-Driver Auto Rate	Rate per Exposure [a]	Indexed to Adult-Driver Auto Rate
Passenger Vehicle driven by:						
Adult	1.6	1.0	490	1.0	490	1.0
Teenager	13.2	8.2	2,300	4.7	2,310	4.7
Pedestrian	4.6	2.9	310	0.6	310	0.6
Bicyclist	9.6	6.0	1,610	3.3	1,620	3.3
School Bus	0.3	0.2	100	0.2	100	0.2
Other Bus	0.1	0.1	120	0.2	120	0.2
Overall Rate	3.5	–	650	–	650	–

Notes: Unit of exposure is person trips in hundreds of millions (100,000,000 trips) by students during normal school hours.

Based on 1991 through 1999 FARS and GES crash statistics and 1995 NPTS data.

Includes only pedestrian and bicyclist crashes involving a motor vehicle operating on (or entering/leaving) public streets or highways.

[a] "Total Injuries" rounded to nearest 10 in conformance with "Non-Fatal Injuries" data.

Sources: Committee on School Transportation Safety (2002), with "Total Injuries" and indexing by the Handbook authors.

All of these crash statistics involve estimation of the exposure measure. None are as accurate for pedestrians and cyclists as for motorized forms of transportation. Studies of emergency room records suggest that there is significant undercounting in official crash statistics of pedestrian and bicycle injuries. One study found that even in the category of bicycle/motor-vehicle crashes only two-thirds of events serious enough to entail emergency room treatment were recorded in State motor-vehicle crash records. Another factor contributing to the undercounting of pedestrian and bicycle injuries is that an estimated 64 percent of pedestrian injuries and 70 percent of bicycle injuries did not involve a motor vehicle. Moreover, some 53 percent of pedestrian injuries and 31 percent of bicycle injuries occur in non-roadway locations including sidewalks, parking lots, and off-road paths (Turner et al., 2006). At least the physics of velocity and mass suggest that the injuries not involving a motor vehicle are probably less likely to be in the serious injury or fatal category.

An analytical problem that is especially important in the case of pedestrians is hinted at in the report on risks of travel to school referred to above. Public bus access pedestrian crashes, even when crossing the street to get on a public (non-school) bus, are counted as pedestrian crashes for school children (Committee on School Transportation Safety, 2002). The fact is, the same accounting applies in the case of most adult crash statistics, and not just in the case of public buses, but for all forms of urban rail transit as well. At the same time, the trips involved are identified as public transit trips. This means that transit access walk trips, and also transit access bike trips, are not in the denominator (exposure measure) but are in the numerator (number of crashes) of NMT crash rate statistics. Indeed, a comparable problem occurs in the case of walk trips associated with driving, such as walking from an off-site parking facility to one's place of work. The result is that most NMT crash rates must be to some unknown but significant degree overstated, a rate overstatement certain to be magnified in cities with substantial transit usage and off-site parking, each with their associated walking. This issue potentially pertains whether the exposure measure is miles/kilometers, trips, or hours, although the hours-based fatal crash rate research presented above (Chu, 2003) carefully assigned access and egress times to the walk mode.

Finally, two overall observations may be drawn from the various crash rate data. On the one hand, pedestrian and bicycle fatality rates are high by any measure, clearly demonstrating need for system-wide improvements to increase NMT safety. European data presented below in the "Foreign Versus U.S. Safety Comparisons" show that this can be done. On the other hand, walking and cycling injury rates based on trips made or hours spent in the activity are not so much higher (if any higher) than automobile occupant injury rates as to suggest advisability of avoiding walking or cycling for any age group. The NMT risks—particularly for pedestrians—are not hugely different, on a per trip or per hour basis, than the private mode of travel risks generally accepted by the U.S. populace as a fact of life.

Most Prevalent Crash Causes. Alcohol/drugs are significantly involved in NMT/motor-vehicle crashes, and darkness appears to play a major role as well. Almost one-half (48 percent) of fatal pedestrian-vehicle crashes in 2009 involved alcohol, most often on the part of the pedestrian. Involvement was 43 percent calculated on the basis of intoxication defined as a blood alcohol concentration (BAC) of 0.08 grams per deciliter or higher. Of these, 6 percent involved both an intoxicated pedestrian and an intoxicated driver, 29 percent involved intoxicated pedestrians and sober drivers, and 8 percent involved intoxicated drivers and sober pedestrians. For fatal bicycle-vehicle crashes, the bicyclist and/or the motor-vehicle operator was deemed intoxicated (BAC $\geq$ 0.08) in 1/3 of all cases. Almost 1/4 of the cyclists killed were themselves intoxicated (NHTSA, 2010). Since 2003, there has been a modest absolute and relative decline in intoxication involvement in fatal pedestrian crashes, particularly on the part of drivers, but not much change in the case of fatal bicycle crashes (NHTSA, 2010, Turner et al., 2006).

Studies of pedestrian incidents in 2003 determined that 64 percent occurred at night, whether or not intoxication was involved. Of fatalities involving pedestrians under 16 years of age, 65 percent occurred between 3:00 PM and 7:00 PM. Almost 1/3 of fatal bicycle crashes took place between 5:00 PM and 9:00 PM. Pedestrian and bicyclist activity is quite likely high during late afternoon and early evening hours, increasing exposure, and it may be presumed that reduced visibility is also a factor. Late hours, and also weekends, are the times most associated with alcohol intoxication (Turner et al., 2006).

In judging the safety of walking and bicycling as a travel mode or form of exercise for children or adults, it is important to consider what crash and mortality rates might be if calculated separately for sober pedestrians and cyclists or if calculated only for daylight hours prior to the evening rush. The per-hour pedestrian fatality crash rate calculations reported above, showing walking during the daylight hours of 7:00 AM to 5:00 PM to be as safe as traveling by auto, give strong indication of daytime sober-walking safety.

Speed is a critical factor in fatal crashes, with injury severity strongly dependent on impact speed. An all-new, large data set (previous data were mostly decades old) composed of 490 German pedestrians aged 15 to 96 years suffering injuries from head-on crashes with automobiles has been analyzed. Children under 15, crashes involving SUVs and trucks, crashes involving persons lying on the street, and crashes with no injury reported were not included. The sample was drawn from the German In-Depth Accident Study (GIDAS), and data preparation included an adjustment for underreporting of minor-injury crashes based on comparison with the German national statistics on pedestrian crashes. Both age and speed were found highly significant predictors of fatal events but the results presented here are from a simplified model including only speed. The predictive logistic curve takes an "S" shape, starting to move upward more sharply above 20 to 30 km./hour (12 to 19 miles per hour [mph]) and reaching 50 percent probability of death at a little more than 75 km./hour (47 mph).

The study found the fatality risk in injury crashes to be approximately 1.5 percent chance of death at 30 km/hour (19 mph). Risk more than doubles at 40 km/hour (25 mph) and more than doubles again at 50 km./hour (31 mph), such that the risk at 50 km./hour is 5 times the risk of pedestrian death at 30 km./hour (Rosén and Sander, 2009). An earlier study which reworked previously evaluated crash records from Great Britain allows expansion of the GIDAS-based analysis to children. It derived separate curves similar to the GIDAS-based analysis for both children up through 14 years of age and adults 15 through 59 years of age. The results for both children and adults reach 50 percent probability of death at 70 to 75 km/hour (44 to 47 mph) (Davis, 2001). This is the same result as obtained in the GIDAS-based analysis without adjustment for underreporting of minor-injury crashes. It thus seems reasonable to assume that the newer relationships can safely be used as a basis for understanding childhood risks as well as adult risks.

Both studies found the elderly to be especially prone to fatal crashes. The earlier study developed a predictive curve specific to injury crashes involving persons age 60 and above. It showed 50 percent probability of death at 45 to 50 km/hour (28 to 31 mph) for this age group, compared to 70 to 75 km/hour (44 to 47 mph) for younger ages (Davis, 2001).

Eight crash-type categories encompass two-thirds of all pedestrian crashes involving a motor vehicle on, or entering or leaving, public streets or highways. These eight categories are fairly evenly distributed in prevalence, each accounting for between 7 and 11 percent of all reported vehicle-pedestrian crashes. Most frequently resulting in serious or fatal injuries (1/3 to 1/2 serious/fatal) are midblock dart/dash, other midblock, intersection dash, other intersection, and walking-on-roadway crashes. Only slightly less frequently resulting in serious or fatal injuries (1/5 to 1/4 serious/fatal) are crashes of the not-in-roadway/waiting-to-cross, vehicle turn/merge, and backing vehicle categories.

The eight most common conflict types for bicycle-vehicle crashes cover just over one-half of all cycling crashes involving a motor vehicle. Each account for 4 to 10 percent of reported crashes. Four of these crash types each result in serious or fatal injuries about 1/4 of the time. They are ride-out at stop sign, ride-out at residential driveway or alley, motorist left turn into cyclist, and cyclist left turn into same-direction motorist. Of all crashes in these four categories, 2/5 are of the ride-out at stop sign type. The other four most common bicycle-vehicle crash types incur serious or fatal injuries at the rate of very roughly one in ten reported incidents. These crash types are other cyclist-ride-out-at-intersection (one in six serious/fatal), motorist facing a stop sign, motorist mid-block drive out, and motorist right turn.[71]

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[71] These pedestrian and bicycle crash proportion and severity conclusions are drawn by the Handbook authors directly from the notes to Figures 3-4 through 3-19 in Turner et al. (2006), the original source being an FHWA study of 8,000 pedestrian and bicycle crashes in five states. Only included are pedestrian and bicyclist crashes involving a motor vehicle operating on, or entering or leaving, public streets or highways. Thus omitted in this data are all trail crashes except those occurring at road crossings and intersections. Data provided further on under "Facility Type Safety Comparisons" suggest that falls and collisions with fixed objects are highly prevalent NMT crash types not covered by motor-vehicle-conflict crash data.

Foreign Versus U.S. Safety Comparisons

Pedestrian and bicycle crash fatalities have each declined in the United States over the past quarter century or more. However, accompanying trends suggest that—at least until the 2000–2009 decade—the declines may be mostly related to reductions in walking and bicycling activity. For example, reduction in child cycling has been posited as the underlying cause of the U.S. cyclist fatality decline. An Insurance Institute investigation is reported to have found that adult cyclist fatalities actually increased from 302 in 1976 to 560 in 1997 (Pucher and Dijkstra, 2000). Only since 2000 has a decline in NMT fatalities been seen (NHTSA, 2010) in conjunction with walking and bicycling rates that have climbed slightly or remained stable. (For 2001 and 2009 walk and bike share statistics see Tables 16-85 and 16-87 in the "Extent of Walking and Bicycling" subsection).[72]

In contrast, the pedestrian and cyclist fatality rates in countries such as the Netherlands, Denmark, and Germany are not only much lower today than rates in the United States, they have also dropped much faster over time (Pucher and Buehler, 2008a). This is important because of questions about transferability of results. Contentions that fundamental conditions in European countries are so unique as to explain current NMT safety rate differences are difficult to positively refute. Different rates of safety improvement, in contrast, are less readily linked to inherent differences among countries aside from government policy emphasis. Moreover, cogent explanations linked to deliberate Dutch, Danish, and German policies and programs have been offered for the European fatality reductions. Such explanations lead to corollary conclusions that application of similar approaches in countries such as the United States could bring comparable fatality reductions.

Specific safety improvement approaches applied in the Netherlands and Germany include (Pucher and Dijkstra, 2000, Pucher and Buehler, 2008a and b, Lusk et al., 2011):

- Pedestrian system enhancements—such as pedestrian zones, well-lit sidewalks on both sides of streets, and zebra crosswalks.
- Bike paths and lanes—mileage doubled in the Netherlands and Germany between the mid-1970s and the mid-1990s, with recent emphasis more on design enhancements such as bike lane buffering and physical separation to create cycle tracks.
- Traffic calming—of most streets in residential neighborhoods, including substantial use of 30km/hour (19 mph) speed limits.
- Intersection modifications—such as special bike lane and stop bar arrangements, colored pavement guidance, and pedestrian and cyclist traffic signal provisions including activation, phases, and timing.
- Secure bike parking—positioned for safety, with guarded parking areas at key locations.

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[72] U.S. pedestrian fatalities were 4,763 in 2000 and 4,092 in 2009. Bicyclist fatalities were 693 in 2000 and 630 in 2009. During the same time span, however, the proportion of total vehicular crash fatalities that were pedestrian fatalities increased from 11 to 12 percent and the proportion of total fatalities that were bicyclist fatalities increased from 1.7 to 1.9 percent (NHTSA, 2010). In drawing inferences about the raw fatality numbers, it must be kept in mind that this was a decade that ended with higher gasoline prices, higher unemployment, and a dip in VMT.

- Education and training—grade school classroom instruction and on-facility cycling lessons, mandated driver training, and motorist license exam testing of pedestrian and bicyclist crash avoidance skills.

- Traffic regulations and enforcement (strict compared to the United States)—motorists are basically assumed responsible in crashes involving child, elderly, or disabled pedestrians or cyclists even in cases of jaywalking or other unsafe behavior.

Table 16-117 compares contemporary cycling fatality rates among North American and European countries, expressed in deaths per 100 million kilometers cycled, using country by country averages for the years 2002 through 2005.

Table 16-117 Cycling Fatality Rates in North America and Europe, 2002–2005

Country	Rate [a]	Country	Rate [a]
United States	5.8	Germany	1.7
Italy	3.5	Denmark	1.5
United Kingdom	3.0	Sweden	1.5
Canada	2.4	Netherlands	1.1
France	2.0		

Note: [a] Cycling fatalities per 100,000,000 kilometers cycled.

Source: Pucher and Buehler (2008a).

Facility Type Safety Comparisons

Many safety comparisons can potentially be made among NMT facility types and options. The following discussion is limited, however, to three comparisons of particular interest to broad NMT planning decisions. They are the safety of off-street versus on-street bicycle facilities, cycling on sidewalks versus on-street in traffic, and cycling in cycle tracks compared to other on-road situations.

Cycling Safety on Off-Street Versus On-Street Bicycle Facilities. The relative safety of cycling on separate facilities versus cycling on streets and roads in traffic is a subject that has engendered much controversy (Pucher, 2001). The controversy is not aided by the focus of the primary crash statistics sources on only those crashes involving a motor vehicle using, entering, or leaving a public highway.

One investigation that does provide a slice of data on the relative safety of different types of facilities is the December 1996 survey of League of American Bicyclists (LAB) members. A 20 percent sample was drawn proportionate to state population, and the 1,956 valid survey returns represent a 42 percent useable response rate. The survey population was not intended to be representative of all cyclists. The LAB-member respondents were adult or older teen (average age 48), largely male (80 percent), and fairly experienced, as may be inferred from their average annual cycling distance of 4,670 km. (2,900 miles). Included in the survey instrument was a question about serious crashes, defined as involving at least $50 in property damage or medical expense. Of respondents, 29 percent reported having had a crash in 1996, including falls and striking fixed objects, while 9 percent reported having a serious crash.

A relative danger index (RDI) was calculated as the fraction of bicycle crashes reported for a particular facility type divided by the fraction of kilometers ridden on that facility type. An RDI of over 1.0 thus indicates a facility type where the rate of crashes is higher than the overall crash rate, on all types of facilities, for the survey population. The lowest crash rates were for on-street bike lanes (RDI=0.41), followed by signed on-street bike routes (RDI=0.51), major streets without bike facilities (RDI=0.66), minor streets without bike facilities (RDI=0.94), shared use paths (RDI=1.39), and off-road/unpaved paths (RDI=4.49). The highest crash rates were on "other" facilities, mostly sidewalks (RDI=16.34). Sidewalks are thus shown to be by far the most unsafe type of facility for a LAB-member cyclist (Moritz, 1998). This is a finding that when generalized to the adult cycling population is mostly but not universally corroborated in the "Cycling Crashes on Sidewalks Versus Other Facilities" discussion.

The LAB survey and two earlier studies agree that on-street bike lanes and signed on-street bike routes taken together have the lowest crash rates, with RDIs around 0.5. On the other hand, the detailed LAB survey results showed crashes least likely to be serious on off-road/unpaved paths, shared use paths, and minor streets without bike facilities (Moritz, 1998). The result, for other than sidewalks, is less difference among facility types in terms of serious crashes. In round numbers, calculation of serious crash RDIs from the reporting of LAB-member survey results shows them to be 0.6 for on-street bike lanes, a little over 0.9 for all other on-street conditions, 1.3 for shared use paths, 2 for off-road/unpaved paths, and 19 for "other" facilities, mostly sidewalks.

There is an element of "apples and oranges" non-comparability encountered in trying to compare crash rates for on-street facilities with off-street facilities. Relative to on-street facilities, shared use paths attract more child cyclists—including cyclists in training—and relatively fewer "hard-core" experienced cyclists. They also serve pedestrians, in-line skaters, and the occasional baby conveyance, wheelchair, and dog-walker with or without leash. If even a subset of the resultant user mix were to be introduced on-street, the on-street crash rates would likely be altered for the worse, even for the adult bicyclist component. (See "More—Off-Street Versus On-Street NMT User Mix" in the "Special Mini-Studies in Montgomery County, Maryland" case study, including Table 16-129, for a direct off-street versus on-street user mix comparison.)

A safety study of three mixed-use trails in Connecticut's Farmington Valley, also based on survey respondent recall, utilized surveys handed to all trail users 18 years of age and older. The bicyclist crash rate was 150 per million miles of travel. Falls were included, constituting 63 percent of all crashes, and were found to be about as often associated with an injury as collisions. Analysis indicated that cyclists on the trails incur three times the crash rate of on-trail pedestrians but only roughly one-half the crash rate of in-line skaters. In light of the relatively small sample size, the crash rate difference between cyclists and in-line skaters was not statistically significant, but the crash rate differences between pedestrians and wheeled users were. Slightly less than one in five of all crashes occurred at trail intersections with roads. The trail with the highest overall crash rate was the most heavily used and had the most intersections, while the trail with the lowest rate had the smallest percentage of wheeled users and the fewest crossings (Aultman-Hall and LaMondia, 2005).

Whereas the Farmington Valley study did not examine relative crash rates among facility types, there has been a highway agency study in Boulder, Colorado, which did so. Described at the end of the "Sidewalks" discussion below, it found shared-use "side path" safety to be at least as good as the safety of Boulder's on-street bicycle facilities (Roskowski et al., 2010).

Cycling Crashes on Sidewalks Versus Other Facilities. Designation of sidewalks as bikeways has generally been identified as a practice to be avoided if possible for safety reasons. Cycling on sidewalks may be desirable for children traveling at low speeds, but for the general population most data suggest it presents greater risk compared to other cycling environments. Safety issues on sidewalks include conflicts with other people, poles, and sidewalk furniture, and most importantly, conflicts with driveway, alley, and street intersection vehicular traffic. Cyclists on sidewalks are placed in particular danger at traffic conflict points by their relatively fast movement in directions not allowed on adjacent traffic lanes and their inability to act like vehicles in intersections. Either of these circumstances can engender motorist surprise and confusion (Turner et al., 2006).

Researchers in a 1979 Eugene, Oregon, study found the crash rate on the three sidewalk bicycle-route sections to be close to 3 times higher than on the city's signed or striped bicycle lanes. Similarly, a 1974 Palo Alto, California study found that while only 15 percent of bicycle travel occurred on streets with sidewalk bicycle paths, about 70 percent of the bicycle-motorist collisions occurred on such streets (Zehnpfenning et al., 1993).

A 1995 route choice and fall-and-collision survey taped to handlebars of bicycles parked at employment areas throughout Ottawa and in central Toronto, Ontario, Canada, confirmed substantially higher event rates (falls and crashes per-kilometer bicycled) for sidewalks.[73] The commuter cyclist respondents who used sidewalks did so mainly along major roads. It was determined that cyclists who choose to use sidewalks have higher event rates than non-sidewalk cyclists even when on roads and to some extent on paths. These "sidewalk cyclists" (bicyclists who used sidewalks) thus had higher event rates in general than other cyclists. Sidewalk cyclists reported higher helmet use rates, suggesting more caution, and bicycled fewer miles. The researchers posited that the sidewalk cyclists in Ottawa and Toronto, where sidewalk bicycling is by no means encouraged, are on the whole less skilled and perhaps themselves more "dangerous" and in need of training (Aultman-Hall and Adams, 1998).

A somewhat different understanding of sidewalk bicycling risks was developed in a follow-up Palo Alto study of bicycle-motor vehicle collisions at intersections. Bicycle crash statistics were obtained from police reports for 1981 through 1990. Bicycle/motor-vehicle collisions accounted for 314 out of the 371 crashes for which substantially complete reports were available. Bicycle observations and counts were taken in May 1987 at intersections where 92 of the 233 intersection crashes had occurred, in order to establish a basis for exposure rate calculations by cyclist and behavior category. Only the bicycle/motor-vehicle collisions were analyzed, and only those occurring where the exposure counts were taken were carried into the final analysis. The final sample was 89 crashes with information on all four key variables. Relative crash risk factors for different demographics and circumstances were calculated, indexed to a value of 1.0 as the average risk factor for all cyclists and situations analyzed (similar to the RDI described above for LAB members).

While cyclists 17 years of age and under had a relative risk of 1.0 when cycling on sidewalks, the same as for all cyclists and situations overall, cyclists 18 years of age and older had a risk factor of 2.4. Contributing factors may have been ongoing safety education in the school system for younger cyclists and the faster speed of older cyclists. A key determinant was direction of travel. Cyclists of all ages had a risk factor of 0.7 when cycling on sidewalks in the same direction as vehicular traffic in the adjacent lane, but incurred a risk factor of 3.0 when traveling counter to the flow of adjacent traffic. The study authors note a lack of success in Palo Alto's attempt to enforce one-way bicycle travel on certain sidewalks. Overall, bicycling on sidewalks was associated with a risk factor of 1.4 as compared to 0.8 for cycling on roadways, a statistically significant sidewalk to roadway risk ratio of 1.8 (Wachtel

[73] The survey not only allowed evaluation of fall and collision events not covered by police records, it also found that none of the 82 sidewalk falls and 32 sidewalk collisions recorded by survey respondents had been reported to police. Only two might likely have shown up on medical records.

and Lewiston, 1994). (Compare these factors to the RDIs for LAB members presented above, which show even higher relative danger in sidewalk cycling by adults [Moritz, 1998].)

A review of 682 year 2000 police reports on crashes involving bicycles in Phoenix, Arizona, tends to confirm that bike riding on sidewalks is much more risky in the direction of travel opposite of vehicular flow in the adjacent travel lane. (Exposure measures and rates were not developed.) Of pre-crash bicyclist riding positions and directions, 5.9 percent involved sidewalk bicycling "with traffic" and 22.6 percent involved sidewalk bicycling "against traffic." Bicyclists aged 11–20 were most frequently involved in bicycle-vehicle crashes overall, twice the number in the next highest 10-year age increment (Cynecki, 2011).

While the literature on safety issues and crash rates for bicycling on sidewalks is obviously not extensive, and some questions about underlying risk factors are raised by the Ottawa and Toronto Research, only one study has been encountered that takes serious issue with the proposition that sidewalk cycling tends to be relatively hazardous on average. Noting a basic intersection conflict similarity between sidewalks used for cycling and Montreal two-way cycle tracks, the Montreal cycle track safety study described below took a critical look at the Wachtel and Lewiston analyses in Palo Alto. The Montreal study authors report finding that the Palo Alto evaluation was limited to intersection crashes. They further report that when non-intersection crashes are included, the relative risk for sidewalk cycling versus on-street is lowered from 1.76 (corresponding to the 1.8 value given above and statistically significant) to 1.07 (not statistically significant) based on the Palo Alto data, and that sidewalk cycling in the same direction as the closest traffic lane becomes almost twice as safe as in-traffic cycling (Lusk et al., 2011). It would appear that the relative danger of sidewalk cycling cannot be regarded as an issue that has been completely resolved.

Boulder, Colorado, has "side paths" along roadways among its inventory of shared-use paths. Built to various standards, some operate more satisfactorily than others. An array of signage, coloration, and geometric design retrofit strategies has been applied to improve conditions. Safety is also thought to be enhanced by the relatively large number of bicyclists, who thus make themselves "expected" users. The Colorado Department of Transportation has conducted an analysis of pedestrian- and bicycle-related crashes showing the side paths to have crash rates no higher than the on-street bicycle system, which consists of a mix of streets with bike lanes, signed bike routes, and bikeable shoulders (Roskowski et al., 2010).

Cycle Track Versus Other On-Road Cycling Safety. Conventional bike lanes are generally credited with enhancing safety (Moritz, 1998, Cynecki, 2011, Cambridge Community Development, 2011) although safety conclusions have been drawn in significant measure from studies of bicycle behavior rather than differential crash rate analysis (Harkey, Stewart, and Rodgman, 1996). A few specific examples of safety gains with bike lane implementation have been presented, in conjunction with traveler response information, in the "Response by Type of NMT Strategy" section (see "Bicycle Lanes and Routes"). Time series bicycle crash risk data for the St. Kilda Road bike lane in Melbourne, Australia, is tabulated in the preceding "Time to Establish Facility Use" subsection (see "Melbourne St. Kilda Road Bike Lanes" including Table 16-114 from Davies, 2007). An important inference which may be made from that information is the occurrence of a hazard increase in the 1 year following St. Kilda Road bike lane implementation—somewhat more than a doubling—followed by a return to previous bicyclist hazard levels and then, after 4 or 5 years, a decline into much lower levels of risk concurrent with increased bike lane use.

The issue of whether on-street cycle tracks offer similar or more safety advantages over bicycling in mixed traffic flow is of particular concern as U.S. cities consider their introduction. Looking to European examples, the 29,000 kilometers of cycle tracks in the Netherlands have been credited—

along with other initiatives (listed above)—for the very low bicyclist injury rate in that country. After the Netherlands, next in degree of cycle track deployment is Denmark (Lusk et al., 2011).

A before-and-after study of cycle tracks and intersection treatments in Copenhagen included 1,000 interviews, 1,500 counts, and analysis of 8,500 crashes. The bike-lane and cycle-track traffic stream in Copenhagen includes 5 percent mopeds. Contrary to surveyed Copenhagen bicyclists' perceptions and North American experience, installation of bike lanes was accompanied by increases in crashes of 5 percent and in injuries of 15 percent, with the risk falling disproportionately on bicyclists and moped riders. Corresponding combined crash and injury statistics for cycle tracks indicate a 9 to 10 percent increase in crashes and injuries. Unlike the case with bicycle lanes, the safety decrease associated with cycle tracks occurred entirely at intersections, with the stretches in between intersections exhibiting a 10 percent reduction in crashes and a 4 percent decline in injuries (Jensen, Rosenkilde, and Jensen, 2007).

The cycle track risk in Copenhagen has fallen primarily on pedestrians, bicyclists, and moped riders navigating intersections. Their crash experience has led Copenhagen to experiment with different treatments in and approaching intersections, some of which hold promise. The study authors also judge that gains in health from increased physical activity induced by the cycle track and bicycle lane system are producing gains that "are much, much greater than the losses in health resulting from a slight decline in road safety" (Jensen, Rosenkilde, and Jensen, 2007). The role of mopeds in the mix was not examined, and neither was the newness of the studied bike lane or cycle track installations reported.

There have been many concerns about transferability of overall European experience to the North American context. To address these concerns, and learn more about cycle track safety, an international team—lead by the Harvard School of Public Health—took advantage of Montreal's well established system (and comprehensive records) for a comparative cycle track safety analysis. The local emergency medical response database was used as the primary bicycle injury record source. Police crash records were employed for missing information such as direction of cyclist travel. For comparison, a "reference street" (or streets) was selected for each of the six cycle tracks studied, generally a parallel street. The reference streets had no special bicycle facilities. Historic bicycle volume records were available for the cycle tracks. These bicycle volumes were adjusted/extrapolated to the reference streets on the basis of 2-hour counts taken simultaneously on each pairing of a cycle track with its reference street(s). The relative risk of injury (RR) for the cycle tracks was computed as the ratio of injuries to bicyclists on each cycle track divided by the corresponding ratio for its reference street(s).

Statistically significant results were obtained for three of the cycle tracks, with RR values ranging from 0.32 to 0.48, indicating that bicycling on these particular cycle tracks was 2 to 3 times as safe as cycling on their reference streets. Including results not statistically significant, the range of RR values for the six studied cycle tracks becomes 0.32 to 1.18. The RR value for all studied cycle tracks combined was 0.72, indicating that bicycling was 39 percent safer on the six cycle tracks than bicycling in mixed traffic on the reference streets. These favorable results were obtained despite the fact that Montreal cycle tracks are two-way facilities, not as safe as one-way facilities according to Dutch guidelines, and lack parking setbacks at intersections as recommended by the Quebec Ministry of Transport (Lusk et al., 2011).

A cycle track and a pair of buffered bike lanes in Portland, Oregon, were not in place long enough, when studied, for crash statistics analysis. A survey showed that a majority of surveyed users felt safer. On the SW Broadway cycle track, which replaced a bicycle lane configuration, the proportion of bicyclists who elected to cycle in mixed traffic rather than on the bicycle facility itself fell from 12 to 2 percent. The buffered bike lanes were placed on a one-way couplet, SW Stark and State Streets, that had not had bicycle lanes previously. The Portland study made video observations of intersections along the new facilities. Analysis of the videos identified nearly one in 10 of all interactions between cyclists and pedestrians as potentially unsafe. Survey respondents included high proportions of motorists and bicyclists expressing confusion about relevant traffic regulations (Monsere, McNeil, and Dill, 2011). The latter findings are hardly definitive with regard to safety impact but do suggest need for further education of the public.

Other Traffic Safety Issues and Findings

Following are some pedestrian and bicyclist safety topics likely to be of special concern to practitioners focused on encouraging active transportation but cognizant of the need for awareness of safety implications. Note that schoolchild safety information was included above within the "Pedestrian and Bicyclist Safety Highlights" discussion (see "Crash Rates from Various Perspectives" including Table 16-116 and associated text).

Street Crossing Safety. One street crossing safety issue in particular deserves special mention here, namely, pedestrian safety within marked crosswalks. Although there are many uncertainties in the existing research, it does appear that an unfortunate trade-off exists with respect to crosswalk marking under certain problematic conditions. These conditions involve uncontrolled at-grade crossings of roadways (i.e., with no traffic signal or stop sign protection for the crosswalk) in the presence of substantial traffic volumes and multiple travel lanes. Marked crosswalks may attract some additional pedestrian activity (see "Street Crossings"—"Crosswalks and Traffic Controls"—"Pedestrian Crossings" in the "Response by Type of NMT Strategy" section), but where the described problematic multi-lane traffic conditions exist, they apparently do so at the risk of pedestrian-vehicle crash rates that are higher to a statistically significant degree.

A review of 11 intersection studies from 1965 to 2005 determined that nine of the 11 found *higher* pedestrian-vehicle crash rates in the presence of plain painted crosswalks than in situations where legal crosswalks (projections of intersecting sidewalks or roadsides) remained unmarked. Most of these studies did not differentiate between controlled and uncontrolled intersections (Chu, Guttenplan, and Kourtellis, 2007).

A Federal Highway Administration (FHWA) study published in 2005, however, did make this differentiation, looking only at uncontrolled crossings—2,000 of them in 30 U.S. cities within 17 states. It also differentiated by number of lanes, presence or lack of a raised median, average daily traffic (ADT), and posted speed. The study examined 5 years of pedestrian crash experience and developed exposure measures at 1,000 marked crosswalks along with 1,000 unmarked matched comparison sites. Statistical analysis indicated that posted speed limits did not significantly affect the prevalence of crashes, although 43 percent of crashes at posted speeds of 35 mph and above were fatal or involved serious injury, as compared to 23 percent at sites with lower posted speeds.

No difference in crash rates with and without crosswalk markings was found for two-lane streets. However, at crossings of the wider, busier arterials—generally those with ADTs over about 12,000 vehicles per day, or 15,000 in the case of roadways with raised medians—crash rates were found to be several times higher in the presence of plain marked crosswalks than without them. Midblock crossings were included in the analysis, and seemed to adhere to the same overall crash experience patterns (Zegeer et al., 2005, Chu, Guttenplan, and Kourtellis, 2007). Results are summarized in Table 16-118.

Table 16-118 Marked Crosswalk Versus Unmarked Crosswalk Crash Rate Comparisons

Roadway Type	Number of Lanes	Average Daily Traffic	Crosswalk Crash Rate		Significant Difference	Number of Sites
			Marked	Unmarked		
No Median	2	All	0.12	0.12	No	914
No Raised Median	3-8	≤ 12,000	0.17	0.25	No	260
No Raised Median	3-8	12,000 - 15,000	0.63	0.15	Yes	149
No Raised Median	3-8	> 15,000	1.37	0.28	Yes	417
Raised Median	3-8	≤ 15,000	0.17	0	No	87
Raised Median	3-8	> 15,000	0.74	0.17	Yes	173

Note: Crash rates are given in units of vehicle-pedestrian crashes per million pedestrian crossings.

Source: Zegeer et al. (2005).

Effects of crosswalks per se on crash severity that were isolated in the 2000-crossings study were not statistically significant, but there appeared to be more fatal and serious injury crashes in marked as compared to unmarked crosswalks on multilane roadways. This may be related to the greater tendency of elderly persons to choose marked crossings over unmarked crossings, noted in the "Street Crossings" subsection cross-referenced above (Zegeer et al., 2005, Chu, Guttenplan, and Kourtellis, 2007). On the other hand, one Florida study of midblock crosswalk crashes under conditions of darkness identified lesser severity for those crashes occurring in marked crosswalks (Chu, Guttenplan, and Kourtellis, 2007).

Among the various uncertainties surrounding these research findings is the question of what causes the observed crash rate relationships. At first it was hypothesized that the cause is a false sense of security on the part of crosswalk users. Subsequent observational studies of pedestrian "looking behavior" when crossing two- and three-lane streets found that pedestrians in marked crosswalks had as good or better crossing behavior than those in unmarked crosswalks. More recently, in a paired-crosswalk study of six locations, multiple factors have become evident. The studied sites were all in San Francisco, Oakland, or Berkeley; one was two-lane, one was three-lane, and the others involved four-or-more lane roadways. At the two sites where looking behavior differences were significant, both multi-lane locations, pedestrians using the unmarked crosswalk looked both ways more than those using the marked crosswalk. Pedestrians using the unmarked crossings were more likely to run (significant at four locations), and waited for longer gaps in traffic (significant at five locations). Prompt yielding of right-of-way by vehicles was more prevalent at marked crosswalks (significant at all six locations), yet average pedestrian exposure to vehicles was also higher in the marked crosswalks (significant at five locations).

The observation deemed most critical, statistically significant at three of the four sites with four-or-more lanes, involved incidence of multiple threats. In this scenario the approaching vehicle in the lane nearest to the pedestrian yields and a vehicle traveling in the same direction in the next lane over, the view of which is now obstructed by the yielding vehicle, does not. The occurrence of multiple threats was higher with the marked crosswalks than with the unmarked crosswalks at these three sites and showed a similar trend at the other four-or-more lanes site as well. Thus four-or-more lane marked crossing users not only exhibited ordinary caution as compared to the extraordinary caution of unmarked crossing users, they were also exposed by the higher yielding behavior (the legal response) to more multiple-threat situations. Multiple-threat scenarios produce the most common type of vehicle-pedestrian crash at uncontrolled intersections (Mitman, Ragland, and Zegeer, 2008).

In the context of this marked-crosswalk dilemma, it has been observed that "doing nothing for established [pedestrian] demand is not sound public policy" (Chu, Guttenplan, and Kourtellis, 2007). Noting that many U.S. agencies "have elected to remove marked crosswalks at uncontrolled intersections or have shown resistance to installing them in the first place," it has been advised that "[s]uch an approach does not address the safety and mobility needs of pedestrians" (Mitman, Ragland, and Zegeer, 2008). Cutting back on attractive street crossing opportunities certainly detracts from built environment ingredients found important in this chapter to encouragement of all forms of active transportation.

Engineering response has been placed on modifying traffic signal warrants for more emphasis on pedestrian needs and augmenting crosswalks on busy arterials at uncontrolled locations with additional treatments. These treatments range from geometric features such as median refuge islands to "active when present" traffic control devices/beacons (Fitzpatrick et al., 2006). Surveys and focus groups have identified substantial motorist and pedestrian confusion concerning pedestrian right-of-way laws, a confusion that is worse in the case of unmarked crosswalks. Recommended education and enforcement countermeasures have included signage to encourage careful looking behavior, improved state driver license testing and driver manual coverage of pedestrian right-of-way law, and enforcement designed to educate, such as highly publicized "stings" (Mitman, Ragland, and Zegeer, 2008).

Transit Access Safety. Transit passengers are almost inevitably pedestrians for some part of their trip. Access points for transit, such as bus stops or rail stations, are typically areas with higher levels of pedestrian activity than other locations. Further, the nature of bus service normally requires each passenger to make at least two street crossings as part of every round trip. Street crossings also can be more dangerous at bus stops than at other intersections, as stopped buses can impede sight lines. Boarding and alighting passengers may try to cross at a point without a crosswalk, particularly if they are about to miss the bus. The majority of transit passenger pedestrian crashes and fatalities occur at locations without pedestrian signals, either at an intersection or a mid-block location. The nature of streets on which transit is typically operated, characteristics of transit service and vehicles, the increased level of pedestrian activity at transit stops, and the high use of transit by recent immigrants unfamiliar with U.S. traffic norms, all contribute to high pedestrian crash rates near transit access points (Burnier, 2005, Nabors, et al., 2008).

Pedestrian crashes while accessing transit may not be a significant factor in travel decisions,[74] but they are increasingly recognized as a major safety concern. The effect of transit service and transit stops on pedestrian safety has been studied, but reliable and complete data about pedestrian crashes is difficult to assemble. Several studies have shown that vehicle-pedestrian crashes are more likely to take place in areas with high levels of transit service. In a study of crashes in Baltimore, 78 percent of pedestrian crashes were found to have occurred in areas with high transit accessibility (Burnier, 2005). This observation reflects both the increase in pedestrian activity and the increased risk in these areas. *TCRP Report 125: Guidebook for Mitigating Fixed-Route Bus-and-Pedestrian Collisions,* made further strides in determining the hazards to pedestrians accessing transit by categorizing reports of collisions involving interaction of pedestrians and buses according to "bus action." The study found that 34 percent of

[74] While transit-related pedestrian crashes may be "below the radar" for individual adult travel decisions, the potential danger for children has certainly been a factor in the choice to maintain or introduce separate yellow school bus transportation systems in preference to use and adjustment of local public transit services for school access.

the crashes reviewed occurred while the bus was turning and 25 percent occurred when the bus was at or near a stop. Both the data and the perception by transit agency staff underscore the importance of safe crossings for pedestrians accessing transit and of addressing pedestrian safety during bus turning maneuvers (Pecheux et al., 2008).

Safety in Numbers. At least six published analyses of crash statistics have developed empirical evidence that *rates* of collisions between pedestrians or cyclists and motor vehicles are lower in areas with higher amounts of non-motorized travel. The findings do not imply that the absolute number of crashes would be lower, although that has been observed in one reported instance. The "safety in numbers" pattern seems to hold across countries, states, cities, and specific intersections, and across time periods. An explanation offered is that motorists apparently drive more cautiously when greater numbers of walkers and cyclists are in evidence (Jacobsen, 2003, Victoria Transport Policy Institute, 2007, Alliance for Biking & Walking, 2010). A corollary deduction may be drawn "that shifts from driving to nonmotorized modes can reduce total per capita crash risk." (Victoria Transport Policy Institute, 2007).

Some caution is required in drawing conclusions from analyses such as these, insofar as environmental factors that support increased walking and cycling may also contribute to increased safety, introducing questions of causality (Thunderhead Alliance, 2007). Conclusions may also be affected by the apparent exclusion from some or all of the safety calculations, for lack of complete data, of pedestrian and bicyclist crashes not involving motor vehicles—such as falls and fixed-object crashes.

Two of the studies estimated mathematical relationships, which proved similar, between NMT vehicle crashes and various measures of non-motorized travel activity. Both aggregate cross-sectional data and time series data were employed. For all cases except those involving time-series data, results converged around a relationship indicating that crash totals increase with the 0.4 power of the measure of pedestrian or bicyclist activity.[75] Again excepting the time-series data, the values obtained in the two studies ranged from 0.13 to 0.67 for the exponent across nine sets of circumstances, four involving walking and five involving bicycling. Individual aggregate values were computed for a dataset of 68 California cities; a dataset of 47 Danish towns; Hamilton, Ontario, Canada; Gothenburg, Sweden; and datasets of eight to 14 European countries. All showed NMT crash rates to be less in the presence of more walking or bicycling activity, with diminishing numbers of additional NMT crashes associated with incrementally higher active transportation volumes.

The time series data results, from the United Kingdom and the Netherlands, and all pertaining to bicycling, were more varied. Overall, however, they supported the inverse relationship between crash rates and walking or bicycling activity. Data from the Netherlands actually showed a decrease in absolute numbers of fatalities with increasing cycling (Jacobsen, 2003). The time-series observations may well have been more subject to exogenous factors such as global shifts in traffic conditions and safety programming.

[75] A power (exponent) of less than 1.0 indicates that the increase in injuries is less than a 1:1 linear relationship with non-motorized travel activity—an inverse relationship between the crash rate and the measure of walking or cycling. An exponent of 0.4 indicates, for example, that a community with twice as much walking can expect to have just 32 percent more total injuries. Taking into account the amount of non-motorized activity, an individual pedestrian's risk in the example city with twice as much walking would be 66 percent of the risk of an individual pedestrian in the city with less walking (Jacobsen, 2003).

Public Health Issues and Relationships

Health is defined by the World Health Organization as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." Health is enhanced by physical activity directly and also indirectly through avoidance of excess body weight associated with inactivity. Inadequate physical activity is one of four primary risk factors for obesity, along with poor nutrition, caloric intake in excess of calories expended, and genetic predisposition. Transportation infrastructure and land use arrangements, especially the provision or lack of elements supportive of non-motorized travel, affect an individual's options for physical activity. Consequently, "Health should be an important consideration in transportation decisions" (Dannenberg, 2004 and 2005).

Some idea of the separate albeit related dangers of excess weight and inactivity may be garnered from the World Health Organization estimate that 2.8 million deaths worldwide annually result from overweight and obesity whereas "physical inactivity is (separately) responsible for an additional 3.2 million deaths" (de Nazelle et al., 2011). Each year an estimated 200,000 to 300,000 premature deaths occur in the United States as a result of physical inactivity (Heath et al., 2006). Persons who are capable of exercise yet participate in no leisure time physical activity exhibit a mortality hazard ratio of 1.6 over an average of 4 years of follow-up. This hazard ratio value is estimated relative to reporting *any* leisure time physical activity (hazard ratio of 1.0) in the 1997–2000 National Health Interview Surveys (NHIS). It is adjusted for sociodemographic variables, health behaviors, chronic diseases, and serious psychological distress (Pratt, 2009).[76]

Earlier analysis with the 1987 NHIS found direct medical costs to be higher for inactive persons whether they were grouped by smokers or non-smokers, presence or lack of physical limitations, or gender. When stratified by gender and age, the only categories where active individuals had higher direct medical expenses than corresponding sedentary persons were adolescent/young-adult males (age 15–24) and elder males (age 75 and older). U.S. annual direct medical costs resulting from lack of adequate physical activity were estimated in the same study at $330 to $1,053 in 1987 dollars per able person age 15 and above per year. On the basis of the lower $330 figure, this equated to $76.6 billion annually in 2000 dollars (Pratt, Macera, and Wang, 2000). This estimate is given further context in the subsection on "Economic and Equity Impacts" to follow.

The Surgeon General in 1996 recommended 30 minutes or more of at least moderate physical activity daily for adults. The standard has more recently been refined by the U.S. Department of Health and Human Services (HHS) into minimum recommendations for able adults of 150 minutes a week of moderate-intensity or 75 minutes a week of vigorous-intensity physical activity, preferably spread throughout the week. Suitable activity lasting at least 10 minutes at a stretch counts toward the minimum. The recommendation for children and adolescents is at least 60 minutes of activity daily. Brisk walking is a common standard for moderate physical activity. A walking speed of 3 to

[76] Leisure time activity is not the ideal measure for use in the context of walking and cycling, which can be for utilitarian purposes as well as leisure, but the leisure time emphasis is imposed by the design of the NHIS. The NHIS offers the advantage of a nationally representative sample of non-institutionalized U.S. adults that is large enough to allow segregating out persons incapable of physical activity. (Such persons have an estimated hazard ratio of 2.3 or greater [Pratt, 2009].) A hazard ratio may be thought of as an expression of relative probability. A hazard ratio of 1.6 in the context given suggests that an exercise-capable adult who engages in no leisure time physical activity is 60 percent more likely to die at any given time than someone of similar age, sex, and circumstances who engages in any such activity.

4 mph (15 to 20 minutes per mile) qualifies. Bicycling qualifies, with health benefits far exceeding risks from traffic injuries. Walking or cycling as part of a daily commute or for any utilitarian purpose counts as much as leisure activity (Besser and Dannenberg, 2005, Committee on Physical Activity, Health, Transportation, and Land Use, 2005, Department of Health and Human Services, 2008, Pucher, Dill, and Handy, 2010, de Nazelle et al., 2011).[77]

Examination of relationships between the built environment on the one hand and physical activity, obesity, and health on the other is a relatively new field of research. The causal link is well established between physical activity and health. It is the connection between the built environment and adequate physical activity that is less well understood. Features of the built environment that can play a role in increasing physical activity range from public parks and readily accessible gymnastic facilities to pedestrian and bicycle facilities and access to public transportation (Committee on Physical Activity, Health, Transportation, and Land Use, 2005, Besser and Dannenberg, 2005).

Baseline Walking and Bicycling Activity

CDC analysis of the Behavioral Risk Factor Surveillance System (BRFSS) national survey for 2001 found 45 percent of the U.S. adult population to be meeting the recommended physical activity guidelines, with 26 percent of adults deemed inactive. Corresponding findings for 9th to 12th grade adolescents were 69 percent meeting guidelines and 10 percent inactive. There is preliminary indication of a moderate upward trend. BRFSS data for 2009 indicate 49 percent of adults to be meeting minimum guidelines. The BRFSS surveys have shown walking to be a dominant form of physical activity, but activity definition changes have prevented drawing a more definitive conclusions (Committee on Physical Activity, Health, Transportation, and Land Use, 2005, Centers for Disease Control and Prevention, 2011).

The Nonmotorized Transportation Pilot Program Evaluation Study performed a 2006–2007 baseline "before" analysis, covering the five pilot program communities. It affords an indicator of how much present day walking and bicycling activity alone contributes to meeting the Surgeon General's recommendations. A word of caution is, however, in order. The activity comparison drawn upon here was presented by the Pilot Program researchers as a demonstration of survey results reasonableness. Using the analysis to draw activity contribution conclusions is almost certainly not an originally intended use of the data.

Pilot Program findings were drawn from a five-area self-administered survey of adults that obtained a 15 percent response rate, with 34 percent of eligible respondents completing a follow-up interview or web survey. Elaborate sample weighting procedures keyed to the U.S. Census were applied to compensate for follow-up survey respondent differences relative to year 2000 community demographics and also overrepresentation of non-auto commuters, bicyclists in particular. The sample weights served to expand the results to the five study-area populations. The number of final weighted samples totaled just under 1,380 overall (Krizek et al., 2007).

Residents of the city of Minneapolis and surveyed portions of Marin County, California, were found overall to engage in walking and cycling at greater frequencies and for longer durations than

[77] These recommendations derive from findings that these minimum degrees of physical activity are associated with substantial health benefits, but should not be taken to imply either that more is not better or that less is useless. Various non-transportation physical activities also qualify (Physical Activity Guidelines Advisory Committee, 2008).

in the city of Columbia, Missouri; Sheboygan County, Wisconsin; and Spokane County, Washington. Combined 2006–2007 walking/cycling frequency and duration results for the five communities are provided in Table 16-119. Also provided is roughly parallel national moderate and vigorous activity information from BRFSS public data files. The questions used by the two surveys were similarly structured, although one deals with walking and cycling while the other addresses all forms of moderate and vigorous exercise. The pilot study results are from the weighted samples described above, while the BRFSS results are taken from very large numbers of unweighted samples (Krizek et al., 2007).

Table 16-119 Pilot Program Five-Community NMT Activity with National BRFSS Physical Activity Comparison

	Five-Community Pilot Project		National BRFSS	
	Walk	Bike	Moderate	Vigorous
Days per week engaging in activity for at least 10 consecutive minutes				
0 days	16.5%	80.1%	18.5%	58.4%
1 day	3.7%	3.8%	3.3%	7.1%
2 days	8.3%	4.5%	8.5%	9.0%
3 days	16.5%	5.7%	16.4%	11.0%
4 days	9.1%	2.0%	10.2%	4.8%
5 days	17.4%	2.6%	13.4%	4.7%
6 days	5.5%	0.3%	4.6%	1.5%
7 days	23.0%	1.0%	25.1%	3.5%
Minutes of activity per day on days with at least 10 consecutive minutes of activity				
0 to 9 minutes	18.0%	80.7%	19.1%	58.8%
10 to 29 minutes	19.4%	2.8%	16.6%	6.6%
30 to 59 minutes	32.8%	6.3%	29.7%	14.2%
1 hour or more	29.9%	10.3%	34.6%	20.4%

Source: Krizek et al. (2007).

From Table 16-119 it may be inferred, accepting various simplifying assumptions, that probably some 30 percent of the five-community adult population was fully meeting the HHS minimum physical activity recommendation by either walking or bicycling. In addition, the tabulation suggests that for more than five out of six of the surveyed population, walking or cycling made at least some contribution toward the activity recommendation. It may be similarly inferred from Table 16-119 that the *average* qualifying walk/bike activity contribution for the five-community adult population slightly exceeded 1/2 of the 150-minute weekly minimum physical activity recommendation. One rough estimate of the relative contribution of walking versus bicycling suggests that walking may make up as much as 96 to 98 percent of the active transportation contribution to qualifying physical exercise.[78]

[78] The Nonmotorized Transportation Pilot Program Evaluation Study researchers make no assertion that the five-community data represents the universe of travel activity in the United States. The four Pilot Program communities were selected by act of the U.S. Congress, which in itself suggests at least some proactivity in the communities' approach to walking and bicycling. The control community, Spokane, was selected to be as representative as possible of the other four Pilot Program communities but without a notably proactive program of NMT facility improvements or programs (Krizek et al., 2007, Federal Highway Administration, 2007). National sources tend to show substantially higher percentages of persons not walking in the preceding week (35 percent in the 2001 NHTS) or month. (See the "Extent of Walking and Bicycling" subsection also under "Related Information and Impacts.") Note that the analytical assessments in this paragraph are by and fully the responsibility of the Handbook authors.

More narrowly focused research, carried out by the CDC, has determined that 29 percent of public transit users achieve the recommended 30 minutes or more of physical activity a day simply by walking to and from their transit service. This research employed a rigorous examination of the previously described 2001 NHTS travel data for all trip purposes, focusing on adults. On the other hand, the 2001 NHTS also indicates that only 3 percent of all U.S. adults undertake travel via the walk/transit mode on any given day (Besser and Dannenberg, 2005). This suggests that just under 1 percent of the U.S. population presently meets or exceeds the recommended physical activity levels solely by virtue of the walking connected with public transit use.

A related question of interest is the proportion of all health-benefit-qualifying exercise that comes from active transportation. The one dataset found that comes close to addressing this question is from five Pacific Northwest cities of various sizes (see Table 16-124). In this dataset, compared to a total composed of active transportation and sports exercise, the transportation component ranged from 37 to 72 percent, averaging 59 percent (Socialdata, 2008). When including other forms of qualifying exercise in the total, such as certain activities of gardening, the transportation proportion would be somewhat reduced. A "typical" urban area range of 50 to 70 percent for the active transportation exercise component of total exercise seems reasonable, and appears to conform with data presented above in Table 16-119.

Health Benefits for Adults of Enhanced NMT Systems and Policies

Physical activity has been clearly shown to have a causal and positive relationship with good adult public health. The Surgeon General's report of 1996 reported "an inverse association between physical activity and several diseases that is 'moderate in magnitude, consistent across studies that differed substantially in methods and populations, and biologically plausible' " (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). The HSS document "2008 Physical Activity Guidelines for Americans" lists the health benefits now shown to be associated with physical activity, with evidence ratings of "strong," "moderate to strong," and "moderate." A Physical Activity Guidelines Advisory Committee developed the list and ratings taking into account "dose response" (benefit per given amount of exercise) and evidence of causality (Department of Health and Human Services, 2008, Physical Activity Guidelines Advisory Committee, 2008). Table 16-120 consolidates this listing and includes the HHS findings for children and adolescents. Health benefits for children are further examined following this discussion of adult benefits.

Confirmatory research also demonstrates that endurance-type physical activity, with walking and bicycling as key examples, "reduces the risk of developing obesity, osteoporosis, and depression" and "may improve psychological well-being and quality of life." A regimen of brisk walking has explicitly been associated—in public health research—with lower risk of both all-cause mortality and cardiovascular disease, especially in women, as well as lesser Type 2 diabetes, increased cardiovascular fitness, and other health benefits (Committee on Physical Activity, Health, Transportation, and Land Use, 2005, Physical Activity Guidelines Advisory Committee, 2008).

Table 16-120 Health Benefits Found to be Associated with Regular Physical Activity

Adults and Older Adults	Children and Adolescents
Lower risk of early death (S)	
Lower risk of coronary heart disease (S), stroke (S), high blood pressure (S), and adverse blood lipid profile (S)	Improved cardiovascular biomarkers (S)
Lower risk of Type 2 diabetes (S) and metabolic syndrome (S), and reduced abdominal obesity (M/S)	Improved metabolic health biomarkers (S)
Lower risk of colon cancer (S), breast cancer (S), lung cancer (M), and endometrial (uterine) cancer (M)	Improved cardiorespiratory fitness (S)
Improved cardiorespiratory and muscular fitness (S)	Improved muscular fitness (S)
Prevention of weight gain (S), weight loss, especially when combined with fewer calories (S), and weight maintenance after weight loss (M)	Favorable body composition (S)
Reduced depression (S), improved sleep quality (M), and — for older adults — better cognitive function (S)	Reduced symptoms of depression (M)
Increased bone density (M) and lower risk of hip fracture (M)	Improved bone health (S)
Prevention of falls (S) and — for older adults — better functional health (M/S)	

Note: (S) = strong evidence, (M/S) = moderate to strong evidence, (M) = moderate evidence.

Source: Department of Health and Human Services (2008).

Physical inactivity and excessive caloric intake are the key contributors to the energy imbalance associated with obesity, a critical public health problem (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). Almost 1/3 of U.S. adult males were obese in 2007–2008 (32.2 percent), and over 1/3 of adult females were (35.5 percent).[79] In contrast, 1976–1980 statistics show 1/8 of males (12.5 percent) and 1/6 of females (16.4 percent) as being obese. That represents almost a tripling in adult obesity for males, and over a doubling for females. The only bright spot, if one can call it that, is that obesity increases for women between 1999–2000 and 2007–2008 were not statistically significant, suggesting stabilization. Although obesity definitely continued increasing for men, it may have stabilized over the latter three years (Flegal et al., 2010).[80]

[79] Body mass index (BMI) is used to define obesity and overweight in large-scale public health studies and epidemiological analyses. BMI is a simplified proxy for percentage of body fat based solely on weight and height. In Metric units, BMI is equal to weight in kilograms divided by the square of height in meters. (In customary units, the weight in pounds must be multiplied by 703 before dividing by the square of height in inches.) A BMI of between 18.5 and 25 is judged to approximate normal weight; 25 to 30, overweight; and above 30, obesity (World Health Organization, 2011).

[80] The emphasis here is deliberately on obesity rather than overweight and obesity. Studies agree on the adverse effect of obesity on life expectancy and health, though the mortality effect has decreased perhaps 20 percent in recent years, presumably in response to improved medical care. A major work drawing on three rounds of National Health and Nutrition Examination Surveys using normal weight as the reference category has found no excess deaths associated with non-obese overweight. Indeed, the estimated excess deaths for the overweight category were negative. It should be noted that there may be health (morbidity) and quality of life disadvantages of overweight that are not reflected in mortality (Flegal et al., 2005). In any case, the predominant weight-related public health problem is obesity, thus the focus on that category.

Adult Physical Health and Activity Relationships. Three studies highlighting the inverse relationship between active transportation and physical disease are summarized in Table 16-121. Although none of these aggregate-data analyses were structured to prove causality, the presumed relationships stand out clearly. The first-listed study related nation-level active transportation mode shares (including transit) with obesity rates. It found the lowest active transportation shares and the highest obesity rates to be in the United States, and estimated inverse relationships across countries that apparently explained more than 3/4 of all variation. Measured body mass index (BMI) ranged from 34 percent obesity in the United States (12 percent active transportation) to 11 percent obesity in the Netherlands (52 percent active transportation) (Bassett et al., 2008).

A subsequent reworking of this same international data, but focusing on walking and cycling alone, found the same general relationships, although the proportions of variation explained were lower. Pearson correlations of r=–0.54 and r=–0.20 were obtained for self-reported and measured BMI, respectively (Pucher et al., 2010). One may speculate that the loss in explanatory power is to some degree related to not having—in the revised analysis—the effect of transit use, with its associated walking for access.

The 2nd study in Table 16-121, as already discussed, repeated the international analysis of the 1st study without inclusion of transit mode shares. It then extended the analysis to U.S. states and cities, on the basis of commute trips instead of all trips, with the results shown in the table. The city-level results were less robust than the state-level results, possibly in part because the health and travel data were collected using different area definitions, All results were, however, statistically significant except when using measured BMI data at the international level. (The international measured-BMI dataset, in contrast to the self-reported-BMI dataset, was quite limited in size.) The study demonstrated that whether measured on the basis of countries, the 50 states, or the 47 largest U.S. cities, exercise and health are related to walking and bicycling prevalence in the expected manner: the more walking and bicycling, the more physical activity, and the less disease (Pucher et al., 2010).

Table 16-121 Illustrative Examples of Aggregate Studies Relating Active Transportation to Physical Health at the National and State Level

Study (Date)	Process (Limitations)	Key Findings
1. Bassett et al. (2008)	Aggregate, national-level, cross-sectional analysis of obesity rates as they relate to active transportation mode shares (walk, bike, transit) in Australia, No. America, and Europe. Shares cited here are for all purposes of travel. (Raw and published data sources, some work-only shares, no exogenous-factor controls.)	Active transportation shares ranged upward from 9% walk, 1% bike, and 2% transit in the U.S. (34% measured national obesity) to 30% walk, 5% bike, and 32% transit in Latvia (14% obesity). The inverse active transportation vs. obesity relationship had a Pearson correlation of r=-0.86 for self-reported and r=-0.76 for measured BMI.
2. Pucher et al. (2010)	Aggregate state- and city-level, cross-sectional analysis of exercise sufficiency, obesity, and diabetes rates as they relate to percentages of commuters walking and bicycling, utilizing 2007 ACS and BRFSS data. (No controls, city-level ACS/BRFSS area coverage mismatches.)	Positive relationships were established between walk/bike share and activity sufficiency, paired with negative relationships for obesity and diabetes. Pearson correlations, state and city, respectively, of r=-0.59 and r=-0.14 for activity, r=-0.31 and r=-0.28 for obesity, and r=-0.55 and r=-0.22 for diabetes.
3. Alliance for Biking & Walking (2010)	U.S. "Benchmarking Project" state-level, cross-sectional analysis of hypertension and diabetes as they relate to walk- and bicycle-to-work rates. Hypertension correlation r=-0.54; diabetes correlation r=-0.66. (No controls. None of these three studies demonstrate causality.)	Inverse disease vs. active transportation relationship running from a 9% walk/bike commute share in Alaska, with 6% of residents ever told they had diabetes, and 25% ever told they had high blood pressure; to a 1% walk/bike commute share, 10% diabetes rate, and 33% hypertension rate in Alabama.

Note: In the 3rd entry, the walk/bike commute shares shown are the highest and lowest, but the full range across states for diabetes is 5% to 12%, and for hypertension is 20% to 34%.

Sources: As indicated in the first column.

The 3rd study, a 2010 "Benchmarking Project" covering U.S. bicycling and walking, related levels of walking and cycling to work with rates of high blood pressure and diabetes at the state level. It, too, used 2007 ACS and BRFSS data and found negative disease relationships. It confirmed a strong positive correlation across states between walk/bike-to-work rates and percent of adults with 30 or more minutes of daily physical activity, and a negative correlation with percent of adults who were obese. The correlations for the exercise and obesity relationships were r=0.72 and r=0.45, respectively (Alliance for Biking & Walking, 2010). As can be seen, the state-level analyses of the 2nd- and 3rd-listed studies support each other, but with somewhat different reportings of statistical strength of the relationships.

Adult Mental Health and Activity Relationships. The mental health component of public health was for a long time less well studied in terms of how it is affected by exercise, although HHS guidelines now give the relationship a "strong evidence" ranking for adults (Table 16-120). A number of studies do tend to support a relationship similar to that for other types of illnesses (Heath et al., 2006, Department of Health and Human Services, 2008). The first two study examples presented in Table 16-122 link reduction in risk of dementia to greater amounts of exercise. The 1st-listed study, from Finland, used long-term follow-up data to confirm earlier findings that had been derived using relatively short follow-up times: findings that physical activity seems to promote lower risk of Alzheimer's disease and other dementias (Rovio et al., 2005). The 2nd study examined the linkage between exercise, specifically walking, and memory capability. It utilized a controlled experimental environment. Normal age-related decline in the anterior hippocampus of the brain, linked to spatial memory, was reversed for monitored walkers but not for study controls (Erickson et al., 2011).

The 3rd study in Table 16-122 brings the built environment into consideration in the context of supporting mental health. It specifically links neighborhood walkability with reduced rates of depression in the case of elderly males in the Seattle area (Berke et al., 2007a). The 4th study listed serves as a reminder that the mental health relationships with urban form remain less well established than for physical health. The original researchers found the lack of a demonstrable association between urban sprawl and depression, anxiety, and psychological well-being to be particularly surprising in view of the physical health relationships demonstrated and the frequent link between physical and mental problems. It is hypothesized that a smaller geography than the metropolitan-level used would offer a more refined analysis (Design, Community & Environment et al., 2006).

Adult Physical Health Effects of Non-Motorized Transportation Features. Essentially all studies obtained from the travel behavior literature on adult physical activity effects of enhanced NMT systems and policies, and a fair number from the physical activity literature, express their findings in some form of travel behavior metrics. Such studies have been examined under individual pedestrian and bicycle facility or program "Response by Type of NMT Strategy" subtopics. Some studies obtained from the physical activity literature describe their findings, however, solely or primarily in terms of physical exertion measures or health metrics. These are presented here in this subsection, in most cases only here, and are listed below in Table 16-123. They are also taken into account in the "Adult and Child Public Health Relationships Summary" immediately following the discussion pertaining to children.

Table 16-122 Examples of Studies Relating Physical Activity, Walkability, and Sprawl to Mental Health

Study (Date)	Process (Limitations)	Key Findings
1. Rovio et al. (2005)	Prospective analysis, with a 21-year-average follow-up, relating leisure-time physical activity to dementia and Alzheimer's disease (AD) at age 65-79 years, controlling for socio-economic, health, and health-habit factors. (Physical activity definition not specifically related to NMT.)	Mid-life physical activity was found negatively related to risk of dementia and AD. Finnish subjects engaging in such activity at least twice weekly had 50% lower odds of dementia and 60% lower odds of AD than more sedentary individuals. Relationships were significant for both men and women.
2. Erickson et al. (2011)	Randomized, controlled, single-blind study of healthy but sedentary subjects, ages 55 to 80. Half were brought up toward optimal heart-rate moderate walking for 40 min., 3 days per week. Half were controls assigned to stretching and muscle-toning. (Memory improvement differences, per se, not significant.)	After 1 year, hippocampal brain volume (HBV) declined by 1.4% for controls (normal aging) but increased by 2% for walkers. Walkers had 7 times the improvement of controls in maximum oxygen consumption. Tests correlated both participant HBV and aerobic fitness, before the trial and after, with spatial memory acuity.
3. Berke et al. (2007a)	Cross-sectional analysis of fine-grained walkability scores for King County, WA, and Adult Changes in Thought (ACT) data, including measures of depression, obtained in a prospective, longitudinal cohort study. (Walkability might be a proxy for confounding variables.)	Found, after controlling for various socio-economic and health status variables, a significant negative association between neighborhood walkability and symptoms of depression in older males (odds ratio approx. 0.32). (Negative relationship for females not statistically significant.)
4. Strum and Cohen – 2004, as summarized in Design, Community & Environment et al. (2006)	Aggregate, cross-sectional analysis of metropolitan-level urban sprawl index calculations relative to 16 chronic physical health conditions plus depression and anxiety. (Large geographic scale to attempt using for measurement of mental health.)	Higher sprawl (+1 standard deviation relative to -1) associated with 96 more chronic physical health problems per 1,000 population, but "no statistically significant or robust associations" with sprawl for mental health conditions after adjustment for other factors.

Sources: As indicated in the first column.

Table 16-123 Summary of Findings on Direct Relationships between the Non-Motorized Travel Environment and Measures of Adult Exercise and Health

Study (Date)	Process (Limitations)	Key Findings
1. Eleven studies focused on exercise opportunities, and/or quality of urban environment, summarized per SR 282 and not covered elsewhere in this subsection	U.S., European, Australian, and Canadian studies reported on in 1989-2001, mostly cross-sectional, relating level of exercise to physical environment and/or availability of exercise facilities close at hand. (Practically all availability measures and neighborhood environmental quality measures used in these particular studies were based on self-reported perceptions).	Physical activity was positively related to neighborhood opportunities for such activity in 3 studies, 1 of which found satisfaction with the neighborhood environment insignificant. In 1 study walking was positively related to neighborhood environment but not exercise facilities. Unmet desire to exercise was correlated with lacking or inadequate facilities in 1 study. No notable vigorous exercise relationships to neighborhood opportunities or characteristics were found in 2 studies that did find availability of home equipment to be significant, while 1 study found pay facilities important. Vigorous exercise or degree-of-exercise effects were not found significant in 3 studies, though 1 found more walking in Chicago than in rural areas.
2. Booth et al. – 2000, Brownson et al. – 2001, and Powell et al. – 2003, each as summarized per SR 282	Australian national, U.S. national, and Georgia state survey analyses. National studies controlled for socio-economic factors. (Perceived facility availability, self-reported exercise, no controls in GA study.)	Meeting recommendations for physical activity was significantly and positively related to conveniently located safe places to walk or exercise ranging from local sidewalks (or streets in GA) to parks, paths, treadmills, and gyms.
3. De Bourdeaudhuij et al. – 2003, Eyler et al. – 2003, and Wilcox et al. – 2000, each as summarized per SR 282	Ghent, Belgium, and two U.S. national women's survey analyses, focusing on effects of sidewalks, related factors (e.g., lighting), and environment/safety. Controlled for socio-economic factors. (Self-reported facilities and exercise.)	Sidewalks significantly related with more walking for some but not all gender/ethnic stratifications, with no significance at all in Wilcox study. A few other urban environment factors were found sometimes significant: no loose dogs, lighting, land use mix, etc.
4. Giles-Corti and Donovan (2003), and SR 282 (see "Sidewalks and Along-Street Walking" under "Response by Type of NMT Strategy" for related studies)	Cross-sectional analysis in Perth, with controls, relating walking sufficiency to individual characteristics (e.g., behavioral control), social environment (e.g., exercise partners), and objectively measured physical environment (e.g., shops, sidewalks, attractiveness). (Environment measures limited to resident's street; fairly well-off population.)	Only 17% met 12-walks, 360-minutes 2-week minimum standard. Those who added other exercise were found more likely to get a sufficient amount (78% of multiple exercisers). Individual, social-environment, and physical-environment factors had roughly equal effects on walking. Walking odds 47% higher with high vs. low access to open space, 25% higher with sidewalk and/or shops, 49% higher if area attractive.
5. Giles-Corti et al. (2003)	Parallel study to Perth research described above, but focusing on BMI. Assessed prevalence of both overweight and obesity vs. normal weight. (Self-reported height and weight, and perceived acceptable walk to store, and walk or auto access to paths.)	Living on highway strongly associated with overweight but not obesity. Odds of overweight/obesity were 32%/57% higher living on street with sidewalk on one side only and 40%/69% higher with no sidewalk as compared to dual sidewalks. Adequate shop/path access associated with normal weight.
6. Huston et al. (2003)	Cross-sectional analysis of effects on exercise of availability of places for activity including sidewalks in	Presence of trails and perceived general access to places for physical activity were the only factors found positively

Table 16-123 (Continued)

Study (Date)	Process (Limitations)	Key Findings
	6 North Carolina counties. (Limited list of places, all data self-reported.)	and significantly associated with achieving recommended activity levels.
7. Hennepin County (2005) (see also Tables 16-63 and 16-106 for seasonal usage and purpose of use distributions)	The Hennepin County summer of 2005 trail user survey obtained 3,127 user responses with an approach designed to obtain data only once from each intercepted user of 3 rail trails in/around Minneapolis. (No non-user or before-trail data or comparisons, relationship of moderate vs. vigorous users unclear.)	Trail users self-reported 4.8 days average of moderate physical activity, 3.0 of the days on the trail system; and 3.7 days of vigorous activity, 2.5 of the days on-trail. Among users, 61% met recommended exercise minimums through total moderate activity and 70% through total vigorous activity. When intercepted, 84% were bicycling.
8. Gordon, Zizzi, and Pauline (2004)	Analysis of a trail access intercept survey of users of two new rail trails in Morgantown, WV, totaling 12 mi. of paved surface. Of randomly approached users, 98% participated. Ten types of exercise were probed, with "regularity" defined as at least 3 times weekly for 20 min. (Study design did not provide assessment of impact on overall community.)	Of trail users, 22% were new exercisers and 78% were habitual. Increases in exercise following trail opening were found for 98% of new and 52% of habitual exercisers. Median increases overall were roughly 80% for new and 20% for habitual exercisers, with 25% overall becoming regular exercisers because of the trails, the only physical activity venue for 31% of new users.
9. Evenson, Herring, and Huston (2005)	Longitudinal analysis of a rail-trail extension in Durham, NC, using before and after (follow-up) surveys of residents living within 2 miles. (Before/after survey seasonal mismatches, no proximity analysis.)	Retrospective survey questions indicated an increase in physical activity but the primary longitudinal analysis did not support a finding of overall activity increase in this area already above average in sidewalks/trails.
10. Troped et al. (2001) (see text for cross-references)	Health, environment, and trail use survey of Arlington, MA, residents with cross-sectional analysis. (Did not report on direct relationships between trail proximity and exercise.)	Trail use declined with distance of residence from trail. Trail users exercised 60% more days/week than non-users (3.7 vs. 2.3 days), for nonsignificantly longer times (46 vs. 44 minutes).
11. Ewing et al. (2003), and Ewing, Brownson, and Berrigan (2006)	Nationwide cross-sectional analysis, relating U.S. BRFSS data to a sprawl index based on population density and block-size averages/distributions. In 2006, focused on young adult/adolescent BMIs, and added longitudinal analyses. (County-level aggregate-index application, longitudinal results lacked significance.)	In 2003 found, controlling for individual socio-demographics and behavior, small associations between sprawl and leisure walking (negative), and BMI, hypertension, diabetes, and heart disease (positive), statistically significant except for the last two. In 2006 obtained similar BMI results for young adults and adolescents.
12. Frank, Andresen, and Schmid (2004)	Atlanta region cross-sectional study of 10,878-participant travel survey with health questions. Used logistic regression with socio-demographic indicators, built environment variables, and calculated daily driving time and walking distance all in same formulation. (Little variety of land use forms in most of area, self-reported height and weight.)	Land use mix associated with a 12% obesity likelihood reduction. Lesser reductions for residential density and intersection density, mainly for whites. Inclusion of the physical activity variables moderately dampened the built environment effect estimates. Each km./day walked was associated with a 5% obesity likelihood reduction, vs. a 6% increase per daily hour of driving.
13. Rutt and Coleman (2005)	El Paso border community cross-sectional analysis of health survey results and objective environmental	Higher BMIs were associated with lesser reported amounts of moderate physical activity, *higher* socio-economic

(continued on next page)

Table 16-123 (Continued)

Study (Date)	Process (Limitations)	Key Findings
	data. Sample was predominantly semi-skilled, 79% Hispanic, moderately acculturated, and 71% female. (Unfamiliar modeled relationships encountered.)	status, poorer health (which caused barriers to physical activity), and *greater* land use mix. No significant relationship found with density or sidewalk availability.
14. Saelens et al. (2003), and SR 282	Cross-sectional analysis using survey and accelerometer results, with socio-economic controls, related 8-factor walkability scores to moderate and vigorous activity in two San Diego neighborhoods on the basis of exercise time per 7 days. (Small sample; 107 adults.)	Found significant moderate and total activity relationships, with high vs. low walkability moderate exercise of 195 vs. 131 min. respectively (210 vs. 140 min. for total exercise). Other measures with significance included walking for errands (30 vs. 15 min. unadjusted) and BMI (35% vs. 60% overweight).
15. King, et al. (2003)	Similar approach as Saelens et al. (above) but relating a neighborhood convenience score based on 20-min.-walk destination accessibility (14 possible destination types) to walking levels and physical activity of older women in southwest Pennsylvania. (Self-judged-and-reported walk times to destinations.)	Good utilitarian trip accessibility and perception of walkability linked to more physical activity. Greatest total activity differences (> +20%) were for accessibility to department, discount, or hardware store (+54%), food store (+37%), library (+26%), and walk/bike trail (+22%). An area's 2 most walkable destinations produced most of effect.
16. Berke, Koepsell, Moudon, Hoskins, and Larson (2007b) (see also "Ped… …cycle Friendly Neighborhoods")	Cross-sectional analysis of fine-grained walkability scores for King County, WA, and Adult Changes in Thought (ACT) cohort study data, including BMI and frequency of walking. (Extent of walking self-reported.)	Found, after controlling for various socio-economic and health status variables, a significant positive association between neighborhood walkability and walking, and a mostly negative albeit not significant asso–ciation between walkability and BMI.
17. Handy, Cao, and Mokhtarian (2007)	Northern California cross-sectional and quasi-longitudinal analysis of days with moderate or vigorous physical exercise, in the neighbor-hood, in the last 7 days, as related to built environment features, control-ling for pro-bike/walk attitudes, neighborhood preferences, and socio-demographics. Land use mix, distance to nearest health club, and a number of other measures were objectively measured; other neigh-borhood characteristics were as perceived by respondents. (Impre-cise, self-reported activity measure.)	Pro-bike/walk attitudes were signifi-cantly and positively associated with physical activity in the neighborhood, but neighborhood preferences (stand-ing in for "self-selection") were not. Socio-demographics and neighborhood characteristics were of roughly equal importance to each other and more important than the attitudes. The features significantly and positively related to exercise included land use mix; distance away from nearest health club; and perceived attractiveness, socializing, and activity options and stores within walking distance.
18. Lawrence Frank & Co., SACOG, and Mark Bradley Associates (2008)	Cross-sectional analysis of BMI and accelerometer-based activity, meas-ured in NIH Neighborhood Quality of Life Study (NQLS), in relation to plat-level land use within a 1-km. buffer; trip, person, and household sociodemographic data; network-based transportation system meas-ures; and traffic analysis zone (TAZ) regional auto/transit accessibilities. (NMT facilities not accounted for.)	Greater physical activity (PA) related to more children, more workers, fewer cars/adult. Lower BMI and greater PA both related to higher residential density, higher intersection density (system connectivity), and presence of a park within 1 km. Lower BMI also related to better transit accessibility. Denser retail associated with more PA, but food outlets within walking dis-tance linked to slightly higher BMI.

Table 16-123 (Continued)

Study (Date)	Process (Limitations)	Key Findings
19. Besser and Dannenberg (2005) (see also "User Factors" under "Underlying Traveler Response Factors")	Descriptive statistics were calculated from the 2001 National Household Travel Survey covering the walking activity involved in accessing U.S. public transit. Predictors were estimated for achieving in this way the recommended 30 min. or more of daily physical activity. (Trips with 2nd access mode, 5%, excluded.)	During their reported-on travel day, 3.1% of respondents walked to/from transit, averaging 19 minutes total walk time, reaching recommended activity levels for 29% of transit walkers. The highest odds for being transit walkers were found among lower income, less educated, and non-white populations, and in denser urban areas.
20. CDC – 1999 as summarized per SR 282	Related perceptions of neighborhood safety from crime (4-point scale) to reported physical activity. (Self-reported measures.)	Proportions of persons found active on the basis of walking, moderate activity, and vigorous activity were positively related to perceived safety from crime.
21. Matthews, Jurj, and Shu – 2007, Andersen et al. – 2000, and Evaluering af Odense, Danmarks Nationale Cykelby – 2010, each as summarized per Pucher et al. (2010) and also (1st two only) de Nazelle et al. (2011)	Prospective longitudinal health studies in China and Denmark followed Shanghai women (5.7 years average) who exercised or cycled for transportation and Danish men and women who cycled to work along with other physical activity. Odense, Denmark, reported health outcomes over time of a multi-faceted bicycling demonstration project. (Few details, no reporting on system changes in 1st two studies.)	The Shanghai women who exercised or cycled for transportation had a 25% to 35% lower all-cause mortality risk. Cycling to work reduced premature mortality risk by 1/3 to 2/5 in Denmark. In Odense, a 20% 1996 to 2002 increase in cycling levels paralleled a 5-month life expectancy increase for males. Odense has worldwide recognition for proactive bicycling policies and programs, 500 km. of cycling routes for a population of 186,000, and a 25% bike mode share for utilitarian trips. [a]
22. Socialdata (2008), Horst and Brög (2010) (see also the case study, "Variations on Individualized Marketing in the North West United States")	"Before" and "after" surveys of an individualized-marketing target population in Bellingham, WA, provided the opportunity to calculate person minutes and hours of active transportation, inclusive of transit access, from trip diary data. The large samples reflected 76% and 78% survey response rates. The "before" survey included a "sports hours/year" question. (No "after"-survey sports activity investigation.)	Bellingham residents of all ages were in 2007 obtaining 175 hours/year of physical activity on average (relative to the 130 hours/year annual equivalent of the HHS baseline exercise recommendation), 119 hours (68%) via active transportation and 56 hours (32%) from sports. In the individualized-marketing target area, 122 hours/year average of active transportation before the 2008 marketing project increased to 153 hours in 2009, up 25%, going from 94% to 118% of the HHS physical activity standard.

Notes: Where substantial additional information on individual studies is provided in text and tables or figures, this is noted — and the location within the chapter is given — in the first column.

[a] The Odense bicycling policy, program, and mode share information is from the "Cycle City Odense" webpages (Cycle City Odense, 2011).

Sources: As indicated in the first column. The notation "SR 282" is shorthand for Committee on Physical Activity, Health, Transportation, and Land Use (2005) together with Handy (2004).

Those of the studies in Table 16-123 that went beyond walking sufficiency to seek relationships with overall exercise sufficiency, and particularly with body weight and health, faced two layers of analytical burden. Not only were they subject to confounding exogenous transportation and physical environment factors, they were also exposed to additional socio-economic and cultural factors. These range from attitudes toward exercise to dietary implications of ethnicity. All such considerations reduce the likelihood of establishing statistically significant relationships from even the most seemingly obvious patterns.

The 1st entry in Table 16-123 looks beyond the basic scope of this chapter to examine 11 studies focused primarily on activity impacts of access to facilities for exercise, a traditional area of public health research. Roughly 1/2 of these studies found significant relationships between level of exercise and perceived availability of neighborhood facilities, setting what might be regarded as a baseline standard for degree of success in establishing associations.

The next four table entries cover eight studies that included assessing effects of having sidewalks. Six out of seven of these research efforts found positive effects on walking sufficiency or exercise to be associated with presence of sidewalks, although not necessarily for all social/ethnic groups. The 8th study (5th Table 16-123 entry) managed to quantify a substantial relationship between objectively-measured lack of sidewalks and both overweight and obesity, finding two sidewalks to be better than one, and either to be preferable to none.

Four of these same eight studies also lend some support to the usefulness for promoting exercise of having walking or bicycling paths available within reasonable access. In addition, of the next five table entries (6th through 10th), one provides data implying a strong positive relationship between shared use trail presence and physical activity, one finds roughly 2/3 of trail users meeting physical exercise recommendations (likely above the norm even for the Minnesota location), two provide explicit evidence of the contribution of paths to increases in exercise, and one fails to find a relationship to exercise levels. The 3rd of these studies (8th Table 16-123 entry) provides evidence that paths may be particularly useful for attracting to exercise persons who were previously largely sedentary. New exercisers were found to choose the trail-use modes with least apparent risk, primarily walking, and nearly 1/3 were totally dependent on trail use for all of their exercise (Gordon, Zizzi, and Pauline, 2004).

The 4th of this group, the one that found no evidence of trail impact on exercise (9th Table 16-123 entry), employs the "gold standard" of a prospective study, but mainly serves to illustrate how difficult this can be when dealing with quasi-experimental designs. For example, trail construction was delayed but study deadlines were not, so the "after" survey was only 2 months after trail opening instead of the planned 1 year (Evenson, Herring, and Huston, 2005). The 5th study of this group (10th table entry) is perhaps out of place, as its outcome measure was trail use, but it does present implicit evidence of apparently strong positive trail impact on exercise levels. More detail on this Arlington, Massachusetts, study and its findings on trail access effects was presented in the "Response by Type of NMT Strategy" section under "Street Crossings" and also "Shared Use, Off-road Paths and Trails"—"Preferences, Route Choice, and Walk/Bikesheds."

The following eight Table 16-123 entries (11th through 18th) focus primarily on exercise effects of neighborhood land use characteristics. The first of these nine entries (11th table entry) examines urban sprawl, finding it to be negatively related to walking activity and positively related to several major diseases.

The next six of these eight studies (12th through 17th) all find some measure of land use mix to be significant, although the study of largely Hispanic El Paso border community residents obtains the notable result of finding land use mix to be positively related to higher BMIs. Each of the other five studies, as well as two studies earlier in the Table 16-123 listing, find some measure of mix to be negatively related to obesity or BMI, or positively related to physical activity. Three of these studies explicitly measured land use mix objectively, including the El Paso border community study; three (with some overlap) used objectively determined or perceived acceptable walking accessibility to stores; and four (again with some overlap) used a measure that did not address mix explicitly but effectively included it in a walkability, accessibility, or attractiveness score.

The study based on Atlanta region data (12th table 16-123 entry) also identified significant negative relationships between obesity and residential density, and also intersection density, a connectivity measure. These findings consistently held only for white respondents, however, with weaker or mixed associations in the case of African Americans (Frank, Andresen, and Schmid, 2004). Density often stands in as a surrogate for related effects, as discussed at length in Chapter 15, "Land Use and Site Design." In this and similar cases, it may in part be standing in for good public transit service and concomitant higher use of transit, which is shown in the 19th table entry to be associated with substantial walking.

Only the last of this group of six studies (the 17th study in Table 16-123), of all the studies summarized in the table, offers a strong claim to demonstration of causality. It controlled for pro-walk/bike attitudes and neighborhood preferences, and then found objectively measured land use mix and distance to health clubs to be significantly and positively related to walking. (The further away that health clubs were, the more walking seemed to be induced, presumably as an exercise substitute.) Significance was also found for positive relationships between walking and reported perceived attractiveness of the neighborhood, presence of socializing, convenience of activity options, and stores within walking distance. BMI was similarly related negatively to most of these factors, but the association did not reach significance (Handy, Cao, and Mokhtarian, 2007). None of the other studies summarized in Table 16-123, while they may have shown strong and/or obvious relationships, found themselves in a position to claim demonstration of causality.

That said, the 18th entry in Table 16-123 offers illustrative ties to the other studies, and has advantages of detailed, quantitatively-measured (not perceived) travel, exercise, and physical environment parameters. (BMI assessment did use self-reported height and weight.) Although the King County, Washington, I-PLACE3S modeling involved did not include walking for transit access in the transportation dependent variables, its effect was implicitly included in the BMI and accelerometer-based activity measurement and modeling. The work adds another study to the tally of those finding residential density, intersection density, and availability of a nearby park or recreation opportunity to be positively related to activity and negatively related to BMI. A negative BMI relationship was also found for regional transit accessibility (Lawrence Frank & Co., SACOG, and Mark Bradley Associates, 2008). This finding meshes with the determination recorded in the 19th table entry, discussed previously and below, that transit riding contributes significantly to meeting recommended daily levels of walking for health maintenance (Besser and Dannenberg, 2005).

The King County exercise/BMI modeling did not find statistical significance in closeness to a bus stop, perhaps because the greater transit use associated with having a close-by transit stop (identified in the transit use model) is counterbalanced by the lesser exercise obtained when the stop is close at hand. Finally, the King County study did not find its land use mix variable to be statistically significant for exercise or BMI, but density of retail—measured as retail floor area ratio—was positively related to exercise. The numbers of fast food and other retail/food establishments within 1 km. were *positively* related to BMI, perhaps as an indicator of opportunity to obtain food, and lending weight to the researchers' notation that, "Health outcomes are distal outcomes—more steps removed from the urban form variables . . . [with] other factors . . . [e.g.] diet . . . play[ing] a much larger role . . ." (Lawrence Frank & Co., SACOG, and Mark Bradley Associates, 2008). Greater opportunity to obtain food could possibly underlie the finding in an El Paso border community of a positive relationship between land use mix and BMI.

The 19th entry into Table 16-123 demonstrates that substantial walking is inherently built into transit use (Besser and Dannenberg, 2005), showing that the practice of some researchers of treating public transit as "active transportation" along with regular walking and bicycling has a strong basis in fact. This demonstration also at least partially explains why most studies that have examined perceived or measured transit accessibility or use, primarily overseas (and not identified in Table 16-123), have found it to be related to more walking or exercise.

The final three Table 16-123 entries (20th through 22nd) cover five studies addressing a mix of environmental, policy and program, and promotion and information situations and outcomes. The 20th entry identifies perceived neighborhood safety from crime as being a significant contributor to higher activity levels. The 21st table entry covers three international studies. The first two are not linked to any reported change in pedestrian and bicycle facilities, but on the basis of prospective longitudinal health studies in Shanghai and Denmark, provide further evidence of linkage between regular walking/bicycling and better health as reflected in longer life expectancy. The third study reports a life expectancy increase in parallel with increased bicycling, presumed to be in response to a demonstration project furthering the proactive bicycle programs and policies of Odense, Denmark (Pucher et al., 2010).

The last study, the 22nd and final Table 16-123 entry, provides information on both the total exercise pattern of residents of the Pacific Northwest city of Bellingham, Washington, and the effect on active-transportation physical activity of an individualized environmentally friendly transportation marketing program. Bellingham is obviously somewhat of an outlier in the amount of physical activity its residents obtain. The analysis provides a comparison with four Oregon cities, presented in Table 16-124. Among the five cities in an area of the United States known for outdoor activity, Bellingham had the highest average hours/year in both active transportation and in the total physical activity of transportation and sports combined. Individualized marketing achieved shifts to walking, bicycling, and transit use, in this already active environment, that increased individual hours of active transportation 25 percent (Horst and Brög, 2010, Socialdata, 2008), as set forth in Table 16-123. Quantification of individualized marketing effects on physical activity in other cities is found in the "Response by Type of NMT Strategy" section under "Walking/Bicycling Promotion and Information"—"Individualized Marketing"—"Home/Community-Based Program Effects on Physical Activity." There it indicates that while Bellingham achieved a 31-hour annual increase in physical activity per individual, 11 to 13 hours per year per person is more typical.

Table 16-124 Average Annual Hours per Resident of Active Transportation and Sports Physical Activity in Five Pacific Northwest Cities

Measure	Bellingham, Washington	Bend, Oregon	Eugene, Oregon	Portland, Oregon	Salem, Oregon
Active Transportation Hrs./Yr.	119	63	80	91	74
Sports Hours/Year	56	106	70	36	38
Total Active Transp. and Sports	175	169	150	127	112
Transportation as Pct. of Total	68%	37%	53%	72%	66%
Transp. as Pct. of HHS Minimum	92%	48%	62%	70%	57%
Total as Pct. of HHS Minimum	135%	130%	115%	98%	86%

Notes: Represents all individuals in each study area.

Bellingham data is from a city-wide 2007 sample, pre-full-scale individualized marketing.

Data for the Oregon cities was obtained circa 2005-2007.

Source: Socialdata (2008).

The considerably expanded pace of empirical investigation into relationships between the built environment and walking in particular provides a continuing flow of additional information. Perspective is provided by a 2005 and early-2006 update of not only the review in *TRB Special Report 282* (Committee on Physical Activity, Health, Transportation, and Land Use, 2005) but also other reviews. The update authors conclude that, "Many of the conclusions from prior reviews are supported by this more recent evidence, particularly in the consistent associations found between walking for transportation purposes and density, land use mix, and proximity of non-residential destinations" (Saelens and Handy, 2008).

The 2005–06 update authors report, however, that some of the associations with the urban environment do not strongly pertain to recreational walking. The observation is also made that sidewalk infrastructure appears to be of differing importance, depending on travel category, with recreational walking and walking to school noted as types more influenced by quality of sidewalk infrastructure (Saelens and Handy, 2008). Selected individual-study findings from the update's study summaries are presented in the applicable pedestrian and bicycle facility or program "Response by Type of NMT Strategy" subsections.

Finally, a newer-still infusion of synthesis information is provided by an international review of research through 2010 prepared by 39 authors—many represented elsewhere in this chapter's references listing—from research agencies, educational institutions, public health departments, and consultancies in Belgium, Canada, Chile, Denmark, Finland, France, Greece, Ireland, the Netherlands, New Zealand, Spain, Switzerland, United Kingdom, and the United States. This international review finds many areas of concern still poorly understood, stresses "the complexity of interactions among people, places, and the natural environment," and highlights need to consider possible unintended consequences of actions and policies. Firm conclusions are nevertheless offered, as follows (de Nazelle et al., 2011):

- Strong evidence links walkability factors involving transportation infrastructure and land use "with more active transportation and less driving."

- Active travel policies offer the potential for large public health benefits through physical activity increases, combined with smaller benefits accruing from transportation pollution reduction.

Information provided on crash and pollution risks in this international review is contained within the upcoming "Tradeoffs Between Health Benefits and Crash/Pollution Disbenefits" discussion. Additional, strategy-specific perspectives from the overall review are inserted in the "Adult and Child Public Health Relationships Summary" that concludes this "Public Health Issues and Relationships" subsection. On the whole, previously synthesized outcomes of providing new NMT facilities and pursuing NMT-supportive policies and programs conform well with the new information.

Health Benefits for Children of Enhanced NMT Systems and Policies

The relationships of child and adolescent health to physical activity have not been as well developed as for adults, in part because key adverse outcomes—notably premature mortality—do not much evidence themselves prior to adulthood. There is not much doubt, however, but that the benefit of pre-adult physical activity is every bit as important. Table 16-120, in the preceding adult-oriented discussion, contains a column listing HHS determinations as to benefits for children and adolescents of regular physical activity. By examining this listing, juxtaposed with adult benefits, it can be seen that many childhood conditions ameliorated by physical activity are precursors to chronic health conditions of adulthood. In addition, low levels of physical activity among children have been linked to more immediate adverse effects including low physical fitness, low bone density, and higher risk of obesity (Davison and Lawson, 2006, Department of Health and Human Services, 2008).

Obesity in children has—over the course of three decades—more than tripled for 6 to 11 year-old children, and more than doubled for other child and adolescent age groups. Although obesity in childhood may not be immediately linked with the most serious clinical symptoms, the adult obesity which most often follows is. Moreover, the social and emotional effects of childhood obesity, including negative stereotyping, stigmatization, and discrimination by their peers, are immediate. Some physical disorders are also immediate, including high blood pressure, sleep disturbances, menstrual abnormalities, orthopedic problems, impaired balance, insulin resistance, and even Type II diabetes, to name a few. As a result of the childhood obesity epidemic, diet and physical inactivity seem destined to supersede smoking as the leading cause of death (Committee on Prevention of Obesity in Children and Youth, 2005).

The National Association for Sport and Physical Education has recommended that elementary school children partake in at least 30 to 60 minutes of appropriate physical activity on all or most days (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). The HHS now seeks higher child and adolescent involvement in physical activity, 60 minutes or more each day (Department of Health and Human Services, 2008).

Childhood Health, Development, and Activity Relationships. In the context of childhood health and obesity, the expenditure of calories is both a positive indicator and desirable outcome. Studies conducted in the London suburb of Hertfordshire in March and May of 2002 and 2003 sought to determine the energy expenditure of children in all activities of a week during the school year. Boys and girls in grades 6 (ages 10–11) and 8 (ages 12–13) were asked to wear tri-axial accelerometers and keep an activity/event diary for 2 weekdays and 2 weekend days. A total of 195 children successfully completed the assignment, representing 98 percent of the sample. Results were expanded to a 7-day week. Energy expenditure was calculated in activity calories per unit of time. Activity calories are those calories consumed by the body in physical activity, as contrasted to baseline bodily functions (Mackett et al., 2005a).

One subdivision of daytime events/activities examined employed 19 different event types. (Swimming, which might be considered a 20th type, had to be omitted.) Overall energy expenditure was 0.9 activity calories per minute, ranging from 3.1 when at school in PE class or a "games lesson" down to 0.6 when in other classes or at the child's own home. The top six activities for energy expenditure, in addition to PE/games lessons, were unstructured ball games at 2.8, structured ball games at 2.4, walking at 2.3, unstructured events not including ball games or play at 2.1, and school break/recess at 1.9 activity calories per minute. Next after that came bicycling at 1.7 activity calories per minute.[81]

A measure of the importance of travel mobility to exercise is the finding that average energy expenditure outside the home is 1.1 activity calories per minute, twice the at-home rate if correction is made for the children's weights. The number of cycling trips in the sample was too small for detailed analysis, but walking—mostly to and from school—was shown to be a major contributor to physical activity. In contrast to PE or games lessons, which involved an average of 70 minutes per week, walking averaged 153 minutes per week. Overall, this makes the walking a roughly equal contributor to total exercise when compared with school PE and games lessons for younger children, and much more important in the case of older children, especially boys (Mackett et al., 2005a).

In addition to the physical and mental health benefits, compelling evidence is accumulating that physical locomotion adds to the quality of childhood development, most specifically to enhancement of spatial perception skills (Yan, Thomas, and Downing, 1998). Findings are mixed as to whether or not the benefit is greater for those school-age children allowed to walk and bicycle unaccompanied by adults. A pair of Italian researchers has postulated that differences in study outcomes relate to study approach. Measurable declarative knowledge of landmarks in the environment may be enhanced by walking with adults and learning place identifications from them. Measurable cognitive mapping of routes and points of interest—spatial or survey knowledge—may best be acquired by independent active travel. The researchers' own study of schoolchildren in a suburb of Rome found 9- to 11-year-old elementary students who walked to school on their own more accurately mapped their route and locations of points of interest than children who walked accompanied by parents or who were driven (Rissotto and Tonucci, 2002).[82] Roughly similar research covering elementary students in the vicinity of London, England, likewise found a positive relationship between level of independence and accuracy and detail

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[81] No mention was made of inability to fully record bicycling energy expenditure, but at least one other accelerometer-based study has noted difficulties.

[82] The 46 children in this intriguing study participated in three special classroom exercises. They located their home and drew their route to school first on a sheet of paper that was blank except for the location of the school and two boundary features, a railroad and an arterial road. Later they did the same on a map of streets and buildings that was unlabeled except for the school, railroad, and arterial. In between they located prespecified landmarks, along with any more they could think of, on the streets and buildings map. In both route drawing tests, students who walked to school on their own more accurately mapped their route (based on an average of four accuracy measures) than students who walked accompanied by parents. The accompanied walkers in turn more accurately mapped their route than children who were driven. Two-thirds of the differences in mapping quality were statistically significant. Results from the landmark-identification test were less clear. Students who walked unaccompanied by parents did best, always significantly so compared to those walking with parents. Students driven to school did somewhat better, however, than students who walked with parents. A confounding factor may have been that although auto-driven children were less likely to be allowed out to play without adults than children who walked to school unaccompanied, they were more likely be allowed to play unchaperoned than children who walked to school guided by parents (Rissotto and Tonucci, 2002).

of maps drawn. Children driven to school were, for example, less accurate in recalling locations of local area landmarks (Mackett et al., 2007a).

Fitting children with GPS and activity monitors, the London area study noted immediately above found that 8- to 11-year-olds walk from origin to destination at speeds about 2 to 3 times faster when accompanied by an adult than when left to their own devices. In the process, their intensity of energy expenditure as measured in 10^{-2} activity calories per kilogram of body weight per minute is 6.7 for boys and girls accompanied by adults versus 7.4 for unaccompanied boys and 3.7 for unaccompanied girls. The higher caloric energy expenditure by unaccompanied boys, despite slower origin-to-destination speeds, resulted from numerous detours and vigorous play enroute. Girls did much less of this (Mackett et al., 2007a). Nevertheless, given that more time was taken enroute when walking unaccompanied, the total caloric energy expenditure per unit of direct route distance would still be higher for unaccompanied than accompanied girls, and much higher for unaccompanied versus accompanied boys.

Childhood Health Effects of Non-Motorized Transportation Features. Studies addressing effects on child and adolescent physical activity of enhanced NMT systems and policies are primarily from the physical activity literature and are smaller in number than for adults. Moreover, most express their findings in terms of physical activity measures. Practically all of the relevant studies encountered have been covered in a review of the literature by researchers at the University at Albany, New York (Davison and Lawson, 2006). Those of the studies reviewed that offer findings in terms of travel behavior metrics have been examined individually under the applicable pedestrian and bicycle facility or program "Response by Type of NMT Strategy" subtopics. Table 16-125 below presents those study findings expressed in physical activity metrics, and also summarizes the findings of the few child-focused studies covered in "Response by Type of NMT Strategy" subtopics.

Table 16-125 Summary of Findings on Transportation Infrastructure and Land Use Effects on Children's Travel and Physical Activity

Studies	Process (Limitations)	Key Findings
1. Boarnet et al. – 2005a, Ewing et al. – 2004 (both U.S.)	Boarnet studied change in walking and biking to school in response to CA Safe Routes to School program (SRTS) improvements and Ewing modeled the effect on walk/bike school access of a variety of factors. (SRTS school access mode changes were as perceived by parents.)	Boarnet found increases in walking/cycling relative to study controls for children who passed via SRTS sidewalk and road crossing improvements, and Ewing identified a significant relationship between main road sidewalk availability and higher student walking rates, while failing to find any relationship between bicycle lanes and walking/cycling to school.
2. Carver et al. – 2005 (Australia), Mota et al. – 2004 (Portugal)	Carver conducted cross-sectional analysis with parent and child perceptions of various facilities and environmental conditions and Mota similarly studied various factors based on adolescent reports. (Both studies used self-reported physical activity measures as well as perceived environment measures)	Carver found adolescents to walk/bike more where roads were perceived safe, there were more sports facilities, and — oddly — where cycling was *less* easy and convenience stores *farther* from home. Mota found higher activity adolescents to report greater access to stores and transit stops, more local recreational opportunities, and better neighborhood aesthetics. No significance was found for other "friendly neighborhood" measures.
3. Jago et al. – 2005 (U.S.)	Jago analyzed neighborhood and ped/bike system characteristics and accelerometer-measured physical activity. (Accelerometers did not pick up cycling well.)	Desirable sidewalk characteristics such as distance from curb and trees serving as a buffer showed a positive relationship with light-intensity physical activity. Cycling provisions showed no discernible effect.
4. Timperio et al. – 2004, Timperio et al. – 2006 (Australia)	Timperio conducted cross-sectional analysis with parental or adolescent perceptions (2004) and objective measures (2006) of various area or school access conditions. (Parent reporting of walking and cycling.)	Lesser walking/cycling was, for most age/sex combinations, associated with poor public transportation, heavy traffic, and multiple road crossings. Lesser walking/cycling to school was also associated with distances over 800 meters and (for ages 5-6) steep grades.
5. Braza et al. – 2004, Norman et al. – 2006 (both U.S.)	Both studies employed cross-sectional analysis of objective measurements of school area (Braza) or neighborhood (Norman) characteristics along with objective measures of walking/biking rates or physical activity to explore explanatory relationships.	Braza found higher surveyed walking and biking rates to school to be associated with greater population and intersection densities. Norman found accelerometer-measured activity to be significantly related to measures of walkability including retail accessibility (boys), intersection density (girls), and recreation opportunity accessibility.

Note: Drawn from summaries of 33 studies, omitting those not directly relevant.

For additional information see the "Sidewalks and Along-Street Walking," "Street Crossings," "Bicycle Lanes and Routes," and "Pedestrian/Bicycle Friendly Neighborhoods" subsections of the "Response by Type of NMT Strategy" section.

Source: Davison and Lawson (2006).

In considering the findings in Table 16-125, it is useful to establish context by quickly examining the role of non-transportation physical environment effects on childhood physical activity. It is also important to note that relationships between the physical environment and the physical activity of children differ from those of adults. Children are in different circumstances: they are not able to drive, spend long hours at school, have extensive time for recreation, gain substantial physical activity through play, and are under restrictions judged wise by adults (Davison and Lawson, 2006). Importantly, there is some evidence from studies of male children, adolescents, and children in general, that those who do not walk or bicycle to school, or who encounter restricted physical activity at school, are less active—not more—during out-of-school hours (Boarnet et al., 2005a).

Focusing on non-transportation physical environment effects, no association was found in four of six studies between home exercise equipment and childhood physical activity. Significant positive association was found in 10 of 14 studies for availability of recreation areas or proximity to the home of recreation areas or parks and playgrounds. No discernible relationship was found in seven of nine studies between perceived safety and children's physical activity, but three out of three studies found a significant negative relationship between physical activity and objective measures of crime or area deprivation (Davison and Lawson, 2006).

Review of Table 16-125 suggests that children's physical activity may be related to a shorter list of transportation and physical environment characteristics than for adult physical activity, though final judgment should be withheld until there is a larger body of research on the activities of children. Of the nine studies in the table, three specifically identify higher incidence of walking where sidewalks are present, of higher quality, or improved over prior conditions. Similarly, three of the studies found walking and bicycling to be more prevalent in the presence of street crossing improvements, fewer roads to cross, and less traffic. Relationships such as these presumably have a strong association with the safety perceptions of parents and guardians, though explicit exploration of this aspect was not encountered. (For perspective on the role of adult supervision on childhood travel choices, see "Underlying Traveler Response Factors"—"Behavioral Paradigms"—"The Travel Choice Making of and for Children.")

Two studies attempted to find effects on children's physical activity associated with presence of bicycle lanes or other cycling provisions and found none. Two studies found accessibility to stores to be indicators of more walking/cycling, while one did not. Measures of transit service adequacy were positively related to physical activity in two studies, which is logical, since not only is public transit a form of active transportation, it is also the only option children have for independent travel over longer distances. Two studies found a positive relationship between intersection density and walking and biking activity, while one found no impact for most walkability measures.

One study in Table 16-125, the first-listed within the 5th and last table entry, found a positive association between walking and biking rates to school and higher population densities (Davison and Lawson, 2006), logical since higher density is presumably associated with shorter distances to school. Along the same vein, one of the studies in Table 16-123 (Ewing, Brownson, and Berrigan, 2006) examined adolescent weights along with those of adults, and found adolescent obesity to be positively related to urban sprawl.

Tradeoffs Between Health Benefits and Crash/Pollution Disbenefits

Concerns related to the exercise and health benefits of walking and bicycling are the negative effects on well-being of crashes, associated fatal and non-fatal injuries, and also exposure to pollutant emissions (de Nazelle et al., 2011). The concern about crashes, as they affect cyclists, was addressed in depth in a 1992 study for the British Medical Association. That research concluded that the benefits in terms of life years gained from the increased physical activity of bicycling far outweigh any possible negative effects in life-years lost from injuries or fatalities. It was estimated that the aerobic exercise provided by bicycling compensated for crash risk by a factor of 20 to 1 in terms of average life expectancy (Hillman, 1992, Zegeer et al., 1994, Reynolds et al., 2010). Since the crash rate for bicycling exceeds that for walking, it follows that walking benefits likely also strongly favor the activity over crash concerns. Additional support is provided by studies showing positive association between engaging in active transportation and reduction in all-cause mortality risk (Reynolds et al., 2010), a risk that would include crash-related deaths, and also air pollution effects.

Modeling the effects of a twofold increase in walking and an eightfold increase in bicycling in London produced an estimate that the exercise would decrease premature mortality by 528 per million people, while the increased crash exposure would result in 11 fatalities per million. The corresponding years-of-life impacts were an exercise-induced increase of 5,496 life-years per million people versus 418 life-years per million lost through crashes (Reynolds et al., 2010). For pollutant risks to active transportation participants, however, unknowns presently impede making any such estimate. Some studies indicate that pedestrians and bicyclists are exposed to pollutants at lower concentrations than persons using motorized transportation. Indeed, walkers and cyclists often can and do choose routes away from heavy vehicular traffic flows. Other research suggests that higher breathing rates and longer trip times for active transportation participants result in higher inhalation exposure. Evidence of in-travel active-transportation pollutant-exposure effects has been developed in controlled experiments, but degree of effect on health under everyday conditions has not been established. Drawing of firm conclusions regarding air pollution risks for pedestrians and bicyclists will require additional research (Reynolds et al., 2010, de Nazelle et al., 2011).

Adverse health effects of air pollution are of elevated concern when considering the benefits and disbenefits of compact living environments. Higher densities and street interconnectivity at the place of residence have been shown to reduce key air pollutants carbon monoxide (CO), volatile organic compounds (VOCs), and nitrogen oxides (NOx) overall, but may produce higher NMT exposures to CO and VOCs along with particulates in street environments within compact developments themselves. Measurements in Vancouver, British Columbia, Canada, have found higher concentration of primary traffic pollutants, but not secondary pollutants such as ozone, in more walkable as compared to less walkable neighborhoods. Not only the unknowns noted above, but also the lack of research simultaneously addressing the multiple relationships between the built environment and public health, impede understanding of risk/benefit tradeoffs (Frank and Engelke, 2005, de Nazelle et al., 2011).

The appropriateness of considering fatal and non-fatal injury and pollutant exposure risks as a partial trade-off against the healthful exercise benefits of walking and cycling may pertain more to the individual perspective than to society as a whole. Studies reported on in the "Safety Information and Comparisons" subsection (see "Other Traffic Safety Issues and Findings"—"Safety in Numbers") find that where there are more walkers or bicyclists, crash rates tend to be markedly lower. It is argued on the basis of these relationships that achieving growth in walking and cycling will similarly result in reduced crash rates. Likewise, even if certain individual pedestrians and bicyclists are exposed to more pollutants by engaging in active transportation, the overall effect of more walking and cycling must be some degree of areawide pollutant emissions reduction, however modest (de Nazelle et al., 2011). From a societal perspective, then, the health benefits of more walking and cycling should not have crash injury or pollutant exposure costs deducted from them. There should perhaps even be a credit for pedestrian and cyclist injury reductions and lessening of overall pollution-related disease.

It is reasonable to have some reservations about "safety in numbers" conclusions, even though practically all available evidence worldwide supports the relationship. There is the possibility of exogenous influences, and one must infer cause-and-effect relationships from analyses that are largely cross-sectional (de Nazelle et al., 2011, Bhatia and Wier, 2011). At the least, however, it would seem appropriate to neither deduct nor credit fatal and non-fatal injury costs—in calculations of societal health benefits accruing from increased walking and bicycling activity—until such time as crash-reduction effects can be more firmly established. Similarly, any attempt to adjust for pollutant exposure risks would seem premature, given the present state of the art. Credence is lent to the approach of not penalizing for safety and pollutant risks by two international comparative risk assessments recently reported on. These risk assessments, while addressing the uncertainties, conclude that physical activity benefits of active travel dominate other benefits and amply compensate for increased risks of injuries and pollutant inhalation (de Nazelle et al., 2011).

Adult and Child Public Health Relationships Summary

Research by both the public health and transportation planning professions makes it clear that there is no one “silver bullet” for achieving more walking and bicycling in the interests of either exercise or motorized transportation impact reduction. Individual outcomes appear to be largely incremental, but with significant synergism possibilities. For multi-pronged thrusts involving policy shifts and comprehensive programs, results may be combinative to a substantial degree. They tend, however, to come gradually as program elements are put in place. Achieving fundamental shifts toward more healthy and environmentally sustainable levels of active transportation will take long-range commitment and comprehensive effort, hopefully informed by information such as that provided in this chapter on both traveler response and recreational/exercise response to NMT facilities, policies, and actions.

The following adult and child public health summary is in effect an extension of the “Traveler Response Summary” within the “Overview and Summary” section at the beginning of the chapter. It looks at each pedestrian and bicycle strategy from a public health perspective and is based on material presented in both this “Public Health Issues and Relationships” subsection and, secondarily, the “Response by Type of NMT Strategy” section. Some additional summary observations are drawn from the 39-author international review “Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment” (de Nazelle et al., 2011). These additions, identified as being from “the de Nazelle et al. international review” or simply “the international review,” serve to enhance the coverage and currency of the summary.

Physical and environmental factors such as pedestrian and bicycle infrastructure and programs are, of course, only one component of the influences on choice to walk or bicycle or otherwise exercise. Individual factors and socio-demographic circumstances play important roles as well, as has been highlighted where such considerations most notably pertain.

For strategy categories where public health research is largely lacking, effects on public health must be inferred from reported changes in walking and bicycling activity, volumes, and travel mode shifts. This requires the fairly logical assumption that if active transportation is made more prevalent, then exercise and public health benefits will naturally follow. The inference-making is done from an overview perspective only—the primary travel demand impacts summary remains concentrated in the “Traveler Response Summary.”

Sidewalks and Along-Street Walking. The preponderance of public health research on effects of sidewalk availability has found significant and positive relationships with walking sufficiency, exercise, or normal body weight, although not necessarily for all demographic groups. The research overall found relationships as strong as or possibly stronger than a group of studies on availability effects of a wide variety of mostly non-transportation activity opportunities including parks and various forms of exercise facilities. On the other hand, it has been found that persons who engage in both active transportation and other exercise forms have the highest likelihood of meeting minimum activity recommendations.

Transportation planning studies, although often less statistically rigorous, tend to support the findings of significant and positive effects on walking of sidewalk availability. Commercial area sidewalk adequacy and adjacency to stores appears to be a critical sidewalk system component for inducing utilitarian walking. Sidewalk continuity seems to be positively related to neighborhood walking for exercise and pleasure, and interesting streetscapes and activities to look at along the way may help. Isolated public health and transportation research efforts suggest that narrow and pleasant low-volume streets may offer suitable compensation for lack of continuous sidewalks, at least for able-bodied adults. Limited research has found that strategically located sidewalk improvements are associated with increased walking to school. A positive relationship between presence of main-road sidewalks and walking to school has also, in another study, been established.

Overall, the most critical sidewalk system elements for support of exercise-inducing active transportation appear to be sidewalks providing school access; commercial area sidewalks; sidewalks along busy streets vital for linkage with public transit, shopping, and other centers of activity; and sidewalk continuity in support of recreational walking. Research on trade-offs between exercise benefits of walking and associated disbenefits of crash risk and pollution exposure suggests that health outcomes strongly favor walking over non-active alternatives. Risks of breathing emissions while engaging in active transportation need much more study, but conclusions presented in the de Nazelle et al. international review make it clear that even with poorly understood exposure risk for individual walkers and cyclists, the societal benefits of more active transportation and correspondingly lowered pollution overall are definitive. Walking has been shown to be positively associated with not only physical health but also mental health.

Street Crossings. Scattered and diverse evidence, primarily from transportation planning studies but also from public health investigations, identifies the need to cross multiple, busy, or major arterials—particularly at locations without traffic signals—as a barrier to choice of walking and even bicycling. There is weak evidence that painted crosswalks encourage a slight increase in pedestrian activity. Unfortunately, except on two-lane streets with low to moderate speeds, painted crosswalks without traffic signals or pedestrian-activated lights or beacons may increase serious crash incidence. In contrast, a redistribution and increase in traffic signals along a central London neighborhood boundary saw an increase in pedestrian volumes that was more than mere route-shifting. Small-scale studies indicate that painting crosswalks on routes to school has little effect on schoolchild pedestrian volumes, but full traffic signal installation of key crossings can lead to schoolchild crossing volume increases. Pedestrian grade separations, in addition to being expensive, will not be much used if they impose significantly more crossing time than crossing at grade.

Pedestrian Zones, Malls, and Skywalks. Creation of special pedestrian places and ways in central business districts (CBDs) has not much attracted the attention of active living specialists. Traditional CBD pedestrian streets (malls) have been greatly affected by secular business activity trends and many were converted back to streets as retail activity fled U.S. downtowns. Some examples, especially the variations known as transit malls because of shared transit and pedestrian use, have been moderately to outstandingly successful and are believed to have helped preserve the pedestrian-friendly downtowns they serve. As such, they have lessened sprawl with its associated health disbenefits. Sufficient studies were done of Boston's Downtown Crossing pedestrian zone and the Nicollet transit mall in Minneapolis to demonstrate that their implementation brought increased pedestrian activity. The much-newer Broadway mixed-design mall in Manhattan's Midtown saw short-term pedestrian volume increases equivalent to twice the preceding annual long-term growth. Count-based studies of the Minneapolis and St. Paul weather-protected Skyway systems seem to show that they work with parallel sidewalks and crosswalks to maintain fairly constant downtown lunchtime pedestrian activity throughout the year rather than enduring a dip during northern winters.

Bicycle Lanes and Routes. On-street bicycle facilities are another NMT improvement approach without much coverage by original research from within the public health sector. Bicycle lanes have been found to reduce both perceived and actual conflicts with traffic and to attract cyclists from nearby parallel roads, as well as potentially tapping latent demand. A small number of both Census-based corridor studies and city-level aggregate studies have linked either new bicycle lanes or more extensive networks of lanes with additional commuter bicycling. Representative of major successful installations is the Minneapolis-St. Paul experience of a 64 percent average increase in commute travel bicycle share, representing a 1.38 percentage point increase in corridor work-trip bicycle share. No research specific to non-commute bicycle travel share or physical activity increases linked to bicycle lanes has been encountered.

A number of installations have averaged roughly a 50 percent increase in total bicycle traffic on the treated streets but with major proportions representing bicycle trips diverted from other streets rather than more cycling. The user makeup of bicycle lanes, relative to other facility types, may possibly be tilted toward use by adults commuting to work. In that context, however, it is relevant that prospective studies in Shanghai and Denmark have shown bicycling to work can reduce premature mortality risk by roughly 1/3. No conclusive evidence has been encountered that bicycle lanes are attractive to children. Bicyclist route-tracking research provides evidence that they are more attractive to experienced male cyclists than either inexperienced/infrequent cyclists or female cyclists. Infrequent cyclists and females biking the street system appear more attracted by quiet streets (some of which can be logically designated bicycle routes) and in particular by specially treated bicycle boulevards.

The response to new bicycle facilities may be gradual. Peak usage of the St. Kilda Road bike lane in Melbourne, Australia, did not quite double in the first year after installation, but had increased by a factor of 12 after 10 years. The bicyclist injury rate gradually declined, after an initial spike, to 1/5 that in the "before" condition. Cycle tracks and other forms of traffic-separated but on-road bicycle facilities appear to attract more usage than standard bicycle lanes, based primarily on overseas experience, and were found in Montreal to attract well over twice the bicycle volume of parallel undifferentiated streets.

Shared Use, Off-Road Paths and Trails. The combined public health and transportation planning research on urban/suburban off-road shared use paths has, for the most part, isolated significant, positive contribution of path proximity to active transportation and exercise levels. Transportation researchers were for many years not able to establish as strong a relationship with commuter bicycling levels for paths as for bike lanes, which may be because a number of studied path systems featured indirect parkland routings and/or lacked hard surfaces, but newer U.S. research has placed them on at least equal footing for commuter attractiveness when well designed, reasonably direct, and well integrated.

Shared use paths serve a broader clientele of bicyclers of all skill levels along with walkers, joggers, in-line skaters, and groups/families seeking recreation and exercise. Indiana studies that avoided common methodological problems found users of five out of six trails to be roughly equally split between wheeled users and users on foot, with the sixth trail—like other long partially–rural trails—bicycle-dominant. Although path use seems to be most common for adults neither particularly young nor old, scattered but generally strong evidence indicates that shared use paths are attractive for learning cyclists, inexperienced cyclists, and new exercisers, predominantly walkers. Two flat trails developed on old railroad roadbeds (rail trails) in a city of steep grades and limited sidewalks, Morgantown, West Virginia, attracted new exercisers (22 percent of users), increased exercise rates for a majority of users, and established regularity of exercise. Paths well aligned with business destinations serve utilitarian users who may, limited findings suggest, be deliberately combining need to make a trip with achievement of exercise. Survey-based studies show that among summer users of the Hennepin County (Minneapolis area) trail system, 60 to 70 percent meet exercise sufficiency guidelines. Of the total qualifying exercise of the trail users, 62 to 68 percent is obtained on the trails themselves.

Pedestrian/Bicycle Systems and Interconnections. Systems approaches have produced the more notable shifts to use of active transportation. In Portland, Oregon, a 215 percent increase in bikeway system extent and critical improvements to four central area bridges were accompanied, over a 13 year period, by an estimated 210 percent increase in bicycle trips. Downtown-destined walk-to-work shares in Brisbane, Australia, tripled over two decades and bike-to-work shares increased six fold in parallel with development of a three-corridor path system, a major pedestrian and bicycle bridge, and more downtown housing. Individual bridges and closings of missing links in paths have seen anywhere from modest to substantial usage with tributary facility volume growth increases ranging from 1/3 to tripling (including redistribution effects) depending on context. On a new bridge with pathway over the harbor in Charleston, South Carolina, 2/3 of all walkers and cyclists reported increased physical activity. A majority of commuters on both this bridge and the Brisbane pedestrian and bicycle bridge were found to be deliberately combining exercise with their commute.

Various analytical approaches have shown the importance of good connections. Research is beginning to show that route directness is a walking inducement, as are higher-than-average ratios of neighborhood pedestrian connectivity relative to vehicular connectivity. Effects on exercise per se, and health, have not been quantified but presumably are proportional to positive outcomes of the types identified for sidewalk, bikeway, and path improvements.

Pedestrian/Bicycle Linkages with Transit. Almost one in six of all U.S. walk trips in 2001 and 2009, and roughly one in 10 of U.S. bicycle trips, involved accessing public transit stops and stations. An estimated 29 percent of transit users achieve the recommended 30 minutes or more of physical activity a day solely by walking to and from transit. There has been little definitive research on active transportation increases achievable through transit access improvements other than transit system expansion effects. Positive association has been noted in some cross-sectional studies between good transit access and incidence of walking by adults and by children.

Stated preference experiments and modeling based on cross-sectional travel survey data have been used to explore effects of access improvements, including provision of bicycle parking. Parking for cyclists has been estimated to be nearly as important, to much *more* important (depending on cyclist experience levels) relative to other access improvements. Walking and bicycling transit access shifts in the range of 2 to 7 percent increases have been estimated with cross-sectional models for suburban Chicago commuter rail stations. Bike-on-bus and bike-on-rail programs, a relatively new development, expand the reach of transit service and typically serve on the order of 1 percent of riders on systems well equipped to offer the service. The exercise benefits of accessing transit (including users of bike-on-bus programs) reach a disproportionately lower-income population relative to most active transportation enhancement programs.

Point-of-Destination Facilities. Secure and weather-protected bicycle parking is an obvious example of point-of-destination facilities that can be provided to make it more feasible or easier to use nonmotorized transportation. Workplace showers and changing facilities, and nearby convenience services to decrease need for an automobile, are other examples. These are key strategies that remove barriers to walking and bicycling for utilitarian purposes, but have not been studied in isolation to assign exercise encouragement or health effects to them. A study in the United Kingdom based on stated preference research estimated a 22 percent increase in commuter cycling would be associated with provision of secure indoor bicycle parking and showers. A Los Angeles area study found walk- and bike-to-work shares about 1/3 higher (starting at 2 to 4 percent) with an assortment of workplace amenities including a high aesthetic appeal and perception of safety. Although early results from a Minneapolis bike-sharing application show a majority of users treating it as an alternative to other forms of active transportation, 1/3 reported their alternative as traveling by auto or not making the trip at all.

Pedestrian/Bicycle Friendly Neighborhoods. A major thrust of transportation planning and public health active transportation research, including a number of multi-disciplinary studies, has been to examine the effects of urban design. While individual design elements have been found unimportant in one or a number of studies, and some logical relationships have not achieved formal statistical significance, the overall direction seemingly established is that pedestrian and bicycle friendliness of neighborhoods matters—especially in the case of walking. Bicycling evidently is an individual choice only moderately associated with the local land use and design environment. Urban sprawl has been found negatively related to walking and positively related to several major health problems.

One study is of particular interest in that it offers a claim to demonstration of causality, having controlled for pro-walk/bike attitudes, neighborhood preferences, and socio-demographics. It found positive relationships for walking with objectively measured land use mix, perceived attractiveness of the neighborhood, stores within walking distance, and convenience of activity options. BMI was related negatively to most of these factors, albeit not with statistical significance. The study took place in Northern California.

The same factors show up consistently with positive relationships to walking and health measures in the vast majority of studies, joined by higher land use density (which brings activities closer together), proximity of jobs, street intersection density (a surrogate for pedestrian system connectivity), and better public transit accessibility. In the case of children, broadly-defined land use mix may not be important, although retail proximity is, and accessibility from the home to recreation areas or parks and playgrounds should be added to the list of indicators of greater physical activity. Distance to school is critical, with multiple studies consistently finding distance to school to be inversely related to choice of active transportation for school access. Objectively measured crime or area deprivation shows, in a number of studies, a negative relationship with activity of children.

Further support for the importance of land use density and mix; proximity to home of shopping, services, and transit stops; more and better-quality sidewalks; system connectivity; and adequate and safe bicycle facilities as built-environment features associated with higher probability of walking, bicycling, and using transit is provided—on the basis of research through 2010—by the de Nazelle et al. international review. The strong association with density of many supportive built-environment attributes continues to make difficult the isolation of density effects and attributes usually but not always found in combination. Two recent studies in Belgium and the United States found residents of neighborhoods classified as having good walkability to be spending 35 to 49 minutes more per week engaged in physical activity than persons in low-walkability neighborhoods. A Minneapolis study, however, found neighborhood type to be associated not with the amount of physical activity but with its nature, such as walking for transportation versus for recreation versus visiting a gym. This exercise trade-off possibility plus the question of whether added physical activity accrues from sedentary people starting to exercise or active people exercising more are questions not yet resolved.

NMT Policies and Programs. Similar to the situation with pedestrian and bicycle system expansions and interconnections, exercise and health effects have not been empirically derived for instances of translating policy into substantial city-wide non-motorized transportation programs, although promising forecasting has been done in connection with policy planning in U.S. urban areas such as Seattle. In terms of travel effects, the exemplary programs in Portland and Brisbane were covered above. An additional 4 years of Portland experience has shown an accelerated (pre- "great recession") growth, giving a 1991 through 2008 bicycling exponential growth rate of 9.6 percent per year, despite a slowing of system expansion in the later years. Possible reasons for the continued and accelerated growth include a lag effect in the response to earlier pre-2004 bikeway system expansions, a doubling of gasoline prices from 2004 to 2008, Portland's ongoing individualized marketing program, and growing visibility and general acceptance of cycling.

Davis, California, still an ideal place for the ordinary citizen to bicycle, offers a cautionary tale. The outstanding bicycle-to-work-trip travel mode share of 14 percent in 2000 and the University of California Davis student bicycle-to-campus share of 48 percent in 2007 actually represent major declines attributed in part to loss of citizen involvement and municipal expertise along with weakened university parking policy. Boulder, Colorado, has focused not on a single active transportation mode but instead has been pursuing a goal of concurrent enhancement of pedestrian, bicycle, and transit facilities and services. Active transportation mode shares between 1990 and 2006 grew by 26 percent for all trips by all residents, by 16 percent for the commute trips of employees working in the city, and by 30 percent for worker midday-trips. Northern European programs provide the example of major non-motorized transportation turnarounds starting in the 1970s and leading to circa 1995 combined walk and bike mode shares 5 to 6 times higher than 1995 U.S. NMT travel shares.

Of particular interest in the context of childhood exercise are the Safe Routes to Schools (SRTS) programs in the United States and elsewhere. California elementary school SRTS studies showed a 46 percent average increase in schoolchild walking in response to sidewalk improvements and one-half that in response to crosswalk signalization, but inconclusive results for other intersection improvements. Among forms of encouragement programs, multifaceted approaches and "walking school bus" programs achieved walking increases—or walking and bicycling increases—within the 6 to over 60 percent range, omitting outliers. Basic coordination and encouragement programs in England produced negligible results, but encouragement with daily tracking of student modes of access combined with student recognition and sometimes other program actions has proved effective in English, Canadian, and U.S. applications.

In a 19-category breakout of child activities, ranging from PE classes to relaxing at home, walking and bicycling were in the top seven for energy expenditure. Walking to school has been shown to improve spatial information retention. Some but not all studies suggest that walking independently improves spatial cognition, such as is reflected in mapping ability.

The de Nazelle et al. international review observes that assessing policies designed to effect behavior change requires consideration of "bundles" of programs and strategies, and that both interactions and opportunities for "co-benefits" (multiple benefits) require attention. The desirability of considering auto disincentives among policy options is noted: In the example of London's central area congestion pricing, the congestion charge and cycling infrastructure investment saw a doubling of bicycling levels. The international review also speaks of a "cultural shift" that may occur when walking and cycling reach a level that signals "that these are safe and enjoyable and perhaps even fashionable activities." This sort of "virtuous circle" or "critical mass" was noted above as a possible reason for continued and accelerated cycling growth in Portland, Oregon.

Walking/Bicycling Promotion and Information. Results of most mass-market walking, cycling, and transit use promotion programs tend to be inconclusive and not encouraging. Exceptions are seen in some instances where individuals have been induced to try an active transportation mode they have had little direct experience with, as in a bike-to-work-day event. As marketing becomes more focused, short-term results become more positive, though long-term impacts have been little studied and dissipation of beneficial effects is a major concern. A higher order of targeted marketing intensity is provided by the promotional and informational protocol known as individualized marketing. In environments typical of Australia and the United States, benchmark applications have produced walk-share gains among trips for all travel purposes of 1 to 4 percentage points and bicycle-share and transit gains of 1 to 2 percentage points. Surveys on three continents have demonstrated substantial durability of mode shifts after 1 to 4 years. The mode shifts translate into added physical activity. Three U.S. estimates of physical activity gain linked to individualized-marketing-induced active transportation lie in the range of 11 to 13 hours per person per year averaged across the contacted target area population. In a fourth estimate, a 2008 large-scale program in Bellingham, Washington, averaged a walking and cycling time increase of 31 hours per person per year including transit and parking access mode changes.

Public health individual or household interventions have also been tried in an effort to increase walking. A major synthesis effort focusing on outcomes of such interventions, primarily undertaken at a research scale in the United States and Australia, concluded that more walking clearly can be encouraged when the interventions are tailored to individual needs. In a typical example, three interventions involving 12 to 16 counseling sessions over 12 to 24 weeks, communicated to sedentary adults via telephone or Internet, resulted in net increases in self-reported walking of 32 to 62 minutes per week as measured after 3 to 6 months. Evidence was found less convincing in the case of measures taken at the institutional level, whether workplace, school, or community. A major question, which only five of the 27 reviewed studies examined, is sustainability of intervention results over time. A majority of the five studies determined that walking increases recorded at 4 to 16 weeks were not sustained as measured at 24 weeks or 1 year. A Pittsburgh intervention, however, that started with 8 weeks of twice-weekly walking training for post-menopausal women, followed with various encouragements and even home visits, produced sustained walking increases that stood at 7.3 miles per week in a 10-year follow-up.

The de Nazelle et al. international review, as discussed above with respect to policies and programs, identifies promotional strategies as a partner in bundles of strategies that may even bring active transportation to a "certain 'critical mass' " of greater public acceptance and normality. On the other hand, the same international review notes that practitioners are putting more emphasis on changes in the urban environment to engender more physical activity. These conclusions are not necessarily in conflict—strategy synergism appears to offer enhanced outcomes.

Traffic, Energy, and Environmental Relationships

Walking and cycling trips may be broadly characterized according to purpose as being either recreation/exercise NMT trips or transportation/utilitarian NMT trips. Both are important from the perspectives of public health and quality of life. Only utilitarian NMT trips, however, can normally be viewed as possible substitutes for auto use. Therefore, it is only walking and cycling trips made for utilitarian purposes that in theory have the potential to affect congestion, energy use, and pollution (Krizek et al., 2007).

Driving Avoidance Estimates

The Nonmotorized Transportation Pilot Program Evaluation Study developed initial estimates, based on the 2006 baseline survey alone, of the amount of driving currently avoided in five U.S. urban areas thanks to present-day walking and cycling choices. Refined estimates along with energy and emissions savings calculations are expected as part of the final pilot program documentation (Krizek et al., 2007). The baseline survey was briefly described above under "Public Health Issues and Relationships" (see "Baseline Walking and Bicycling Activity," including Footnote 78).

Only utilitarian travel was considered in the estimates of NMT substitution for driving. Survey constraints required limiting the analysis to adult travel, thus chauffeuring of children was not addressed. Work commute and other utilitarian trip distances and daily walk and bike trips per adult were estimated from the five-area pilot survey. A low estimate was prepared on the basis of calculated "reference trip" distances and a high estimate was drawn from the daily walk and bike travel time totals reported. These steps were followed by survey-based estimation of degree of walk or bike substitution for auto driving relative to other travel options.

Commuter driving substitution was computed using the ratio of walk or bike commuters listing driving as their alternative mode to the total of walk or bike commuters reporting any alternative mode. Across the five communities, 32 percent of bicycle commute trips and 36 percent of walk commute trips were estimated to represent driving substitution. Non-commute utilitarian trip driving substitution was estimated based on alternative modes reported for applicable reference trips. In this manner, 93 percent of non-work utilitarian bicycle trips and 95 percent of such walk trips were estimated to be replacements for driving. The overall five-community driving avoidance estimate is summarized in Table 16-126 (Krizek et al., 2007).

Table 16-126 Reduction in Auto Driving Estimated for 2006 Levels of Walking and Cycling

Community	Low Estimate (miles/day)	High Estimate (miles/day)	Adult Average (miles/day)	Daily Driving per Adult (mi.)	Percentage Reduction
Columbia, MO	0.40	0.50	0.45	15.1	3.0%
Marin Co., CA	0.56	0.78	0.67	23.6	2.8%
Minneapolis	0.69	0.94	0.82	20.7	3.9%
Sheboygan	0.16	0.35	0.26	22.3	1.2%
Spokane	0.22	0.40	0.31	25.9	1.2%
Total	0.40	0.59	0.49	n/a	n/a

Source: Krizek et al. (2007).

The walk and bike modes of travel together were estimated to replace approximately 1/4 to 3/4 miles per day of driving per adult resident, depending on urban area characteristics. Present day use of NMT modes, in the context of 15 to 25 miles per day auto travel in the communities studied, thus appears to reduce driving by 1 to 4 percent. Roughly 70 percent of this avoided driving was attributed to walking, and the rest to cycling. Although bicycle trips are longer than walk trips, trip length differences are overshadowed by the much larger number of people who make utilitarian walk trips on any given day.

The researchers note the many factors that render difficult the estimation of NMT effects on driving, and report an earlier analysis by Handy and Clifton in 2001 that estimated walk trip substitution of 2.1 miles of driving per *month* (Krizek et al., 2007). That would be 1/5 the walk component of the average overall interim driving substitution estimate prepared for the pilot project, but within range of the low estimate for Sheboygan County, Wisconsin.

Facility and Project Impacts

A different perspective is provided by estimates of the traffic and emissions reductions attainable from individual new pedestrian and bicycle facilities and programs. An evaluation and assessment of Congestion Mitigation and Air Quality Improvement Program (CMAQ) projects funded between 2002 and 2007 takes such a perspective, noting that pedestrian and bicycle projects generally serve multiple goals ranging from improving mobility and access for non-drivers to improving NMT safety. That said, such projects were determined to have modest effects on vehicle trip and emissions reductions. The sum of estimated VOC, CO, and NOx reductions for individual projects examined were 4.6 kg./day for the 8.3 mile Swansea bikeway facility in Massachusetts, 3.6 kg./day for a 4.3 mile bike path to Pinhook Park in Indiana, 8.5 kg./day for a Transit Bike Depot in Colorado, and 42.8 kg./day for New York City's CyclistNET marketing program. Estimated reductions in vehicle trips per day ranged from 83 to 902, with the higher reduction pertaining to the New York City program. Effects on congestion were not estimated given the modest numbers of vehicle trips removed relative to total travel (Grant et al., 2008).

It will be noted that, outside of the New York City program, the largest CMAQ pedestrian and bicycle program emissions reduction—among the four projects examined—was for the enhanced bicycle-parking-at-transit in Colorado (Grant et al., 2008). Looking at a different mix of four alternatives, Chicago-area analyses reported in FHWA's National Walking and Bicycling Study of the early 1990s found secure bicycle parking at transit stations (for bike-and-ride) to be the most cost-effective approach for reducing hydrocarbon emissions incurred in accessing transit service. Not among the alternatives studied were enhanced paths and walkways (Replogle and Parcells, 1992).

Transit access trips are of particular interest for emissions reductions. Such trips, when made with conventionally powered vehicles, have higher-than-average pollutant emissions per mile because they usually begin with a cold-start for the engine and—when logical candidates for walk and bike substitution—are normally short enough that there is not much opportunity for engine warm-up. A conventional automotive engine running cold emits over 4 times the CO and about twice the VOCs per mile as when running hot.

Indeed, an estimate prepared for the Chicago area's Metra commuter rail system found that Metra passengers who drove to the station were producing between 50 and 90 percent of the pollution they would if they drove all the way into the downtown "Loop" district (Wilbur Smith and Associates et al., 1996c). A related consideration is that although most bicycling in an area such as Chicago occurs in the 7 months from April to October, that is also the most critical time of year for atmospheric pollution in the form of ozone, for which VOCs (light hydrocarbons) are an essential ingredient (Pinsof, 1982).

In 1980, the Chicago Area Transportation Study (CATS) and the Illinois Department of Transportation (IDOT) undertook a rare quantitative evaluation of bike-and-ride effects on emissions. IDOT had installed bicycle racks at nine Edens Expressway corridor commuter rail stations near Chicago, in July 1979, with a capacity of 457 bicycles. Additional bicycles parked at the stations in the new racks totaled 222 by August. The associated vehicle travel reduction was estimated at 1,739 VMT per day. (The emissions estimates are not reported here because of the many significant automotive emissions-control improvements made in the three-plus decades since.) National Walking and Bicycling Study estimates suggest that, for the circa 1990 vehicle mix, 150 gallons of gasoline per year are saved for each park-and-ride commuter attracted to bike-and-ride. In the case of commuters previously using an automobile for the entire trip, the corresponding savings is an average of 400 gallons per commuter diverted to bike-and-ride (Replogle and Parcells, 1992).[83]

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[83] It does not appear that these gasoline savings estimates have any adjustment for auto-access or auto-commute carpooling, or for reduced bicycling in cold or inclement weather. Both would reduce the annual fuel savings.

Program Impact Model Findings

Bicycle program estimates of energy savings are available from a "Conserve by Bicycle Program Study" conducted by the Florida Department of Transportation (FDOT). A key goal of the FDOT study was to determine the energy savings that could be realized if more and safer bicycle facilities were built. Under the study research plan, a corridor-level multinomial logit mode choice model pertaining to utilitarian bicycle trips was developed. The travel data source was intercept survey results from 17 corridors with various types of bicycle facilities: shared use lanes, bicycle lanes, shared use paths adjacent to the roadway, and independent shared use path alignments. With the model, the energy savings (in terms of fuel costs saved) could be estimated based on estimated mode shift from the motor vehicle to the bicycle mode (Petritsch et al., 2008).

The mode choice model, calibrated from a data set of 1,554 motorists, 55 transit riders, 11 bicyclists, and 21 pedestrians, exhibited an R-Square of 0.91. The model included variables representing highway congestion, transit quality of service, trip length, network friendliness for bicyclists and pedestrians, quality of bicycle and pedestrian facilities, and population and employment density. It was not possible to include a household income variable and an additional bicycle friendliness measure because of limited variability in the relevant variable values within the data set and the limited number of non-motorists making utilitarian trips.

The Nebraska Avenue Corridor in Tampa was selected to illustrate the calculations of energy savings resulting from modeling different types of bicycle facilities with the mode choice model. Given key assumptions concerning selected parameters such as average utilitarian trip length, miles per gallon of fuel, and fuel price per gallon, the study predicted fuel costs that would be saved relative to the no-bicycle-facilities condition by providing bicycle lanes, shared use paths adjacent to the roadway, and independent shared use path alignments. The estimated annual transportation corridor fuel savings were $3,452, $113,858, and $387,596, respectively (Petritsch et al., 2008).

A Washington State Department of Transportation (WSDOT) study of urban form alternatives and pedestrian and transit improvements as greenhouse gas (GHG) reduction strategies is the first the study authors knew of to relate sidewalk availability with VMT and GHG emissions (CO_2 in this case). Information on 2,699 King County households and their associated 39,297 trips from the Puget Sound Regional Council (PSRC) 2006 Household Travel Survey formed the travel data for the analysis. Seattle and six suburbs provided GIS sidewalk data indicating lack or presence of sidewalks on one or both sides of all streets. A "Sidewalk-to-Street-Ratio" variable was used that described the ratio of total sidewalk length within a 1 km. network buffer compared to total length of street right of way within the buffer. The maximum theoretical value was 2.00, which would indicate sidewalks on both sides of all streets. In addition to the key sidewalk data, other variables studied in the analysis fell into the categories of urban form, transit service, travel costs, and socio-demographic and household characteristics (Frank et al., 2011).

The multivariate regression equations derived from the study exhibited the expected direction of sidewalk effects on VMT and CO_2 reduction and the sidewalk variables were thus retained in the model. The sidewalk variable was not found to reach statistical significance in explaining VMT, but was marginally significant in explaining CO_2 emissions.[84] The lack of variation in the data

[84] This is a logical outcome to the extent that vehicle trips diverted to walking would tend to be short and not very consequential from a trip mileage perspective, but important to emissions reduction because of the vehicle start-up and turn-off cycles eliminated.

set, skewed as it was towards the more urban and walkable parts of King County, may have contributed to this lack of strong statistical significance as well as to insignificance of variables such as residential density and intersection density—known to usually relate importantly to VMT and CO_2.

Such limitations notwithstanding, the study results still provide early evidence of the potential effectiveness of sidewalk availability for reducing VMT and CO_2. For example, increasing sidewalk coverage on both sides from 30 percent to 70 percent of all streets was estimated to result in 3.4 and 4.9 percent decreases in VMT and CO_2, respectively. By comparison, using the same model, an increase in hourly parking cost from $0.28 to $1.10 resulted in 11.6 and 9.9 percent estimated reductions in VMT and CO_2, respectively (Frank et al., 2011).

Economic and Equity Impacts

Active transportation has often been largely overlooked and therefore undervalued in conventional transportation studies. The full extent of walking in particular is difficult to survey, and once surveyed, may be partially "defined out" of trip data by classifying multimodal trips according to a hierarchy that never affords NMT "primary mode" status when combined with motorized travel. This particular analytical problem, among others, is introduced within the "Analytical Considerations" subsection of this chapter's "Overview and Summary." Ironically, the oversight diminishes understanding of one of walking's particularly important functions—the critical system interconnectivity it provides. Walking links homes and businesses to public transit, connects parking facilities with shopping and workplaces, and knits transportation services together.

There are other ways that conventional survey and analysis procedures have contributed to understatement of NMT valuation. One is the heavy emphasis on commute trips, not the province of highest mode shares for NMT. Another is the frequent omission of travel by children, heavy users of the walk and bicycle modes as an alternative to parental chauffeuring. Still another is the poor representation of trips short enough to "disappear" within the confines of traditional traffic analysis zones (TAZs), the finest level of geographic disaggregation typical until recently. Short NMT trips link businesses with each other, offices with restaurants and stores, and homes with neighborhood activities. Only with analysis of such surveys as the 2001 NHTS (and its successor the 2009 NHTS) is the full scope of NMT activity and contributions becoming clearer (Victoria Transport Policy Institute, 2007). It is now understood, still not counting those walk trips linked to auto parking, that some 12 to 13 percent of all trips in the United States involve walking or bicycling either as the only mode used or as part of transit travel (Kuzmyak et al., 2011).

The array of evaluation factors historically employed in motorized-transportation-based planning presents still other set of issues for NMT economic evaluation and equity analysis. Conventional transportation planning focuses heavily on travel time saved as a benefit, and NMT travel generally does not save time. The pedestrian or cyclist, if he or she has a choice at all, trades off acceptance of greater travel time for other benefits. One of these benefits may be cost savings, which *is* covered by conventional analysis, but typically only to the extent of out-of-pocket costs. Other user or public benefits typically go unquantified. If the NMT trip is purely for recreation or exercise, conventional transportation planning offers no metric at all for measuring benefit (Victoria Transport Policy Institute, 2007). In summary, economic and equity analysis for NMT facilities and support is not well developed. The discussion which follows briefly offers a few glimpses of benefits unique to NMT and some indications of the full scope of NMT economic and equity valuations and concerns.

Societal Economic Impacts

On the one hand, as observed in *NCHRP Report 552: Guidelines for Analysis of Investments in Bicycle Facilities*, "the majority of past [NMT benefit-cost] work has a clear advocacy bent; it is not always known how and where much of the data are derived" (Krizek et al., 2006).[85] On the other hand, practically all available NMT benefit analyses—particularly those done with demonstrable rigor—focus solely on one area of concern and thus omit major components of benefit. The very small number with a broader focus have generally been limited in their ability to include the full range, although the Australian example to follow does make the attempt for walking only.

Pedestrian and bicycle facilities and programs provide benefits in many forms. While analyses of a single category of benefit can be instructive, no single benefit category can properly illustrate the overall societal economic impacts. This situation is very important to keep in mind when reviewing the several examples presented here of single-benefit analyses. An unimpressive or even unfavorable benefit-cost ratio for a single benefit may become strongly favorable when the full range of benefits is considered. Indeed, some NMT investment outcomes—such as improvements in quality of life—will require effectiveness (goals attainment) analysis in lieu of benefit-cost analysis to receive due consideration.

Breadth of Benefits. An indication of the breadth of factors worthy of including in NMT benefit and cost analyses is provided by an Australian computation of monetized benefits to society of shifting 1,000 km. of travel from driving to walking. The total value estimated, in 2001 Australian Dollars (AUD), was AUD 181 in the current year and AUD 2,339 over 30 years (Victoria Transport Policy Institute, 2007). Of arguably greater interest, however, are simply the categories of benefit and cost employed and the sign and relative magnitude of the benefits/costs. Table 16-127 lists the benefits and disbenefits considered and the corresponding monetized net-benefit estimates.

Table 16-127 Estimated Value[a] of Shifting 1,000 km. of Travel from Driving to Walking

Benefit/ Disbenefit Category	Current Year	10 Years	30 Years
Vehicle operating cost savings	AUD 113	AUD 819	AUD 1,446
Improved health	84	607	1,071
Crash risk (from increased walking) [b]	-95	-687	-1,212
Crash risk (from reduced driving)	34	246	435
Reduced air pollution	20	145	256
Reduced greenhouse gas emissions	20	145	256
Reduced traffic noise	3	22	38
Reduced water pollution	2	11	19
Total Benefits	AUD 181	AUD 1,318	AUD 2,339

Notes: [a] Estimated in 2001 Australian Dollars, using a 7% annual discount rate.

[b] This computation apparently does not reflect the "safety in numbers" benefit explored above under "Safety Information and Comparisons" — "Other Traffic Safety Issues and Findings" — "Safety in Numbers." Also, it is important to note that the finding of NMT crash risk costs in excess of monetary benefits of improved health conflicts with contrary evidence reported above under "Public Health Issues and Relationships" — "Tradeoffs Between Health Benefits and Crash/Pollution Disbenefits."

Source: Ker – 2001, as reported in Victoria Transport Policy Institute (2007c).

[85] The users of this subsection should be aware that this critique undoubtedly applies to some of the benefit-cost values reported herein on the basis of the available literature.

Another benefits listing, this one from the perspective of bicycling, is provided by *NCHRP Report 552*. "Mobility" is first listed, focusing on the ability of cyclists to reach their destinations faster, more safely, and via more attractive routings when provided with bicycling improvements. "Health" addresses the inducement of more children and adults to shift from inactivity to meeting recommended basic physical activity guidelines. "Safety" covers the benefits of crash prevention, although the researchers reported finding little agreement or conclusive evidence to support safety benefit calculation, except perhaps from the perspective of "safety in numbers" as might be computed for an entire metropolitan area. "Reduced auto use" is set forth as a benefit measure to cover societal benefits of congestion reduction, air quality improvement, and transportation energy conservation. "Livability" is presented as a benefit that can be measured on the basis of housing premiums paid by purchasers of homes with good accessibility to bicycle facilities. "Fiscal" is couched in terms of future cost savings through preservation of linear rights-of-way that may facilitate future transportation uses. "Recreation" is the final benefit introduced. *NCHRP Report 552* offers suggested benefit value computations for mobility, health, reduced auto use, and recreation (Krizek et al., 2006).

Even the benefits listings in Table 16-127 and in *NCHRP Report 552* taken together must be viewed as illustrative and not fully complete. Examples of more benefit categories introduced below include certain revenue benefits, ADA and schoolchild transportation cost savings, and commercial sales increases. Goals attainment categories beyond those covered in the benefit analysis examples include enhanced mobility for the transportation disadvantaged, more travel options for the general population, and support for sustainability. Some benefits are not explicit in the Table 16-127 and *NCHRP Report 552* category headings, but are covered, such as land value enhancements (proposed in *NCHRP Report 552* to quantify "Livability") and expanded opportunities for social interaction (an aspect of "Livability"). At the same time, "the other side of the coin" from benefit omission is benefit overlap or duplication, impermissible in benefit-cost assessments. Given the typical approach to estimating recreational benefits, described below, recreational benefit and health benefit valuations may be duplicative to the extent that exercise and training is an objective of the seeker of recreation.

Health Benefits. The "Improved health" benefit of Table 16-127 is a good example of a benefit not covered in conventional transportation evaluations. Even NMT benefit-cost analyses focused exclusively on public health benefits apparently have their problems. A published review of 16 benefit-cost studies covering health effects of transportation policies with data on walking and bicycling illustrates several issues. The 19 analyses lacked "transparent and standardized methodologies," only three "were considered to be of high quality," and only one was in the United States, the rest having been sited in Europe. The benefit-cost ratios reported for health benefits varied widely. Irrespective of these limitations, the median outcome was a substantial 5 to 1 ratio. One study reported a ratio smaller than one, while the other 15 were all positive in outcome. The one U.S. study covered five trails in Nebraska, for which a benefit-cost ratio of 2.95 was found for health benefits relative to "costs associated with trail construction and use" (Gotschi, 2011).[86]

[86] Benefit-cost ratios are reported in three different formats. A 5 to 1 ratio indicates there is $5.00 of benefit for each $1.00 of cost. This result may also be expressed as a 5:1 ratio, or alternatively, as 5.0, the result of dividing 5 (the benefit) by 1 (the cost). Examples of results indicating lack of cost effectiveness would be a ratio of 0.5:1 or an 0.5 benefit-cost ratio.

CDC studies and other research provide background perspective on health benefits. The CDC has estimated that direct medical expenses attributable to sedentary behavior totaled over 76 billion dollars nationwide in 1987, expressed in year 2000 dollars, for the 88 million inactive Americans 15 years of age or more and without physical limitations. Not included in this figure are indirect costs, such as the lost productivity resulting from the physical and mental disabilities to which physical inactivity contributes. These same estimates of direct medical expenses related to physical inactivity, when adjusted to 1993 dollars and compared to smoking-cost studies, placed inactivity just 9 to 15 percent below smoking-related direct medical excess costs. Adding a rough estimate of indirect costs, the 1987 cost in 2000 dollars of inactivity likely exceeded $150 billion dollars. A 1980s study by RAND estimated that the total costs imposed on society by sedentary lifestyles may actually be larger than those imposed by smokers.

None of these particular estimates directly addresses the question of what could be saved through enhanced walking and bicycling programs and facilities, but the excess societal-cost pool is enormous enough that any draw-down would be quite significant. In a 1990s study specific to active transportation, it was estimated that if 10 percent of U.S. adults were to take up walking on a regular basis, the savings in heart disease costs alone would be an estimated 5.6 billion dollars (Committee on Physical Activity, Health, Transportation, and Land Use, 2005, Committee on Prevention of Obesity in Children and Youth, 2005, Pratt, Macera, and Wang, 2000).

An evaluation of the benefits and the costs of City of Portland, Oregon, bicycling investments made starting in 1991 goes further, focusing primarily but not exclusively on health benefits. Benefits of the increased physical activity engendered were drawn from some of the same studies as those enumerated above plus others. An average per capita estimate of annual health care costs attributable to physical inactivity of $544, inflated to 2008 dollars, was developed. Value of added life, derived using the Health Economic Assessment Tool (HEAT) for bicycling provided by the World Health Organization, was considered in a parallel set of calculations. The statistical value of life employed was $5.8 million, a figure suggested by the U.S. Department of Transportation (Gotschi, 2011).

The replacement cost for Portland's 274-mile network of bikeway improvements, in place as of 2008, was estimated to be $57 million. The cumulative cost of Portland's Smart Trips individualized marketing program and associated promotion and education, from 2003 through 2012, was calculated at $7.2 million. Growth in bicycling, from which reduction in inactivity was derived, was estimated using basically the same bicycle count and mode share data for 1991 through 2008 as presented earlier in the "Response by Type of NMT Strategy" section (see "NMT Policies and Programs"—"New World Program Examples"—"Portland, Oregon"), including the exponential growth rate of 9.6 percent per year in central area Willamette River bridge bicycle volumes from 1991 through 2008. Bridge volumes were translated into bicycle miles of travel using the Portland Metro regional travel model. Decrease in inactivity, corresponding health care cost savings, and also energy savings, were estimated on the basis of bicycle miles over the 1991 baseline.

Cyclists were estimated to have accumulated 109 million miles in excess of baseline cycling by 2008. This translated into $42 million in health care costs saved plus $16 million in saved energy costs. Forward projections were made in line with past experience and Portland's 2030 bicycle master plan to put 80 percent of residents within 1/4 mile of a "low stress" bikeway. It was estimated that cumulative benefits since 1991 would begin to exceed cumulative costs in 2015, on the basis of health care and energy savings alone, without including the statistical value of life saved. The evaluation went further, estimating costs and benefits through 2040, representing a 50-year time span. A benefit-cost ratio of 2.3 to 1 was derived for the "80 percent" plan. Two other options produced benefit-cost ratios of 3.8 and 1.3, and benefit-cost ratios were of the next order of magnitude higher when statistical value of life saved was included. The calculations explicitly excluded opportunity costs, and utilized a discount rate of 3 percent (Gotschi, 2011).[87]

Energy Saving and Emissions Reduction Benefits. The preceding subsection, "Traffic, Energy, and Environmental Relationships," presented generalized energy savings estimates for transit access mode shifts to bike-and-ride from park-and-ride commuting and from auto-only commuting, and also for estimated shifts to bicycling given hypothetical corridor improvements in Tampa, Florida. Neither of these analyses was carried forward to the point of making benefit-cost or rate-of-return calculations.

NCHRP Report 552, apparently focusing on shifts to bicycle-only travel, cautions that "these [auto substitution] benefits are relatively small" and "of only minor significance" (Krizek et al., 2006). This might not be the case for shifts to bike-and-ride from park-and-ride at transit stations, where in the local context the benefits of reduced parking demand may be important, especially where space is constrained and spot emissions of automotive pollutants are critical.

As the last example in the "Traffic, Energy, and Environmental Relationships" subsection, modeled estimates were presented for relative VMT and GHG emissions reductions in response to sidewalk coverage expansion in Seattle and eight of its inner suburbs. These results were carried forward to the point of drawing conclusions, on the basis of elasticity-based sensitivity analyses, about the cost effectiveness "in terms of VMT and CO_2 outcomes" of expanding the proportion of streets with sidewalks. The analysis indicated that there are diminishing returns as full coverage is approached. For the sample under study, adding sidewalks was deemed cost effective up to but not beyond the point of having 1.42 miles of sidewalk per mile of street (as compared to the mean ratio under existing conditions of 1.16). A ratio of 1.42 is equivalent to having sidewalks on both sides of 71 percent of the street mileage (Frank et al., 2011). Obviously, consideration of a broader range of benefits would extend the cost-effectiveness break-even point beyond this degree of coverage.

People with Disabilities Mobility Benefits. The "Pedestrian/Bicycle Linkages with Transit" discussion, within the "Response by Type of NMT Strategy" section, notes that construction of suitable bus stop provisions combined with critical links of sidewalk have been shown in specific cases to be quite cost effective in the service of providing mobility to people with disabilities. The Maryland Mass Transit Administration (MTA) has done calculations of cost savings and capital recovery for constructing improvements that allow a wheelchair-bound patron to use accessible

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[87] The researcher, in excluding opportunity costs and utilizing a 3 percent discount rate, chose not to follow traditional engineering economic analysis protocols and U.S. Federal guidelines stating that benefit-cost outcomes should be "determined using a real [inflation-free] discount rate of 7 percent" (Office of Management and Budget, 1992). However, FHWA guidance observing that state governments mostly use 3 to 5 percent for discounting highway investments, based on "best practice" real discount rate calculations, was not violated (Federal Highway Administration, 2011). Indeed, some authors hold that benefits of life and health should not be discounted at all, although in other circles such deviations from uniform discount rate applications are held to be inadvisable. New federal guidance is anticipated. Meanwhile, a recent reassessment has recommended the social opportunity cost of capital approach and used it to determine real discount rates—for benefit-cost analysis—in the range of 6 to 8 percent (Burgess and Zerbe, 2011). Recomputation at a 7 percent discount rate would substantially lower the estimated Portland bicycle program benefit-cost ratios (Federal Highway Administration, 2011) and might well lead to one or more with a ratio less than one. On the other hand, inclusion of more benefits than the two considered, or of benefits of shared-use facilities to walkers, would tend toward counterbalancing the effect of a higher discount rate.

fixed-route bus service instead of having to receive and rely on federally-mandated ADA paratransit door-to-door service. MTA estimates its fully-loaded cost of ADA paratransit at $76.64 per one-way trip. They find the capital cost of simple bus stop "landing" improvements, inclusive of minor sidewalk improvements, to average $7,000 per stop. More extensive improvements can come to $58,000 per stop on average.

Assuming these improvements allow an ADA paratransit patron who uses the service 5 days a week (10 trips) to switch to fixed-route bus service, MTA estimates the lesser of these capital costs will be recovered in 10 weeks from ADA paratransit cost savings. The more extensive improvements take an estimated 18 months for capital cost recovery (Goodwill and Carapella, 2008).[88] There are also benefits to the user, who is no longer constrained to ADA paratransit trip prearrangement and reliability issues. This one example of benefit to the disability community and savings to providers of services to people with disabilities is likely representative of a number of other savings that could accrue from ADA-compliant sidewalk provisions and improvements in general.

Transportation Cost Savings Benefits. A transportation cost saving benefit example, in addition to the one used above as a stand-in for people with disabilities mobility benefits, comes from school transportation operations. The Auburn School District in Washington State initiated an early SRTS program both to address childhood obesity and the high cost of running school buses. A late 1990s pilot project, with $121,770 in state funding, focused on infrastructure improvements paired with education plus student walk-to-school tracking and recognition. A $185,000 federal SRTS infrastructure grant followed in 2007, but results presented here pertain to a time prior to full federal project completion. With more students walking, reaching a milestone of 20 percent walk mode share, it has been possible to scale back school bus service. Transportation cost has been reduced by $220,000 annually. This savings equates to 180 percent each year of the one-time pilot grant, or 72 percent of the pilot grant plus the full amount of the partially implemented 2007 federal grant (Pedestrian and Bicycle Information Center, 2011). The overall Auburn SRTS program was introduced in the "NMT Policies and Programs" section (see "Schoolchild-Focused Programs"—"Infrastructure and Traffic Engineering Improvements").

Transportation Revenue Benefits. Benefits of increased transportation revenue have only been examined in the case of individualized marketing (see "Response by Type of NMT Strategy"—"Walking/Bicycling Promotion and Information"—"Individualized Marketing"). Benefits of shifts to active transportation accruing from this informational and promotional strategy should logically be as broad as the list in Table 16-127. Nevertheless, most individualized marketing rate-of-return computations provide examples of focusing on only one clearly tangible benefit if that alone is sufficient to demonstrate cost-effectiveness. Individualized marketing generally produces shifts to public transportation along with walking and cycling, and the tangible benefit typically selected for cost-effectiveness demonstration is the incremental increase in those transit farebox revenues attributed to the individualized marketing program under study. It could be argued that this is not a walking or bicycling benefit, but it must be remembered that much access and egress walking takes place as part of transit riding, and in any case the added revenue accrual is an outcome of the individualized marketing expenditure.

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[88] The cited source gives the longer cost recovery period as "eighteen weeks" (sic) but other information provided, along with data in an FHWA/FTA Transportation Planning Capacity Building Program Peer Workshop Report (including a presentation by C. Scott Windley of the United States Access Board at the May 7, 2007, meeting in Nashville, TN), clearly indicates "eighteen months" was meant.

Many examples of this benefit-cost analysis approach predate the inclusion of the walk-only and bicycle-only travel modes as options promoted by individualized marketing. In those early (1990s) applications, primarily in Germany and other European countries, the benefit-cost ratio was typically in the 3:1 to 4:1 range with full coverage of costs in the first year (UITP and Socialdata, 1998). Economic analyses based on this transit revenue measure alone will, however, probably show cost effectiveness only in those metropolitan areas with substantial transit usage.

An example of a first-year *rate of return* calculation comes from the city of Linz, Austria. Based only on cost recovery from increased transit revenues, the first year rate of return for individualized marketing costs was in the range of 1.1 to 1.6 (more than 100 percent cost recovery in the first year). Similar calculations for conventional direct marketing in Linz obtained only an 0.5 first year rate of return, not cost effective (Ashton-Graham and John, 2006).

Individualized marketing benefit-cost analysis in South Perth, Australia, a situation more comparable to those seen in North American cities, examined a broader range of benefits of which transit net fare revenue gain contributed the next to largest component. It accounted for 1/3 of all monetized benefit after deduction for additional bus capital costs. The largest benefit, at just over 1/3 of the total, was avoided road construction costs. The remaining benefits computed, summing to not quite 1/3 of the total and listed in decreasing order of importance, were public health savings from reduced air pollution, avoided traffic control costs, and public health savings from improved health and fitness. Benefit-cost estimates were prepared in 2002 covering rather long time periods for a marketing strategy, arriving at benefit-cost ratios of 44:1 for 10 years and 77:1 for 25 years (Parker et al., 2007). Contemporary follow-up surveys following the South Perth full-scale application showed durability of shifts to walking and bicycling for at least 4 years, but with a decay in the shifts to bus transit after 18 to 24 months, as illustrated in Table 16-61 within the "Individualized Marketing" discussion cross-referenced above (Australian Government, 2005).

A consulting study done for the U.K. Department for Transport reported that the early individualized marketing pilot projects undertaken in England had been found to exhibit an average benefit-cost ratio of 31:1. The consultants advised that benefit-cost analyses of individualized marketing taking a broad range of impacts into account typically report positive ratios on the order of 30:1, and that individualized marketing cost effectiveness appears to improve "as the scale of implementation is increased" (Parker et al., 2007). The proportion of benefits attributable to transit net fare revenue gains was not specified in the published reporting of U.K. experience or advice.

Recreational Benefits

Net economic impacts of NMT facilities can legitimately include user benefits not covered from transportation or public health perspectives. For example, quality of life improvements—such as availability of a preferred recreational venue—offer tangible value to users. Since use of NMT facilities is usually free, such value represents consumer surplus: benefit received that does not incur user cost through pricing. Valuation procedures have been developed to address consumer surplus in such instances. Although these approaches likely produce user benefit valuations that include certain effects already captured in transportation- and public health-based benefit-cost analysis, the overlap is only incidental, and it is instructive to look at typical recreational benefit results.

Shared use paths are the facility type most obviously possessed of characteristics that would produce recreational and associated benefits, although it could well be argued that a sidewalk system or bicycle boulevard in a pleasant neighborhood should produce quality-of-life value. A case example involving an off-road rail-trail is provided by economic benefit valuations prepared for the Washington and Old Dominion (W&OD) facility in Northern Virginia. The W&OD Trail extends some 45 miles west from Alexandria, Virginia, through urban, suburban, exurban, and rural communities. The analysis technique applied relies on relating the number of trips taken to costs incurred in traveling to the facility. Empirical data for the W&OD model were obtained from surveys taken in 2003–04 using a nonprobability quota sampling approach. Two functional forms of regression model were used, with variables including annual W&OD trips, round trip access distance and time, perceived availability of a viable substitute recreational venue, annual household income, and group size (number of W&OD users in the household). Travel cost for access was assumed to be $0.131/mile, with no cost for time. Only users whose trail-use purpose was recreation, and who did not live directly on the trail, were included (Bowker et al., 2004).

The two different mathematical functions employed, truncated negative binomial and truncated stratified Poisson, produced consumer surplus estimates per trip of $9.08 to $13.63 in 2003 dollars. Consistent with other studies, W&OD per-user trip making activity was found to be negatively related to group size. Income and perceived availability of suitable recreational alternatives did not prove to have statistical significance, although the variables were retained in the model for logical consistency. Survey respondent reporting of benefits important to them would suggest that perceived health benefits were the primary area of potential overlap with transportation- and public health-based benefit-cost analysis.

W&OD Trail usage was estimated at 1,707,000 visits per year. Setting aside persons estimated to be commuting or “not on a primary purpose visit to the trail,” the $9.08 to $13.63 per trip benefit estimates translated into approximately $14.4 to $21.6 million in annual recreation value. By comparison, comparable estimates for the similar but shorter (7.6 mile) Lafayette/Moraga Trail in the San Francisco East Bay Area, converted to 2003 dollars, were $5.82 to $20.22 per visit depending on the statistical model, or $2.3 million annually. Aggregate annual recreational value estimates for two U.S. trails more rural in character were, in 2003 dollars, $5 million and $10.6 million annually (Bowker et al., 2004). An estimation for the Monon Trail in Indianapolis, detailed further below in connection with off-road path added land value and benefit-cost estimation, gave an annual recreational benefit of $3 million (Lindsey et al., 2004).

Land Value and Commerce Impacts

Financial benefits in terms of increased land value and added commerce do not fit neatly within existing categorizations of societal economic impacts. Together with recreational benefits, they make up an almost “parallel universe” of approaches to valuing NMT facilities, or in some cases, approaches to validating that reallocation of street space to NMT does not detract from the conduct of commerce. No global attempt to rationalize these approaches amongst themselves or to integrate them with the types of societal economic impact analyses discussed above has been found. Lacking an overall NMT economic impact paradigm, the following presentation of land value and commerce impacts simply starts with walkability and path/trail effects on property salability and value, then moves into commerce impacts of trails, and concludes with several perspectives on downtown commerce impacts.

Neighborhood Walkability Effects. Home buyers, despite desire for a larger home and highway access, were found in a National Association of Home Builders and National Association of Realtors survey to be concerned about neighborhood walkability. Top-ranked out of 18 listed community amenities were: highway access (44 percent), jogging/bike paths (36 percent), sidewalks (28 percent), parks (26 percent), playgrounds (21 percent), and shops within walking distance (19 percent) (Victoria Transport Policy Institute, 2007).

Land Values and Off-Road Paths. The economic benefits of shared use, off-road paths and trails have been fairly extensively reported upon, although many of the available studies have focused on rural rather than urban-area facilities. No one study has been encountered that seems to cover all the different types of benefits isolated in individual studies. Paths join other NMT facilities in providing transportation and health benefits of the types already discussed, along with user benefits examined under "Recreational Benefits." There are also land value and commerce impacts. Many of the available impact assessments, such as provided below for the Pinellas Trail, border on the anecdotal but nevertheless provide useful insights.

The implementation and early years of the Pinellas Trail in Florida were accompanied by successful downtown revitalizations in Dunedin, Largo, and Tarpon Springs. These positive developments have been largely attributed—at least by some—to presence of the trail and its users. The Pinellas Trail is a rail-trail. It has been theorized that since now-gone rail lines often dictated the original pattern of community location, the old alignments frequently provide downtown to downtown connectivity, such that trail conversion reestablishes historic linkages—with accompanying economic benefits (Guttenplan and Patten, 1995).

The Indiana Trails Study of six urban, suburban, and rural trails throughout the state sought quantitative data. Trail neighbor surveys found, among the six trails, that 60 to 88 percent felt their trail had improved neighborhood quality. Some 86 to 95 percent perceived that their trail had either increased or had no effect on their property value, and 81 to 93 percent felt that the trail would make it easier to sell their property or would have no effect on ease of selling. Realtors, however, in focus group settings, reported not seeing either major increases in property value or ease of selling (Indiana University, 2001).

A subsequent study in Indianapolis alone sought to capitalize possibly elevated home sale prices along greenways and trails. The study was designed to explore relationships between property values and public choices about public investments having significance to the housing market. After quantifying the effect of property characteristics such as housing age and number of bathrooms, it was established that neighborhood characteristics ranging from property taxes to school quality (expressed as test scores) have significant effects on housing values. Then, with the study's final three hedonic property value cross-sectional models, it was determined that greenways (some with trails) have important and mainly-positive effects on prices. These effects are almost all significant, although not as strong as for property and neighborhood characteristics. Adjusted R^2 values were 0.79 for all three models.

Model 1 differentiated between location within 1/2-mile of the central feature of a greenway and location outside that band, but did not differentiate between greenways with and without trails. It estimated that location adjacent to a greenway corridor was worth $3,700 in the price of a home. Model 2 made the trail/no-trail differentiation. It estimated the average added value of adjacency to a greenway without trail at $5,300 versus $4,400 for a greenway with trail. Finally, Model 3 further differentiated between the "flagship" trail of Indianapolis, the Monon rail-trail, and other greenways with trails. It found a sales premium for location within 1/2-mile of the Monon Trail of slightly over $13,000, nearly $4.4 million dollars total of added value for the 334 sales along the Monon in 1999. In Model 3, adjacency to a greenway without trail was worth $2,200 in home value, but the effect of being next to a greenway with a trail other than the Monon was not significant and slightly negative (Lindsey et al., 2003).

The Monon Trail results alone were expanded to estimate the added value accruing to all 8,862 households located near the trail, rather than just those sold in 1999. Applying the average trail vicinity sales premium to all the homes within 1/2-mile, an added home value estimate of $116 million was obtained. It was noted that such estimates represent an approach to valuing "amenity or ecological values" of greenways that accrue with or without active use (Lindsey et al., 2004).

In conjunction with this estimate, recreational benefits of the Monon Trail were also calculated, using a variation of the opportunity cost estimation procedure described above in connection with W&OD Trail recreational benefits derivation. The primary differences were the inclusion of all trips, with round trips counted as one trip; inclusion of cost of time to access the trail, with time value taken to be 1/2 the prevailing Indianapolis wage rate; and the use of four distance-zones of access. Automotive driving costs were not applied to users in the closest zone, who were assumed to use walk or bike access, and were applied to only one-half the users in the next zone out. In this manner, applying a late 1990s-based usage estimate of 373,581 visits, the Monon Trail recreational benefits were estimated as a total consumer surplus of approximately $3 million.

The Monon Trail economic analysis researchers posited that land value and recreational benefits estimates are largely complementary, with only limited aspects having risk of overlap. Adding the two benefits estimates, they developed Monon Trail benefit-cost ratios on the basis of trail construction and maintenance costs, a 10-year time frame, and a discount rate of 6 percent. The result was an estimated benefit-cost ratio of 5.7. In a sensitivity analysis, the researchers recalculated the estimate excluding the value of travel time in the recreational benefits recomputation, and arrived at a lower-bound benefit-cost ratio of 2.9 (Lindsey et al., 2004), still a substantial return.

A cross-sectional research model for estimation of the value of bicycle facilities as capitalized into home sale prices was also developed for the Minneapolis-St. Paul Twin Cities area, and similarly obtained non-uniform land value results. The Twin Cities area at the time of the study had 1,692 miles of shared use off-street trails and a number of on-street bicycle facilities as well. Physical housing attributes, city versus suburban location, distance to open space, school district and population measures, and distance to downtowns and highways, were all included as model variables. Three types of bicycle facilities were assessed: on street bicycle lanes, shared-use off-street trails in a non-roadside position, and shared-use off-street roadside trails more-or-less in a "sidewalk" position. Substantial differences were found between city and suburban price relationships, similar to earlier Twin Cities research on value of open space proximity and size.

Bicycle facility amenities, like open space amenities, proved to be more valued by city dwellers than suburbanites. Overall, the effects on home prices of bicycle facility proximity were estimated to be limited given all the other modeled considerations involved in home valuation. Measures of facility extent were not significant. Proximity of shared-use off-street trails in a non-roadside position was valued positively in city locations, but proximity of roadside trails was valued negatively, and presence of on-street bicycle lanes was not found to be significant. In the case of suburban locations, proximity was estimated to be a negative factor for all three facility types. The suburban relationship being different than the city relationship for shared-use off-street trails in a non-roadside position, the researchers offered several possible explanations. These included possible suburbanite lack of interest and overriding desire for seclusion, the wintertime use of exurban trails by snowmobiles, and legacy effects in the case of the many rail trails, wherein lingering depression of property values owing to railroad proximity may still pertain (Krizek, 2006).

Commerce Impacts of Off-Road Paths. The commerce impacts of paths and major NMT bridges have one aspect largely unique to these particular types of facility. This aspect might, for easy identification, be called the "tourist dollars" contribution of the facility to the economy. More formally, what is of interest in this regard is the local economic impact of non-local trips attracted to the path or other facility in question. Economic impact evaluation protocol does not allow inclusion of visitor spending by local residents or of non-local visitor spending outside the local area. The W&OD

Trail economic studies introduced in the "Recreational Benefits" discussion did, nevertheless, develop an estimate of total spending as a matter of general interest. The trail, very much oriented to use by local residents, was found to generate about $5.3 million annually in local economy expenditures by local resident users. The non-local visitor contribution, examined further below, equated to some $1.4 million annually, bringing the total local expenditure to on the order of $7 million annually. The grand total recreational spending associated with the W&OD Trail, when non-local spending was included, was determined to be an estimated $12 million annually (Bowker et al., 2004).

The W&OD non-local trail user spending contribution to the local economy, the spending deemed legitimate for economic impact analysis, was found in surveying to consist of lodging (25 percent), restaurants and bars (42 percent), groceries and carry-out (6 percent), gas and oil (22 percent), use fees (4 percent), and miscellaneous (1 percent). The total per individual visitor was $15.40. The W&OD Trail's percentage of non-local users was determined from survey responses to be just 5.24 percent. The $1.4 million annual direct effects contribution to the economy derives from 5.24 percent of the 1,707,000 estimated annual visits making the average expenditure, within 25 miles of the facility, of $15.40. Using a National Park Service "Money Generation Model" (MGM2), indirect and induced effects were added in. In this manner, the total boost to the local economy flowing from non-local visitors to the W&OD Trail was estimated to be $1.8 million of economic output, 34 jobs (full-time equivalents), and $642,000 in personal income (Bowker et al., 2004).

The W&OD Trail is a long-established radial facility, opened in stages from 1974 to 1988. It also lies adjacent to the Nation's Capital and extends a lengthy 45 miles, so it is important to consider that the commerce impacts may be less impressive for other urban-area paths not as ideally situated relative to a well developed path visitor market. For example, the Indiana Trails study set out to do a similar analysis on the six trails it examined. So few of the intercepted trail users were visitors, as compared to trail neighbors, that the sample of expenditure data was deemed too small for reliable reporting (Indiana University, 2001).

Analysis of a 27-mile section of the Little Miami Scenic Trail, at the time of the study a 60 mile suburban, rural, and small-town facility just east of the Dayton, Ohio, urban area, found a $13.54 per person per visit non-durable-goods expenditure. The largest expenditures on average were for restaurants and auto-related costs. Trail visits for the 1996–97 study year were estimated at 150,000 to 175,000 annually. The study area was within Warren County, and of the total dollar value, 77 percent was expended in the county. Virtually all the remaining expenditures were in other Ohio counties (Ohio-Kentucky-Indiana Regional Council of Governments, 1999). The result of multiplying the Little Miami Scenic Trail average non-durable-goods expenditure of $13.54 by the 150,000 to 175,000 annual visitors is $2.0 to $2.4 million, or $1.6 to $1.8 million if restricted to Warren County expenditures. This range of figures should roughly compare with the $7 million grand total annual local economy expenditures seen for Virginia's W&OD Trail.

Downtown Pedestrianization Effects. Scattered economic data is available for introduction of pedestrian zones and malls, primarily for those deemed successful. Boston's Downtown Crossing pedestrian zone was created in 1978 and beautified in 1979. Despite increasing competition from other areas such as Faneuil Hall Marketplace, store visits from 10:00 AM to 4:00 PM weekdays were up 6 percent in 1980, compared to 1978 before the closing of streets to private auto traffic. Individual purchases were up 26 percent. High-end purchases declined somewhat, however, such that the total dollar value of all purchases increased at the same rate as upkeep-goods-and-apparel price inflation. Most of the pedestrian and associated retail activity increase was attributable to midday visits by nearby office workers, and their typical midday purchase price was modest (Weisbrod and Loudon, 1982).

Sales increased by 30 percent on Copenhagen's Stroget, consisting of three contiguous streets in the main shopping district, after it was closed to motor vehicles in 1962. In East Anglia, England, London Street merchants saw sales increases of 5 to 20 percent. The busy State Street Mall in Madison, Wisconsin, a transit mall, was found in the mid-1980s to have average base rents for fronting commercial space of $9.87 per square foot, relative to a downtown average of $8.15. The on-mall vacancy rate was 3.4 percent (Robertson, 1994). The typical U.S. pedestrian mall was not found capable of stemming downtown decline on its own, however, as discussed under "Response by Type of NMT Strategy"—"Pedestrian Zones, Malls, and Skywalks"—"Pedestrian Zones and Malls."

In Minneapolis, the "percentage of metropolitan area residents who 'shopped downtown within the past month' " declined from 48 percent in 1965, to 42 percent in 1967—the year the Nicollet transit mall opened, and to 33 percent in 1969. A 1973 survey indicated stabilization or perhaps even a little recovery, with post-1970 Nicollet Mall retail sales data also suggesting at least temporary stabilization. In any case, declines notwithstanding, surveys of major Nicollet Mall retailers in 1977 encountered almost universal enthusiasm for the transit mall. The owner of a 20-store chain, that included suburban mall anchor stores, noted that the Nicollet Mall department store had the strongest sales. Property owners in the entire transit mall assessment district agreed to pay for a four-block extension. Of 21 merchants on the mall answering a survey question that asked them to imagine freedom to move, 18 indicated that they would stay at their present location or relocate elsewhere on the Nicollet Mall.

Secondary economic indicators, including rental rates and new investment, provided more positive conclusions for the Portland and Minneapolis transit malls. In part this may be because the retail sales data "did not take into account new businesses." The Urban Mass Transportation Administration's Service and Methods Demonstration Program review concluded that the transit malls in Portland, Oregon, and Minneapolis (along with a now-dismantled mall in Philadelphia) "appear[ed] moderately positive" in their economic impact on business (Edminster and Koffman, 1979).

Downtown Skywalk Impacts. A rather unique case of benefits accruing from pedestrian improvements is presented by downtown skywalk systems. Skywalk benefits may include pedestrian and vehicular delay reduction, pedestrian system climate control, concomitant increases in walking activity, intersection traffic flow improvements, related transportation energy and pollution reductions, and land redevelopment impetus. In downtowns with enough inherent drawing power, a second level of retail-commercial and service establishments may develop without necessarily detracting from ground-level potential. A Minneapolis-St. Paul review done after 5 years of Skyways experience found building managers were reporting that second-level rents had increased from "marginally to considerably below" street-level rents to "equal or above" street-level rents. At the same time, street-level rents reportedly did not suffer. Preliminary evidence did suggest, however, that commercial space at the fringes of the central business districts (CBDs) might be negatively impacted, indicative of a possible compaction of retail and service activities (Podolski and Heglund, 1976).

Indeed, circa 1980, St. Paul vacancy rates for buildings on their Skyway system were found to be less than 1/4 the rate for buildings not connected. Subsequent study in St. Paul, the city cited by several observers as the skywalks city where street-level retail decline is readily evident, found that 3/4 of downtown retailing was taking place in the Skyway level by 1994. Downtown retailing had continued to increase, but was paired with a steady movement from ground floors to the Skyway level. The average annual lease rate had become $10.58 per square foot on the Skyway level, versus $8.90 for first floor leases (Robertson, 1988 and 1994). Building design factors specifically affecting the St. Paul situation were discussed under "Response by Type of NMT Strategy"—"Pedestrian Zones, Malls, and Skywalks"—"Pedestrian Skywalks"—"Urban Planning Considerations."

A benefit-cost estimate prepared in advance of Des Moines skywalk system implementation estimated a total annual benefit of $561,600 relative to an annualized cost of $375,000 (values in 1978 dollars). The benefits monetized in this case covered only savings in pedestrian and vehicular delay at intersections, along with related vehicle fuel consumption reductions, although an estimate of 6.5 tons in annual emissions reductions was also prepared based solely on reduced vehicle idling at intersections. The findings resulted in declaration by the FHWA that the proposed skywalk system was eligible for Federal Aid Urban funding (Heglund, 1980).

Commercial Street Modification Impacts. When pedestrian or bicycle improvements along an urban street require reduction in parking, the general expectation is that merchants will lose business. This perception, right or wrong, has delayed or derailed countless NMT improvements. Investigators in Toronto addressed this viewpoint head-on with merchant, pedestrian, and parking surveys along Bloor Street in the Annex Neighbourhood. This neighborhood is in the older city, with the University of Toronto nearby, and has commercial development along Bloor Street.

The typical (median) Bloor Street merchant was found to believe that close to 25 percent of their customers drove to the area. (Sidewalk surveys found 10 percent of interviewees to have come by car.) Despite this belief, almost 75 percent thought that installing bicycle lanes at the expense of one-half the on-street parking would either improve or not affect their business, with 25 percent of businesses feeling that they would be adversely affected. Thus past opposition of city council members to Bloor Street bike lanes was found to have apparently rested in part on misconception of merchant positions on the matter. Surveyed merchant reaction was almost the same to widening sidewalks at the expense of one-half the curb parking. Interestingly, while sidewalk survey respondents overall preferred either a bike lane or sidewalk widening to not tampering with the parking supply, they also preferred a bike lane to widened sidewalks by a ratio of almost 4 to 1. This may have been because the sidewalks were already 4 meters (13 feet) in width and the survey did not indicate what additional width might be used for (Sztabinski, 2009).

Overall Bloor Street merchant intuitions appeared to be backed up by investigation of spending patterns. The median reported monthly expenditure at stores in the area was squarely within the $100–$499 (Canadian) range for surveyed pedestrians who indicated they usually came to the area solely by walking (46 percent mode share). The median for pedestrians who usually arrived by bicycle (12 percent mode share) was in the same range, but with more spending less and fewer spending more. Median monthly spending by transit riders (32 percent mode share) and private vehicle users (10 percent mode share) was the range of $25–$99 (Sztabinski, 2009). Of course, an intercept survey of the type used would naturally tend toward picking up frequent visitors more than infrequent visitors, and the per-month expenditure findings do not speak directly to average expenditure per visit.

A roughly similar study in the SoHo district of Manhattan that asked only about sidewalk widening found 42 and 48 percent, respectively, of those who had shopped or dined on Prince Street in the last month thought that they would be likely to come more often with widened sidewalks and less parking. In contrast, 7 and 8 percent indicated they would come less often. The surveyed section of Prince Street, between Broadway and 6th Avenue, has quite crowded sidewalks (Schaller Consulting, 2006). Toronto's Annex Neighbourhood and Manhattan's SoHo both have intensive public transit service, undoubtedly a factor in the study outcomes.

Equity Issues

Equity for the Transportation Disadvantaged. The improved survey methodology of the National Household Travel Survey (NHTS) has allowed demonstration as never before of the importance to the poor and minorities of good accessibility to daily activities and transit stops for persons traveling on foot. Walking is not only the most affordable of all transportation modes, but also it is the most important means of reaching public transit. According to 2001 NHTS results, persons in households earning less than $20,000 per year make 16 percent of their daily trips solely by walking, versus 8 to 9 percent for persons in families with more income. They also make 38 percent of their daily trips by transit, a travel mode shown to involve substantive walking, compared to a range of 7 to 20 percent for income categories over $20,000. Comparisons are four or more times as dramatic for households without a private vehicle versus households with one or more vehicles (Pucher and Renne, 2003). (For more specifics, see the "Income" and "Automobile Ownership" discussions along with associated tables within the "User Factors" subsection of the "Underlying Traveler Response Factors" section.)

The 2007 Benchmarking Project covering U.S. bicycling and walking provided a basis for examining possible equity issues through the lens of comparison between proportion of non-white workers using NMT commute modes and proportion of all workers using NMT modes.[89] Only a slight difference was found in the case of bicycling, with 0.46 percent of non-white workers bicycling to work compared to 0.43 percent of all workers. A significant difference, however, was exhibited by the walk mode. The walk commute share of 3.6 percent non-white workers is 1/3 more than the 2.7 percent walk share for all workers (Thunderhead Alliance, 2007). The bicycling statistics thus provide only a small and tenuous indication of minority persons being especially captive to the bicycle mode. There is stronger indication, on the other hand, of dependence on the walk mode and of likely related inequities, particularly where pedestrian facilities may be generally inadequate.

The adverse impact of inadequate pedestrian infrastructure on transportation disadvantaged populations is underscored by the already-discussed examination of neighborhood sidewalk provisions and associated pedestrian characteristics in 12 Seattle neighborhoods, six "suburban" and six "urban." The neighborhoods were matched for population density, land use, and approximate income levels, and were also found to have similar per-person auto ownership rates. The suburban neighborhoods were deficient, however, on any number of pedestrian facility and related neighborhood design measures, while the urban neighborhoods did well on these measures. It appeared that the pedestrian facility and design deficiencies had to be a primary explanatory factor for why the "suburban" neighborhoods averaged only 1/3 the amount of walking to each neighborhood's local commercial center compared to the "urban" neighborhoods.

The suburban pedestrians who were observed were disproportionately young people and persons of color, taken as an indication of persons who do not or may not have the option of driving. On average, 41 percent of the suburban pedestrians were under age 18, 180 percent higher than in the neighborhood population, while in urban sites the proportion (16 percent) more or less matched the local population. The high proportion of young pedestrians and pedestrians representing disadvantaged minorities, combined with lack of appropriate pedestrian facilities in the suburban sites, raises significant equity issues. It also raises safety concerns, for the younger persons especially, and for the pedestrians with disabilities observed at three of the suburban sites (Hess et al., 1998, Moudon et al., 1997). Additional information on this revealing analysis is found in the "Pedestrian Activity Effects of Neighborhood Site Design—Seattle" case study below.

The income-based equity case for bicycle facilities is not as strong as for walking facilities in terms of absolute numbers of current usage. Nevertheless, the fact that the 2001 NHTS found bicycling mode

[89] The 2010 Benchmarking Report was not used for this assessment because of a change in method of comparison that would seem to allow differential unemployment rates to possibly cloud conclusions.

shares for zero-car households (2.4 percent) (see Table 16-78) that were three times the bicycling mode shares for households owning vehicles (0.8 percent) (Pucher and Renne, 2003) illustrates that the equity advantages of providing safe and useful bicycle facilities should be a part of bicycle planning, design, and benefit analysis. Indeed, bicycle use by persons with limited transportation options could likely be more extensive were there better bicycle facilities in poorer neighborhoods.

Equity of Access. There are also facility-access equity questions, which take more than one form. One access equity manifestation is illustrated by the instance of differing categories of bicyclists vis-à-vis facility type availability. The concern in this case is equity in provision of facilities to support cycling by not just skilled bicyclists but bicyclists of all skills, ages, and degrees of real or perceived risk toleration. The discussion found in the "Response by Type of NMT Strategy" section under "NMT Policies and Programs"—"European Programs and Comparisons" illustrates how countries with the most intensive NMT programs, including extensive systems of separate cycling facilities, achieve gender balance in bicycling mode shares—along with bicycling shares for persons over 75 years of age that approach or equal shares for younger cohorts. In contrast, countries that rely more on "vehicular cycling" (bicycling in mixed traffic), such as the United States, see gender distributions that are on the order of 1/4 female and 3/4 male. They also have bicycle mode shares that decline with age—to the point of being vanishingly small over age 65 (Pucher and Buehler, 2008b, Pucher and Buehler, 2009a). These disparities are suggestive of category-of-cyclist bicycle network access inequities.

The sharply differing user type distributions of off-road shared use path users compared to mixed traffic bike route users are highlighted in the findings on Rock Creek hiker-biker trail versus Beach Drive bike route user characteristics presented within the case study "Special Mini-Studies in Montgomery County, Maryland" (see "More—Off-Street Versus On-Street NMT User Mix," including Table 16-129). These parallel-facility classification count results show use of the trail by a wide spectrum of cyclists including cyclists-in-training (and also joggers and walkers), while the on-road route attracts a narrow spectrum composed—by all appearances—of sports-minded adult cyclists in their prime.

Facility-specific observations such as this offer confirmation for studies that use aggregate data to conclude that separate facilities are especially important for the less skilled, less fit, and less daring. Provision of separate on-road cycling facilities and shared use, off-road paths thus becomes a form of social justice, facilitating engagement of a much broader spectrum of the population in cycling for pleasure, exercise, and utilitarian travel (Pucher and Buehler, 2009a) and—in the case of off-road facilities—serving walkers and joggers as well. In a sense, this situation exhibits a rough parallel to the decision already made in the United States that pedestrian access must be opened up, by means of ADA-compliant design, to persons with disabilities.

Note that the role of non-separated bike lanes and bicycle boulevards in serving the various categories of bicyclists is less clear given the relative lack of user-type studies on these facilities. However, information of the type presented in the "Trip Factors" subsection of the "Underlying Traveler Response Factors" section (see "Bicycle Trip Distance, Time, and Route Characteristics"—"Bicycle Route Choice") suggests that bicycle lanes are more attuned to the proclivities of adult, frequent, often-commuter bicyclists, while bicycle boulevards and other quiet streets may serve a broader clientele, especially inclusive of female cyclists.

Another access equity manifestation is that of pedestrian/bicycle facility location, and facility access-point proximity. A proximity-equity study of the trail system in Indianapolis, done on the basis of that which was in place as of 1999, examined the populations living in census tracts at least partially within 1/2-mile. It found that the completed trail segments were adjacent to a population that was poorer and with a higher proportion of African Americans than Indianapolis-Marion County as a whole, with more households lacking vehicles and high school diplomas. The study noted, however, that as the trail system expanded it would become more focused on higher-income populations with smaller non-white components (Lindsey, Maraj, and Kuan, 2001). Limitations in this proximity-based methodology could include lack of recognition of multiple versus more limited trail access options and failure to identify lack of access imposed by long segments without access points, such as might be imposed by a rail trail on high embankment or a riparian trail somewhat isolated from the street system.

A more sophisticated analysis of the Indianapolis trail system was subsequently undertaken, this time as of 2006 with more trail mileage in place. The research, actually focused on development of improved use-forecasting methodologies, sought to supplement or replace simple proximity measures with an accessibility measure or measures. A Hansen gravity-model-based accessibility measure was employed in logistic regression models keyed to estimation of trail use on the basis of socioeconomic descriptors and facility accessibility. Four sets of models were tested, one without distance or accessibility as variables, one with distance from the home but not accessibility, and two with accessibility but not raw distance. The models exhibited progressively better fit, with Pseudo-R^2 values of 0.07, 0.13, 0.14, and 0.14, respectively, for the models of usage in the previous month. Importance of ethnicity variables provided a tentative indication of equity. Even without a distance or accessibility variable, neither the proportion of African Americans nor the proportion of non-Hispanic whites proved viable as model variables (Ottensmann and Lindsey, 2008). This may suggest, if the result is not clouded by other factors, that these groups were equitably served by the 2006 trail system.

The variable for Hispanics was significant and positive in both the trail usage model and the use frequency model. It became insignificant in the trail usage model when an accessibility measure (but not the raw distance measure) was included. It remained significant in all trail use frequency models, but shrank progressively in size as raw distance and then accessibility were introduced. These results may possibly indicate above-average trail accessibility for Hispanic populations. The researchers urge caution, however, noting that a less-indirect application of accessibility measures to calculate access equity (such as has been done for playgrounds and public libraries) would be more promising as an indication of relatively underserved or overserved populations. As a matter of interest, accessibility proved to be a strong variable in the trail use research models. Income over 300 percent of poverty level, college graduation, and age less than 65 years were also strong markers for trail usage and use frequency (Ottensmann and Lindsey, 2008). The income, education, and age results do not necessarily indicate inequity, as the effects may have been uniform across ethnic groups.

Access may also be a skywalk use equity factor, perceived by some as reflecting a tendency of skywalk systems to segregate persons in the downtown by economic class. In this view, the lower-rent uses and the people who patronize them are left on the ground floor and outside the skywalk network.

A 1988 five-city survey of skywalk pedestrians indeed found a perception that the typical skywalk user was a white-collar worker of the white race, more often female than male, and more likely to be earning a high income than a modest one.[90] Duluth was somewhat of an exception, thought to be a reflection of the large presence of mining and shipping industries. Cincinnati skywalk use was perceived to be the least office-oriented and most heterogeneous, including use by large numbers of minorities. Two contributors to this more diverse use were noted. An obvious factor was the more varied makeup of downtown Cincinnati itself. A second (hypothesized) factor was provision of direct skywalk connections to sidewalks, and the skywalk system's coordination with a major open space, Fountain Square. The other four skywalk systems were—at the time—accessed solely

[90] This 8:30 AM to 6:30 PM non-random survey did not quantify socio-economic characteristics directly, but instead asked structured questions designed to obtain perceptions of fellow skywalk users.

through buildings, most with tenants observed to cater primarily to middle- and upper-income persons (Robertson, 1988 and 1994).

Other Equity Considerations and Summary. A broad-based attempt to examine societal distributions of effects of public health interventions to increase exercise through walking did not bear much fruit. A systematic review of 48 studies of such interventions found only six with "even a rudimentary economic evaluation," and only 14 made any mention of how outcomes varied among socioeconomic or demographic groups. Three studies noted that effects did not vary significantly between socioeconomic/ethnic groups, while four studies reported lower effectiveness for less educated, lower-income, African American, or English not "usual language at home" groups. Three trials involving promotion of walking in general reported higher response rates for men, while one individualized transportation mode shift marketing effort reported higher active transportation use increases among women (Ogilvie et al., 2007).

The Americans with Disabilities Act (ADA) of 1990 was intended, among other objectives, to address inequities of physical access for people with disabilities. Accessible sidewalks provide physical access to nearby goods, services, and activities. For instance, as discussed above under "Societal Economic Impacts" (see "People with Disabilities Mobility Benefits"), construction of ADA-compliant bus stops along with critical links of sidewalk may be quite beneficial. Examples have been shown to be very cost effective where they allow a person with disabilities to reach conventional transit service instead of being reliant on ADA door-to-door paratransit service (Goodwill and Carapella, 2008).

Although substantive equity discrepancies are noted above, pedestrian and bicycle facilities appear overall to benefit the full spectrum of society perhaps more broadly than any other provision of transportation. The challenge in NMT benefit analysis is to adequately account for all the different forms in which pedestrian and bicycle facilities provide benefit. No single category of benefit is likely to offer an impressive benefit-cost ratio on its own. It is the sum total over the uniquely wide range of NMT benefits that may justify investment in walking and bicycling.

ADDITIONAL RESOURCES

Logical points of departure for general information on pedestrian and bicycle action initiation, development, and implementation are the central websites established by governmental, professional, educational, and advocacy organizations working in concert. Key sites include:

- The Pedestrian and Bicycle Information Center (PBIC), funded by the U.S. Department of Transportation, Federal Highway Administration (FHWA), seeks "to improve the quality of life in communities through the increase of safe walking and bicycling as a viable means of transportation and physical activity" per its http://www.pedbikeinfo.org website. This umbrella site, with pedestrian and bicycle components described next, is heavily but not exclusively focused on implementation and safety.

- The PBIC engineering component includes a section on designing for special populations at www.walkinginfo.org/engineering/pedestrians.cfm, which links to the Accessible Pedestrian Signal (APS) website at www.apsguide.org. The content of the APS site is a product of the National Cooperative Highway Research Program Project 3-62, "Guidelines for Accessible Pedestrian Signals."

- The PBIC pedestrian component at http://www.walkinginfo.org includes a searchable NMT resource library at www.walkinginfo.org/library, graduate level bicycle and pedestrian planning course materials at www.walkinginfo.org/training/university-courses/masters-course.cfm, a compilation of case studies suitable for popular consumption (PBIC and APBP, 2009) at www.walkinginfo.org/case_studies, safety and public involvement courses at www. walking info.org/training/, a safety guide and hazard countermeasure selection system at www.walking info.org/pedsafe, a pedestrian safety guide focused on the needs of transit operators (Nabors, et al., 2008) at www.walkinginfo.org/transitguide, a guide for residents seeking safe and walkable communities at www.walkinginfo.org/residentsguide, and a walkability checklist suitable for layperson use at www.walkinginfo.org/checklist.

- The PBIC bicycle component at http//www.bicyclinginfo.org includes a bicycle safety hazard countermeasure selection system (www.bicyclinginfo.org/bikesafe), which in turn includes case studies (http://www.bicyclinginfo.org/bikesafe/case_studies.cfm), a bikeability checklist amenable to layperson use (www.bicyclinginfo.org/checklist), a benefit-cost analysis tool for bicycle facilities (www.bicyclinginfo.org/bikecost), and a university course on bicycle and pedestrian transportation (Turner et al., 2006) at www.bicyclinginfo.org/univ-course. Bicycle library resources are included in the searchable collection at www.walkinginfo.org/library.

- Useful web sites for obtaining pedestrian and bicycle materials directly from FHWA include, for the office of safety, http://safety.fhwa.gov/ped_bike/, for safety research, http://www.tfhrc.gov/safety/pedbike/, and for general bicycle and pedestrian programs, http://www.fhwa.dot.gov/environment/bikeped/.

- The National Complete Streets Coalition—supporting policy to ensure roadway design and operation with full and appropriate provisions for pedestrians of all ages and abilities, bicyclists, and public transportation services—provides guidelines, fact sheets, policy information, model legislation, news, and more at its http://www.completestreets.org website.

- Safe Routes to School (SRTS) program information, ranging from getting started to training to submission of evaluation results, is provided by the National Center for Safe Routes to School at http://www.saferoutesinfo.org.

- The Institute of Transportation Engineers (ITE) maintains a wiki, open to the public, that covers pedestrian and bicycle resource links, ITE pedestrian and bicycle initiatives, an innovative practices discussion board, and a general topics blog, at www.ite.org/pbwiki.

The *Online TDM Encyclopedia* maintained by the Victoria Transport Policy Institute and located at http://www.vtpi.org/tdm/index.php includes several periodically updated web documents useful for NMT planning. The relevant documents provide concisely summarized findings and generally pro-NMT guidance along with numerous referrals for additional detail, most with Internet links. The "Evaluating Nonmotorized Transport" document, subtitled "Techniques for Measuring Walking and Cycling Activity and Conditions," has especially comprehensive coverage of NMT level of service (LOS), walkability, and NMT quality of service concepts and techniques (http://www.vtpi.org/tdm/tdm63.htm). NMT accessibility and connectivity concepts and applications are covered in "Accessibility—Evaluating People's Ability To Reach Desired Goods, Services And Activities" (http://www.vtpi.org/tdm/tdm84.htm) and "Roadway Connectivity—Creating More Connected Roadway and Pathway Networks" (http://www.vtpi.org/tdm/tdm116.htm).

NCHRP Report 616: Multimodal Level of Service Analysis for Urban Streets, provides a literature review of bicyclist and pedestrian LOS perceptions, and presents bicycle and pedestrian LOS models structured for consistency with the Highway Capacity Manual (HCM). These are developed in a multimodal context suitable for "complete streets" evaluations (Dowling et al., 2008).

The paucity of easily available NMT count information is being addressed by the relatively new National Bicycle and Pedestrian Documentation Project (NBPDP), a cooperative bicycle and pedestrian count and survey effort sponsored by the Pedestrian and Bicycle Council of the Institute of Transportation Engineers. Objectives include establishment of a consistent national NMT count and survey methodology, development of a national database of pedestrian and bicycle count information, and use of the information for analysis of correlations between various factors and walking/cycling activity (Alta Planning + Design, 2008). Project resources can be accessed at http://bikepeddocumentation.org/. A TRB Bicycle and Pedestrian Data Subcommittee (ABJ35(3)) was formalized in July, 2011, with the goal of developing standardized national NMT data structures to facilitate accessing, sharing, and integrating national bicycle and pedestrian information in support of traffic management, travel demand modeling, safety studies, and NMT planning and research.

There are several summary reports and papers encapsulating individual studies and drawing conclusions about interrelationships between pedestrian and bicycle policy, promotion, and facility provision and prevalence of walking and cycling and associated physical activity. *TRB Special Report 282* examines the connection between U.S. physical activity levels and the built environment, using syntheses derived from both transportation and physical activity research results (Committee on Physical Activity, Health, Transportation, and Land Use, 2005). The committee report draws from seven specially commissioned papers on topics ranging from research methods to institutional factors, including a *Critical Assessment of the Literature on the Relationships Among Transportation, Land Use, and Physical Activity* (Handy, 2004) as well as examinations of social marketing approaches, safety and security concerns, and physical activity trends.

A succinct equivalent focused on children, highly condensed but information-rich, is provided by a review of the literature prepared by researchers at the University at Albany (SUNY), New York (Davison and Lawson, 2006). A collaboration by Saelens and Handy partially overlaps, but also serves as an update to, this child-focused review. It casts a large net and covers both adult- and child-focused papers published in 2005 and up to May 2006. Conclusions are drawn from these papers and also from some nine reviews published between 2002 and 2006 (Saelens and Handy, 2008). It thus also offers an update to the adult-focused synthesis found in *SR 282.* A 39-author international review, *Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment,* offers a concise further update from a public health perspective and also addresses environmental impacts and hazards (de Nazelle et al., 2011).

A systematic review of results of promotional/informational interventions to promote walking has been prepared at the Scottish Physical Activity Research Collaboration (SPARC), of the University of Strathclyde. Although a number of the studies covered include other active transportation, the presented summary of results focuses on walking exercise metrics (Ogilvie et al., 2007). The full text and supplement are available from SPARC at http://www.sparcoll.org.uk/SPARCollPublications.aspx. A comprehensive literature review with interpretation of Safe Routes to School (SRTS) programs and outcomes, addressing both travel and safety effects, is found in *Appendix A* of an SRTS statewide mobility assessment (Phase I) prepared for the Washington State Department of Transportation (Moudon, Stewart, and Lin, 2010).

A major synthesis effort by Pucher, Dill, and Handy assesses both peer-reviewed and other responsibly documented domestic and international research, supplemented by secondary data for 14 case study cities, in order to draw conclusions concerning infrastructure, programs, and policies with the potential to increase cycling. Pedestrian programs and effects on walking are not covered (Pucher, Dill, and Handy, 2010). Findings are organized employing an easy to use typology similar to this chapter's "Response by Type of NMT Strategy" section. Finally, this time with the full rigor of a meta-analysis, Ewing and Cervero have revised and expanded their earlier "Travel and the Built

Environment—A Synthesis" (Ewing and Cervero, 2001), adding walk trip and transit trip elasticities to updated elasticities for vehicle miles of travel (VMT). This research, "Travel and the Built Environment: A Meta-Analysis," draws from and provides a tabular summary of over 50 quantitative studies (found suitable for the analytical approach) to derive and interpret these new elasticities for an array of land use and site design parameters. Many additional studies were used in synthesis. Bicycle trips are not covered (Ewing and Cervero, 2010), thus these two 2010 works on adult NMT travel effects serve in complementary fashion. The 2010 SRTS compendium described previously fills in at least the school commute component for children and adolescents.

The Nonmotorized Transportation Pilot Program is applying a "before and after" quasi-experimental design in an attempt to assess the behavioral changes and related effects which occur in response to NMT system enhancement demonstration programs in four urban areas, with a fifth area as a control. The interim Evaluation Study and Report to Congress are available (Krizek et al., 2007, Federal Highway Administration, 2007) and the full evaluation is to be developed following the "after" survey scheduled for 2010. Another ongoing project well worth tracking is the University of Washington pre/post case/control study of changes in travel and physical activity following the 2009 opening of light rail transit (LRT) in Seattle. The study, based on 1,000 persons living either less than a mile from the new stations or living farther away, is investigating the hypothesis that transportation-related walking and physical activity will increase for persons close to stations (TransNow, 2009).

NCHRP Project 08-78, "Estimating Bicycling and Walking for Planning and Project Development," for which research commenced in 2010, will combine an evaluation of state of the practice NMT data collection and travel forecasting techniques with original research to develop transferable methods and travel demand models suitable for various levels of walking and bicycling assessment. The results are to be documented in a guidebook providing step-by-step direction to pedestrian and bicycle practitioners and demand forecasters. Section 5 of the project's *Interim Report* provides an overview of existing bicycle and pedestrian demand estimation practice, and Section 6 examines data needs and resources (Kuzmyak et al., 2011).

The *Healthy Development Measurement Tool* developed by the Department of Public Health of the city of San Francisco allows a user to assess how a development project performs in terms of an extensive list of indications including public transit service parameters and prevalence of NMT facilities. It is found at www.thehdmt.org. The *I-PLACE3S* scenario planning tool provides estimates of transportation, physical activity and obesity, emissions, and energy use impacts—along with return on investment—of alternative land development characteristics, transit service coverage and accessibility, and street network connectivity. It may be accessed at either http://www.kingcounty.gov/transportation/HealthScape.aspx or http://places.energy.ca.gov/places (American Public Health Association, 2010, Lawrence Frank & Co., SACOG, and Mark Bradley Associates, 2009).

Examples of resources available on NMT safety and design, in addition to those listed above in connection with PBIC website resources, include: *A Review of Pedestrian Safety Research in the United States and Abroad* (Campbell et al., 2004), *Pedestrian Road Safety Audit Guidelines and Prompt Lists* (Nabors et al., 2007), the American Association of State Highway and Transportation Officials *Guide for the Planning, Design, and Operation of Pedestrian Facilities* (AASHTO, 2004), and the AASHTO *Guide for the Development of Bicycle Facilities* (AASHTO, 1999). Updating of the latter guide is in progress, and post-1999 on-street bicycle facility design innovations are also available in the NACTO Urban Bikeway Design Guide (NACTO, 2011). A comprehensive street design and retrofitting manual incorporating complete streets and livable communities concepts with a full range of pedestrian and bicycle configurations is available in the Model Design Manual for Living Streets produced by Los Angeles County (and sponsors) in late 2011. It is available from http://www.modelstreetdesignmanual.com. A broad community design focus with a public health emphasis is offered in *Making Healthy Places: Designing and Building for Health, Well-being,* *and Sustainability* by Dannenberg, Frumkin, and Jackson, published by Island Press in August 2011. This book, aimed at students but appropriate for all involved in community design, presents in-depth diagnoses of problems related to the built environment and offers practical treatments.

TRB's National Cooperative Highway Research Program (NCHRP) is preparing a number of guides and related products, some jointly with the Transit Cooperative Research Program (TCRP), on NMT safety. Included to date are *NCHRP Report 500, Vol. 18: A Guide for Reducing Collisions Involving Bicycles, NCHRP Report 562/TCRP Report 112: Improving Pedestrian Safety at Unsignalized Crossings,* and *NCHRP Report 674: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities.*

CASE STUDIES

Special Mini-Studies in Montgomery County, Maryland

Situation. The Handbook authors encountered, during chapter development, several areas of interest that seemed particularly poorly quantified. Some of these were relationships that the literature discusses in qualitative terms but apparently without hard numbers to support the logic. Opportunities were therefore taken to conduct or obtain simple counts paired with careful observation to address the topics in question. The actions and situations covered, all illustrated in real life within Montgomery County, Maryland, include sidewalk reconstruction and expansion, sidewalk indirectness effects, a downtown mid-block crossing installation, volume variability in response to count timing and other factors, provision of a pedestrian connection to a transit stop, and hiker-biker off-road trail traffic mix relative to use of a parallel on-road bike route. Montgomery County is a generally upper-income suburb of Washington, DC, but the count locations are mostly located in older "down-county" transition areas between the higher and more modest incomes.

Actions/Analysis. The actions and situations examined are described under the applicable paragraph headings: "Results" if a specific change is the subject, and "More" if a static condition was observed to develop the information. The analyses have consisted of taking brief-duration counts or obtaining pre-existing full-day intersection counts, and pairing the count information with descriptive analysis. The limitations of using mostly single-day counts of mainly short duration are partially counterbalanced by careful attention to detail and consistency. The results are presented without any tests of statistical significance. They are organized in order of their cross-referencing from the main body of this chapter.

Results—Sidewalk Improvements. A State Highway 547 improvement project in Garrett Park, Maryland, was taken advantage of to obtain a small-sample count, before-and-after sidewalk improvements, under static land use and highway/transit network conditions. A morning 3-hour peak-period count taken in late January 2002 represented the "before" situation. The pedestrian and cross-street vehicular count elements were replicated under nearly identical conditions 4 years later, to provide a post-improvements "after" count.[91]

[91] Pedestrian and partial vehicular counts were made from 6:45 AM to 9:45 AM at the intersection of MD 547 (Strathmore Ave.) and Montrose Ave. in Garrett Park, MD, on Friday, January 25, 2002 (in clear, cool, dry weather), and on Friday, January 27, 2006 (in clear, cold, dry weather). Walkways were fully clear of snow in both instances. An infant and the school patrols in the before condition, and a meter-reader and a bicyclist in the after condition, are omitted from the count presentation. These and other short-duration counts were staged and taken by the lead chapter author. The pedestrian crossing improvements referred to were, one block west, a 24-hour pedestrian-activated crossing signal added at a MD 547 crosswalk long controlled during school hours by an adult crossing guard, and two blocks east, a pedestrian-presence-activated in-pavement-lights crosswalk installation.

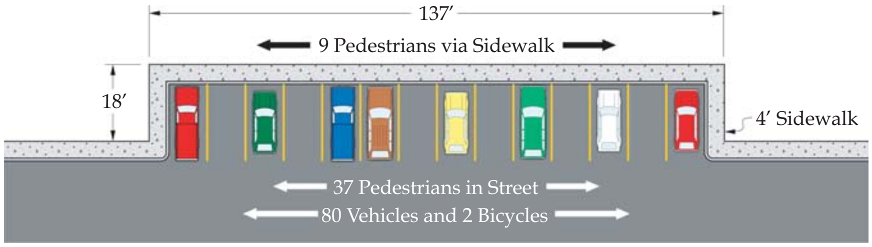
The before condition was a two-lane state highway with a rural cross-section and a poorly maintained 4-foot-or-narrower asphalt sidewalk on one side for five blocks and none for an additional block. In the after condition MD 547 had been reconstructed with a two-lane curbed and drained urban section and ADA-compliant mostly 5-foot concrete sidewalks on both sides for five blocks and one side for the last block, connecting to a pre-existing side path and hiker-biker trail. In the time between the counts, pedestrian crossing improvements were made one block west and two blocks east. The improved section of MD 547 is entirely within the single-family-housing historic town of Garrett Park, laid out as an isolated railroad suburb with an irregular street grid reflecting 19th century "garden-city" influences, but now surrounded by post-World-War-II suburban tracts with limited access points into the town. MD 547 divides the community and carries an average weekday traffic volume on the order of 20,000 vehicles.

The 3-hour adult (and teenager) pedestrian count crossing the intersection parallel to MD 547 increased from five to 21 persons. Of these, one was accompanying a schoolchild in the before condition and five were doing so in the after condition. The comparable child pedestrian count, not including grade school patrols assigned to protect schoolchildren walking parallel to MD 547 in the before condition, decreased from 11 to six children. This 45 percent decrease may reflect exogenous effects, most obviously the termination of school patrol protection, but possibly enrollment variations as well. Subtracting out adults walking schoolchildren, the adjusted 3-hour adult pedestrian count approaching the intersection along MD 547 increased from four to 16 persons. Thus the MD 547 adult pedestrian count increased between 320 percent (raw count) and 300 percent (adjusted to remove adults accompanying schoolchildren). Total pedestrians approaching via the cross-street, with no sidewalks but low vehicular volumes, increased from three to five, up 67 percent. The 3-hour two-way vehicular count on the side street went from 49 to 34 vehicles on the north leg and from 84 to 111 (including schoolchild drop-offs but adjusted for double-counting) on the south leg, a 9 percent increase over all—relatively insignificant compared to the adult pedestrian count increases.

General observation suggests that sidewalk usage is substantially higher in warmer weather, including the block with no prior sidewalk and virtually no pedestrians in the before situation because of patently unsafe walking conditions. It is not known how much, if any, of the new pedestrian traffic is diverted from parallel low volume residential streets mostly without sidewalks. In any case, this instance of a quadrupling in the adult and adolescent pedestrian count cannot be readily explained by other than the sidewalk addition and improvement.

More—Sidewalk Indirectness. A townhouse condominium close by to the Grosvenor-Strathmore Station of Metrorail was built with sidewalks immediately adjacent to the curbs. The curbs and sidewalks jog inward at several locations to accommodate indented perpendicular parking, introducing four right-angle turns. A 36-foot total of deviation from a straight line is produced at the particular location observed and counted. It imposes 27 percent extra in walking distance to get around the parking, or 7 percent extra distance as measured along the entire 500-foot condominium access roadway up to the first townhouses. Figure 16-10 illustrates the general layout and the primary results of the 5:00 to 6:30 PM weekday count.

Figure 16-10 Example of pedestrian route choice in response to sidewalk indirectness.



Note: PM peak 90-minute count along Cloister Drive entranceway into Stoneybrook community, Monday, October 22, 2007, 5:00 to 6:30 PM, in and out traffic combined.

The 90-minute count total of 46 pedestrians is inclusive of the peak evening outflow from the Metrorail station into the townhouse development. Most were walking into the development, but irrespective of direction, 80 percent chose to walk in the street behind perpendicularly parked cars rather than use the sidewalk. A total of five cars came into or left the 14 parking spaces during the count. Even with the relatively low vehicular volumes in the street, this is a design situation that should have been avoided. It is a clear demonstration of the oft-articulated observation that pedestrians want to walk directly toward where they are going and will not stick to sidewalks not designed toward that end.

In other Montgomery County examples, paths chosen by pedestrians to avoid indirectness can be observed in the form of existing or former dirt paths. Here are four such cases:

- Just beyond the situation described above, the access roadway turns right, and the sidewalk goes around two sides of a single-bay parking lot. Pedestrians walk diagonally across the parking aisle, tracing a path through bordering grass, now afforded flagstones. The pedestrian-selected route is 200 feet while the sidewalk route is 236 feet (with two stair steps), such that the avoided sidewalk route suffers from 15 percent indirectness.

- At the Grosvenor-Strathmore Metro Station itself, the original design provided a sidewalk on the most direct possible path north to a cross street and the nearest main intersection. However, a walkway continuing north on the other side of the cross-street was introduced with a 101-foot offset along the cross-street. Metro riders forged a dirt path directly to a point opposite the walkway north. A short diagonal sidewalk reducing the 101-foot offset by 36 feet was to no avail. Ultimately a 260-foot sidewalk was built along the dirt path, resolving a 39 percent indirectness in the original route as measured from the point of path divergence, or 15 percent as measured from the station entrance. The new walk also avoids an unnecessary climb entailing roughly a 5-foot extra gain in elevation.

- When Elm Street Park in Bethesda was refurbished, a 400-foot walkway was paved diagonally across it, more or less along the shortcut pedestrians headed for the downtown district had long been following. The new walkway resolved a 12 percent indirectness in the shortest previously available paved pedestrian route.

- An artistically designed zigzag walkway along a "paper street" right-of-way in Potomac requires 490 feet to cover a 420-foot distance. Dirt path traces give evidence that neighborhood walkers and cyclists reduce their distance to 446 feet at worst, a 6 percent indirectness as compared to the 17 percent indirectness of the paved walkway.

Results—Mid-Block Crossing. The Maryland State Highway Administration (SHA) has of late been installing mid-block crossings at selected state highway locations. Sites picked are where jaywalking was rampant and the cause seemed to be that the "safe" route was circuitous enough to encourage violations. Some of these crossings are not truly mid-block but are at "T" intersections. Nevertheless, they do represent a departure from prior SHA practice of seeking to always locate pedestrian crossings at prominent traffic intersections.

An example is the 2004 installation of a crosswalk and signal in Silver Spring on Georgia Avenue, a major arterial running nominally north-south, where Ellsworth Drive has a "T" intersection. The area, an older suburban downtown, was under redevelopment at the time. Adjacent Georgia Avenue intersections are Colesville Road, a major arterial approximately 400 feet to the north, and Wayne Avenue, a minor arterial 300 feet to the south. Ellsworth Drive splits what would otherwise be a 700 foot superblock on the east between Colesville and Wayne. It is a narrow street fronted by restaurants and other retail, and as part of the redevelopment, was made pedestrian-only during retail hours. The office superblock across Georgia Avenue on the west is triangular, coming to a point at the Wayne Avenue intersection. Office development was sited to provide a pedestrian cut-through across the southern point of the block, aligned with Ellsworth. Prior to crosswalk and signal installation, Ellsworth Drive was treated essentially as an alley. Crossing Georgia Avenue at Ellsworth was considered jaywalking, but anecdotally, "A lot of people were crossing here anyway." The Georgia Avenue median was and remains functionally continuous at Ellsworth Drive.

The available counts contribute to understanding the pedestrian response to the new crossing, but because of seasonal differences, lack of completeness, and ongoing area redevelopment, offer only a partial view of crosswalk impact. A count of jaywalking in the before condition was not made. The earlier (2001/2002) of two all-day winter counts at Colesville Road (see "More—Volume Variability" below) was selected as the preferred before count, it having been made as part of a detailed pedestrian analysis. The other count (2003) seemed strangely low. For the Wayne Avenue intersection, a single summer count (2003) was available. The south Georgia Avenue crosswalk at Colesville Road handled 2,143 pedestrians in 13 hours in December 2001, including 213 in the noon hour. The north crosswalk at Wayne Avenue had 218 pedestrians in 13 hours in July 2003, including 40 in the noon hour.

In the after condition, the one full-scale count was taken at the Ellsworth Drive crossing on August 3, 2004, about one month after opening ceremonies. The total 13-hour volume crossing Georgia Avenue at the new signalized crossing was 1,357 pedestrians including 243 in the noon hour. The new crossing saved most users almost 250 feet of walking indirectness out of 600 feet, a 40 percent savings in a block. Short-duration counts made later that August showed the Georgia Avenue south crosswalk to be serving 530 noon hour pedestrians (relative to 213 before, in the winter), with 42 noon hour pedestrians in the Wayne Avenue north crosswalk (relative to 40 before).[92] Limitations in the data, and lack of any interviews, preclude any firm estimate of pedestrians diverted from other crosswalks, pedestrians not making the walking trip in the before condition, or pedestrians previously jaywalking. Nevertheless, the use of the new crosswalk together with

[92] As a matter of record, it should be noted that the time of the August 2004 noon hour counts, a new multistory building on the east side of Georgia Avenue between Ellsworth and Wayne was not yet occupied, and the north side Wayne Avenue sidewalk east of Georgia was closed partway down the block because of construction.

the increase in both of the noon-hour after counts on the pre-existing proximate crosswalks, slight in one case but much greater in the other, is certainly suggestive of new walk trip crossings and improved mobility. It is obvious that the new signalized crossing meets a real need, significantly enhances downtown pedestrian circulation, and is supportive of the downtown revitalization.

More—Volume Variability. One of the downtown Silver Spring intersection counts utilized in the mid-block crossing analysis above, the December/January 2001/2002 Colesville Road and Georgia Avenue count, illustrates how strongly pedestrian volume characteristics reflect the events of the day and/or the nature of nearby land development, and how major the differences can be among nearby counts, even within the same basic area type. In comparison with a count taken 1 year later, it also illustrates how much variability there can be between two counts at the same location, for whatever reason. The intersection in question is located at the core of the Silver Spring business district, but slightly off-center to the north. Immediately east of Georgia Avenue, the combined office and residential density is greater to the north of Colesville Road, while the restaurant and other retail density is greater to the south. A Washington Metrorail station lies two blocks to the west with exits on both sides of Colesville Road, and sidewalk provisions are comparable all around.

Either the land use differences or the fact that the 2001 count was taken just 5 days before Christmas was enough to make the lunchtime-crowd and afternoon-shopping pedestrian flow dominant in the south crosswalk, parallel to Colesville Road. On the other hand, AM and PM peak commuter traffic pedestrian flows parallel to Colesville Road were easily discernible on the north crosswalk, in January 2002. As in many such instances, it is not certain to what degree these results are related to the land use differences as compared to the seasonal difference (pre/post Christmas). Table 16-128 highlights the different time-of-day pedestrian flow patterns, and the even greater differences between the 2001/2002 counts and the 2003 counts, taken with different objectives and using different protocols. The earlier counts focused exclusively on pedestrians, in an examination of crossing behavior vis-à-vis pedestrian signal indications, while the drastically lower pre-Christmas 2003 counts were taken as an adjunct to vehicular traffic counts intended for capacity analysis purposes.

Table 16-128 Comparison of North-side and South-side Crosswalk Pedestrian Volumes by Hour, Intersection of Georgia Avenue and Colesville Road, Silver Spring

	Hourly Counts				13-hour Temporal Distributions			
Hour Starting	North 1/9/02	South 12/20/01	North 12/2/03	South 12/2/03	North 1/9/02	South 12/20/01	North 12/2/03	South 12/2/03
6:00 AM	n/a	n/a	1	3	n/a	n/a	0.2%	0.7%
7:00	60	51	9	25	4.8%	2.4%	2.0%	6.2%
8:00	89	72	22	45	7.0%	3.4%	5.0%	11.2%
9:00	86	73	30	8	6.8%	3.4%	6.8%	2.0%
10:00	50	81	4	9	4.0%	3.8%	0.9%	2.2%
11:00	99	127	40	3	7.9%	5.9%	9.0%	0.7%
12:00 PM	143	213	26	17	11.3%	9.9%	5.9%	4.2%
1:00	112	166	39	53	8.9%	7.8%	8.8%	13.2%
2:00	96	210	68	135	7.6%	9.8%	15.4%	33.5%
3:00	108	203	21	34	8.6%	9.5%	4.7%	8.4%
4:00	102	271	51	16	8.1%	12.6%	11.5%	4.0%
5:00 PM	141	277	81	34	11.2%	12.9%	18.3%	8.4%
6:00	112	243	51	21	8.9%	11.3%	11.5%	5.2%
7:00	62	156	n/a	n/a	4.9%	7.3%	n/a	n/a
8:00	42 [a]	119 [a]	n/a	n/a	— [a]	— [a]	n/a	n/a
9:00	26 [a]	128 [a]	n/a	n/a	— [a]	— [a]	n/a	n/a
Total	1,260 [a]	2,143 [a]	443	403	100%	100%	100%	100%

Note: [a] Pedestrian volumes from 8:00 to 10:00 PM are not included in the totals or the percentage calculations in order to maintain 13-hour count comparability.

Results—Path Connection to Transit. Construction of a pedestrian/bicycle path and stream crossing connecting Montgomery County's Randolph Hills neighborhood to the north with the Garrett Park MARC commuter rail station to the south provides a documented example of enhancing non-motorized transportation (NMT) access to public transit by means of trail or walkway construction. Even with the small numbers involved, and without formal before counts, the Randolph Hills share of Garrett Park station MARC ridership illustrates the importance such connections can have.

The 800-foot path was constructed in the mid-1980s across what had earlier been overgrown private property adjoining an abandoned coal/oil yard. A major function of the path is to provide neighborhood interconnection and to link Garrett Park and other neighborhoods south of Randolph Hills to trail and recreational facilities to the north, in Rock Creek Park. After the path proved attractive to rail commuters, it was illuminated for use after dark. Prior to path development, the Garrett Park Station was for all practical purposes inaccessible for residents of Randolph Hills and other northerly neighborhoods. Auto access involves a roundabout 9,500-foot (1.8-miles) drive just to go 800 feet (0.15 miles). There was no known MARC ridership from Randolph Hills except for an occasional intrepid soul braving the kudzu and stream crossing in dry weather.

On May 22, 2008, the 33 passengers alighting in Garrett Park on the six outbound trains serving the station were counted according to their egress mode and direction of travel.[93] Of the 33 passengers,

[93] Train P879 (5:58 PM arrival) used the inbound track on 5/22/08, blocking the observer's view of passengers walking into neighborhoods to the south and west. Train P879 alightings were recounted in similarly clear, warm weather on 5/29/08. After determining that other count components were identical, the 5/29/08 count of Train P879 passengers walking south and west was substituted.

14 (42 percent) walked into Garrett Park and adjoining neighborhoods to the south and west. Another 11 (33 percent) drove away in cars parked at the station. The other eight passengers (24 percent) walked north on the path to Randolph Hills. They constituted 36 percent of the 22 walk-egress MARC passengers. It may be inferred that the Garrett Park MARC station ridership is over 30 percent more than it would be without the connection. The path also regularly serves Garrett Park bus patrons accessing the nearest Randolph Hills stop.

More—Off-Street Versus On-Street NMT User Mix. There appears to be a tendency, affecting many bicycling travel demand and safety research and advocacy papers, to overlook the different user mixes attracted by different types of facilities and the implications thereof. Even where user mix differences are discussed, little quantification has been encountered. The ideal might be to quantitatively compare path usage with parallel bike lane usage. That opportunity did not present itself in the Montgomery County special mini-studies. However, it did prove possible to investigate the user mix of the Rock Creek hiker-biker trail versus the on-road NMT user mix of parallel Beach Drive, using short-duration concurrent classification counts.

Beach Drive is a low-speed, curving, two-lane, urban scenic highway with infrequent intersections, flanked by parkland. It has no shoulders or bicycle lanes, but it is signed “Bike Route” and “Share the Road” (on the same posts), and the 25 mile-per-hour speed limit is periodically enforced. Both the parallel trail and the on-road bike route lie entirely within riparian parkland. At the time of the 2005 user-mix investigation, Beach Drive pavement quality was fair-to-good but not excellent, while trail pavement quality was fair. Beach Drive is level. The hiker-biker trail is a low-speed, 8-foot-wide paved facility through partially forested rolling terrain, with frequent, often tight, horizontal and vertical curves.

Two locations where both facilities could be clearly seen were observed and counted. Three 1-hour counts were taken, on a Friday, Saturday, and Sunday in warm early November weather with fall foliage still in its prime. The counts were done in early afternoon, and thus did not pick up NMT commuter traffic, which is thought to be limited given facility orientation, design, and peak traffic conditions. Walkers and cyclists were identified as to sex (except for younger than teenage children), accompaniment by children in conveyances (regular and jogging strollers, carriages, bicycle seats, trailers, and adult/child tandems), accompaniment by dogs, and dress. A binary classification system was used for dress, namely, persons wearing special cycling outfits (“cycling gear”) and persons wearing ordinary pants, jeans, shorts, etc. (“street clothes”). Groups of walkers/cyclists were noted. Trail pavement conditions were not supportive of in-line skating. Results are summarized in Table 16-129 and the two paragraphs which follow.

Table 16-129 NMT User Mix of Rock Creek Hiker-Biker Trail Compared to Parallel Beach Drive Bike Route, Thee One-Hour Counts

User Category (Male/Female shown in data columns)	Fri. 11/4/05 2:10-3:10 PM		Sat. 11/5/05 1:10-2:10 PM		Sun. 11/6/05 2:00-3:00 PM		Three Count Total	
	Trail	Road	Trail	Road	Trail	Road	Trail	Road
Walker, adult, no child/dog	2M 3F	0	10M 18F	0	4M 5F	0	16M 26F	0
Jogger, adult (1 with stroller)	4M 1F	0	7M 4F	1 F	10M 13F	0	21M 18F	1F
Walker with dog	1M 1F	0	2F	0	1M 5F	0	2M 8F	0
Walker w/child in stroller, etc.	2F	0	2M 4F	0	0	0	2M 6F	0
Children in strollers, etc.	4C	0	7C	0	0	0	11C	0
Walker, child	0	0	1C	0	1C	0	2C	0
Cyclist, adult, in cycling gear	0	13 M 3F	8M 4F	59 M 10F	4M 9F	48M 17F	12M 13F	120M 30F
Cyclist, adult, in street clothes	4M 1F	3M	8M 7F	3M 1F	14M 1F	9M 3F	26M 9F	15M 4F
Cyclist w/child in seat/trailer	0	0	3M 1F	0	1M 1F	0	4M 2F	0
Children in cycle seats/trailers	0	0	4C	0	2C	0	6C	0
Cyclist, child (Teens included as M or F)	0	0	1M 1F 7C	0	3C	1M	1M 1F 10C	1M
Total, Male, Female, Child (Teens included as M or F)	11M 8F 4C	16M 3F	39M 41F 19C	62M 12F	34M 34F 6C	58M 20F	84M 83F 29C	136M 35F
Grand total	23	19	99	74	74	78	196	171

Notes: M = Male, F = Female, C = Child (among non-adults only teenagers are identified by gender).

Bicycle trailers were each assumed to contain one child.

The 11/5/05 count was made just south of the Puller Drive connecter trail. The other two counts were made east of Franklin Street.

NMT traffic totals for the Rock Creek off-road hiker-biker trail compared to the parallel Beach Drive on-road bike route over the 3 hours/days were very similar, with roughly 10 off-road trail users counted for every nine on-road cyclists. The distributions of user types, however, varied considerably. On the off-road trail there were three adult walkers or joggers for every two cyclists, while on the on-road route there was only one person on foot, a female jogger. About 5 percent of trail traffic was users walking dogs. Among bicyclists, only 38 percent of adults choosing the trail wore cycling gear, suggestive of moderate levels of involvement and a broad range of skill levels. In contrast, 89 percent choosing the on-road route wore special cycling outfits, suggesting avid involvement and concomitant skill. On the trail, 37 percent of adult and teenage cyclists were female, while 50 percent of adult and teenage trail traffic overall (walkers and joggers included) was female. Younger children constituted 15 percent of trail traffic, with a percentage breakdown of 34 percent on their own bicycles, about 21 percent in bicycle seats and trailers (including one on an adult/child tandem bike), 7 percent walking, and 38 percent in strollers and the like. On the road, just 20 percent of cyclists and of NMT users overall were female, and there were no children other than one male teenager.

Of trail traffic, 55 percent appeared to be in groups, with almost 1/2 of group members appearing to be composed of family groups inclusive of children (26 percent of all trail traffic). Only 18 percent of on-road traffic seemed to be in groups, about 2/3 of which (12 percent of all NMT road users) were male-female pairings. It may reasonably be concluded, at least in the context of the count timing and weekend dominance of count totals, that the off-road trail alternative was the one serving a broad range of NMT modes and user types. The overall male-female balance was essentially equal. Family groupings inclusive of children were common, and all bicycle training for children occurred on the trail. In contrast, the Beach Drive on-road option attracted users—mostly male—focused on bicycling for sport and sustained exercise. The societal functions of the two facility types, although both facilitated exercise, were basically quite different. Neither one alone met needs fulfilled by the other.

Sources. Short-duration counts (AM-, PM-, or midday-only), field observations, distance measurements, and all conclusions, by the Handbook authors. • Ujifusa, A., "Officials want amenities added to Elm Street Park." *The Gazette* (March 18, 2009). • Harvey, P., "Pedestrian education continues in Silver Spring." *Gazette Regional News* (July 14, 2004). • Watkins, C. K., State Highway Administration, Maryland Department of Transportation, letter to the Handbook authors Re. "US 29 (Georgia Avenue) at Ellsworth Drive Mid-block Pedestrian Crossing Studies" with attached 2001–2004 traffic counts at the Georgia Avenue intersections with Colesville Road, Ellsworth Drive, and Wayne Avenue (August 17, 2004).

Pedestrian Activity Effects of Neighborhood Site Design—Seattle

Situation. A series of research projects have been undertaken on the relationship between site design and pedestrian travel in mixed-use medium density neighborhoods of the greater Seattle area. Twelve neighborhoods, each containing a small to medium size neighborhood commercial center, were the focus of the analysis reviewed here. The neighborhoods varied in site design characteristics. These were described in terms of block size and length and completeness of the sidewalk systems. Sites characterized as "urban" by the research had small blocks the equivalent of 300 by 400 in dimension, a complete and continuous public sidewalk system on both sides of all streets, averaging 38 miles total in length per site, and on-street parking together with off-street parking in small lots. Sites characterized as "suburban" had large blocks the equivalent of 1,000 by 1,300 feet in size, an incomplete and discontinuous public sidewalk system lining less than one-half the streets, averaging 8 miles total in length per site, and only off-street commercial parking, in large lots. Retail stores in the urban sites tended to face directly onto one main street, while in the suburban sites retail was located in large blocks of private land containing broad areas of surface parking.

Actions/Analysis. A quasi-experimental methodology focusing on a single point in time was used to study pedestrian volumes into each neighborhood commercial center. The 12 research sites were selected to have substantially different pedestrian environments, one-half with extensive pedestrian facilities and one-half with quite limited facilities. This difference in neighborhood site design constituted the study's independent variable, while the dependent variable was the volumes of pedestrians crossing from residential areas into the central commercial area across a survey cordon line. Each survey was manned during representative hours of the day totaling some 16 hours.

Sites were matched for population density, land use mix and—to the extent possible—income, in order to minimize the effect of these factors. Auto ownership per person, although not per dwelling unit, was found to be similar for all sites, at 0.6 to 0.8 automobiles per person. All sites were described by a 1/2-mile pedestrian travel catchment area around their neighborhood commercial center, with a gross population density of about 10 people to the acre, creating an average population of 6,000 people for each site. Dwelling types within this average density ranged from apartments and condominiums to single family houses. Statistics for each site were normalized to remove the effect of undeveloped sectors resulting from topological features such as bodies of water.

Results. The researchers concluded that the measures traditionally employed to predict pedestrian volumes—population density, income, land use distribution and intensity—are insufficient to explain the variation in pedestrian volumes. Pedestrian volumes were found to be also related to neighborhood site design and pedestrian facilities design, as reflected in block size and extent of pedestrian facilities provided. Absolute size of the neighborhood commercial development was shown not to explain the observed pedestrian volumes. The urban sites exhibited, on average, three times the pedestrian volumes of suburban sites. The urban site volumes averaged 38 pedestrians per hour per 1,000 neighborhood residents walking between residences and commercial centers, while the corresponding suburban volumes averaged between 12 and 13 pedestrians per hour per 1,000. The one site not in Seattle proper among those accorded an "urban" classification produced 24 pedestrians per hour per 1,000 residents, still twice the suburban neighborhood average.

The suburban sites were clearly not without pedestrians. The suburban volume range was between eight and 16 pedestrians per hour per 1,000 neighborhood residents moving between the suburban residential areas and the commercial centers. The majority of these suburban pedestrians were found to use streets with sidewalks where available. Suburban pedestrians are more likely to jaywalk than the urban pedestrians (32 versus 20 percent) *and* more likely to use marked crosswalks (60 percent versus 14 percent). These seemingly contradictory results reflect the lesser availability of legal walking options at suburban sites on the one hand, and the apparently high perceived risk, on the other hand, of crossing wide suburban streets without a marked crosswalk.

The mean distance between points where pedestrians can enter the commercial area was found to be twice as long for suburban sites as for urban sites. Suburban pedestrian route options were found to be constrained not only by the large blocks, but also by apartment and school campus fences/gates. The length of suburban-site actual walking routes was found to be 66 percent longer than airline distance, as compared to 27 percent longer for urban sites. This represents a difference averaging 600 feet, enough, in the opinion of the researchers, to suppress pedestrian activity.

More . . . Young people and non-whites, together with persons judged to be of Hispanic origin, were over-represented proportionally among the suburban pedestrians when compared to the local area population. This was taken to indicate that the suburban pedestrians may represent in substantial measure people who do not have the option of driving. At the suburban sites, an average of 41 percent of pedestrians were under 18 years of age, 180 percent higher than in the neighborhood population. In urban sites the proportion of young pedestrians, 16 percent, was similar to the percentage of youth in the neighborhood population. Non-whites and Hispanics were over-represented among pedestrians at both suburban and urban sites. The suburban site over-representation was by 240 percent, relative to the tributary population, compared to 200 percent for urban sites. The researchers note that the high proportion of young pedestrians combined with lack of appropriate pedestrian facilities in the suburban sites raises troubling safety issues, as does the observed presence of pedestrians with impairments at three of the suburban sites.

Sources. Hess, P. M., Moudon, A. V., Snyder, M. C., and Stanilov, K., "Site Design and Pedestrian Travel." *Transportation Research Record 1636* (1998). • Moudon, A. V., Hess, P. M., Snyder, M. C. and Stanilov, K., "Effects of Site Design on Pedestrian Travel in Mixed-Use, Medium-Density Environments." *Transportation Research Record 1578* (1997).

50 Years of Downtown NMT Facility Provisions—Minneapolis

Situation. Minneapolis is in the upper ranks of cities for active-transportation tripmaking. In 2007 it was 10th out of the 50 largest cities in walking to work (6.4 percent mode share), 2nd in bicycling to work, (3.8 percent), and 10th in taking transit to work (13.4 percent). The city has, in recent years, been progressing forward pursuant to goal-driven pedestrian and bicycle master plans. Even before NMT goal-setting was the norm, however, downtown Minneapolis took ground-breaking actions supportive of pedestrian activity and connectivity. The first pedestrian bridge of the ultimate 8-mile downtown Skyway system was opened in 1962, and the Nicollet transit mall was brought on line in late 1967.

Actions. The first two downtown Skyway links were opened in 1962 and 1963, connecting financial district buildings to the city's first mixed-use building, the Northstar Center. From this start, the Minneapolis Skyway system has grown to 82 bridges in 2004. The cumulative number of links open each year is given in the right-most column of Table 16-130 under "Results." The present-day system connects the office and retail core with various mixed-use buildings, hotels, apartment complexes, close-in and fringe-area parking ramps (i.e., garages), and a west-side I-294 bus transit terminal. All entrances to the Skyway system are through buildings. There are no direct sidewalk connections.

The Nicollet Mall was constructed as an eight-block transit mall in 1966–67. The roadway was narrowed to 24-feet and restricted to buses, emergency vehicles, and taxis. For most of the distance the roadway follows a serpentine path, producing a sidewalk 20 to 36 feet in width, as compared to the original 15-foot width. Bus shelters and street furniture were concentrated in the bulb-outs, leaving a clear path for pedestrians of 15 feet. Original amenities included sidewalk heating for snow removal, fully equipped bus waiting shelters each block on both sides, and bike racks. Bicycles have been allowed on the mall from the beginning. The transit mall was extended by four blocks in 1982, and refurbished in 1991.

Attention to bicycle provisions mostly came later. Among off-road shared use trail projects between 1990 and 2000, two—both 8 miles long—provided important through connections from the southwest and southeast, with the latter connecting into extensive trail systems serving both the Minneapolis and St. Paul sides of the Mississippi River. During the same 1990–2000 decade a 4-mile pair of bike lanes tying the south side of the city to downtown, plus an approximately 1-mile pair to the east, were implemented. Crossing the Mississippi, two pedestrian/bicycle bridges were opened and bike lanes were added to two road bridges, raising from two to six the number of bridges with dedicated bicycle facilities serving downtown. There has also been a major program of adding bicycle lanes to downtown streets.

The entire city has supportive NMT infrastructure, with sidewalks on both sides of 80 percent of all streets, sidewalk provisions deemed appropriate on another 12 percent, 18 miles of off-road bicycle/pedestrian trails with connections to suburban facilities, and 35 major pedestrian/bicycle bridges over highways, streets, railroads, and the Mississippi River.

Analysis. A 12-hour manual cordon count around the Minneapolis CBD has been conducted periodically. There were 18 cordon counts between 1958 and 2003. The cordon circumscribes an area some nine by 12 blocks in extent, bounded by 1st Street N./S. (Mississippi River), 5th Avenue S., 12th Street S., and 2nd/4th Avenues N. (I-394 and railroad). Each count tallies both vehicles and people entering and leaving the CBD at each count station, by mode, by 15-minute intervals, from 6:30 AM to 6:30 PM. The counts have been uniformly taken on the 2nd Wednesday of September.

This case study compares mode share and volume trends over time with development of the Skyway, transit mall, and bicycle lane and path infrastructure. It is important to note that a cordon count necessarily intercepts through traffic; indeed, most through trips are counted twice relative to each CBD-generated trip. This circumstance tends to inflate the auto mode share, and introduces a probable discontinuity in the 1970s as freeway links were completed bypassing downtown, diverting some of the through vehicular traffic. Other known exogenous influences of importance are commented on in the "Results" and "More . . ." presentations. Individual-facility count data available at more than one point in time are introduced under "More . . .". Additional analysis of 1968 through 1974 Skyway count data, and also 2002 Skyway counts, is found in the "Response by Type of NMT Strategy" section under "Pedestrian Zones, Malls, and Skywalks"—"Pedestrian Skywalks"—"Skywalk Impacts on Walking."

Results. Table 16-130 presents 1958–2003 findings of the Minneapolis CBD Cordon Count, focusing on the transportation of people. Both the cordon counts and other time-series data indicate that economic conditions and development trends have strongly influenced the ups and downs of downtown Minneapolis pedestrian and other person-flows. The first 7 years shown are annual counts, before the Nicollet Mall and before any more than two Skyway bridges. They serve to illustrate the variabilities affecting such counts, with the walk and bike share totals oscillating between roughly 6 percent and roughly 7 percent. Separate walk and bike shares are not available for years prior to 1974, but it is thought that bicycle shares were very low, as suggested by the 0.2 percent 1974 share. It will be noted that the pedestrian (and bicycle) count and mode share reached a low point in the 1961 cordon count, dipping again in the period concurrent with I-35W freeway completion and economic downturn in the 1970s.

Table 16-130 Total Persons Entering and Leaving the Minneapolis CBD, with Percentages by Mode, 6:30 AM–6:30 PM

Year	Total Persons	NMT Persons	Percent Mode Shares at Cordon: Walk	Bike	Bus	Auto	Other	Employment	Skyways
1958	564,992	41,511	7.3%	—	21.7 %	61.9 %	9.1%	n/a	0
1959	555,569	36,863	6.6	—	22.5	61.6	9.3	n/a	0
1960	558,194	39,320	7.1	—	20.1	64.0	8.8	n/a	0
1961	522,021	30,824	5.9	—	19.8	65.5	8.8	n/a	0
1962	526,228	37,041	7.0	—	20.4	63.7	8.9	n/a	1
1963	532,543	33,639	6.3	—	19.6	65.1	8.8	n/a	2
1964	514,425	34,289	6.7	—	20.0	64.2	9.1	See	2
1970	548,307	38,123	6.9	—	16.5	66.3	10.3	Notes	5
1972	516,059	33,402	6.4	—	18.8	64.3	10.3	n/a	5
1974	475,278	27,026	5.4	0.2%	22.8	61.0	10.5	n/a	10
1975	489,765	30,698	5.8	0.5	23.9	61.1	8.7	n/a	10
1977	492,173	29,475	5.5	0.4	26.9	57.2	10.0	n/a	13
1981	460,822	33,862	6.6	0.8	25.7	58.5	8.5	141,304	16
1984	494,540	35,532	6.7	0.4	23.0	62.6	7.2	143,562	30
1987	515,543	44,133	7.9	0.8	22.0	62.3	7.1	151,780	38
1990	494,188	42,228	7.7	0.9	23.0	60.0	8.5	155,932	45
1998	541,195	44,941	7.4	0.9	19.8	64.2	7.6	164,463	68
2003	522,815	39,578	6.7	0.8	20.8	64.2	7.4	153,732	82

Notes: Downtown retail sales declined sharply from 1957 to 1963. Circa 1967 CBD employment was about 95,100 (area definition unknown). The 1990 and 2000 employment totals in the area roughly encompassed by the freeway loop and the Mississippi River were 132,617 and 146,474, respectively. The 1981-2003 employment data within the table are for a larger "downtown area" and are presented simply to show trends, including the post-9/11 (2001) downturn.

The "Skyways" column tallies Skyway bridge crossings of streets.

All data in Table 16-130 are from before opening of light rail transit (LRT) in 2004.

Although the 1987 through 2003 cordon counts indicate no growth in bicycle shares, 1990 and 2000 Census mode share tabulations suggest otherwise, at least for journey-to-work trips headed for the downtown area. The downtown Minneapolis destination bicycle commute share grew from 2.27 percent in 1990 to 2.58 percent in 2000, a 0.31 positive percentage point shift (and a 14 percent increase) concurrent with the extensive bicycle facility provisions enumerated above under "Actions." In St. Paul, where there were few if any downtown area cycling facility improvements, the corresponding downtown bicycle commute shares declined from 0.64 percent in 1990 to 0.59 percent in 2000, despite overall bicycle commuting increases in both cities.

More . . . Asked why they were on the Nicollet Mall in a 1977 survey, with multiple answers allowed, 57 percent reported shopping, 42 percent were walking for pleasure, 24 percent were there because of their work, 16 percent were there because it was their bus stop location, another 16 percent were headed to some place off the mall, and 5 percent had other reasons. Asked to select among specified alternative locations the place they were most likely to walk or browse, 85 percent chose the Nicollet Mall (of course they were on the Mall), 10 percent selected the Skyway system, 2 percent chose parallel Hennepin Avenue, and 1 percent picked parallel Marquette Avenue.

Pedestrian and other counts are available for Nicollet Avenue at various points in time. In September of 1958, well prior to 1966–67 transit mall construction, the 12-hour pedestrian volume average between 4th and 10th Streets was 12,800 per side, per block. Individual block-face pedestrian volumes ranged from 23,600 to 4,700. Shortly after initial opening of the mall the average had increased to 13,600, up 6 percent despite the sharp 1957–1963 retail decline noted with reference to Table 16-130. By 1976, however, the 4th to 10th Street 7:00 AM to 6:00 PM average, per side, per block had declined to 7,400 pedestrians. (The comparable 1958, 11-hour average was 12,400.) The 1972–1981 period had exhibited an overall decline in downtown NMT activity, as seen in the Table 16-130 tabulation, but of greater importance to Nicollet Mall walking was the burgeoning development of the Skyway system. By 1976, all major department stores on the transit mall were connected by Skyways. With 1/3 to over 2/3 of pedestrians shifting to available Skyways, depending on weather, the combined 1976 pedestrian flow in the Nicollet corridor may well not have reflected a decline at all.

Nicollet Mall counts, supplemented by estimates, are also available for 2002. The highest 11-hour sidewalk volume on a single block face was 14,550. For computation of averages, data availability requires shifting the coverage by one block, to between 5th and 11th Streets—a shift that is consistent with the southward movement of major retail establishments. Full 11-hour counts cover 3 blocks, and extrapolations from 3-hour midday 2002 or 2000 counts cover the other 3 blocks. On this basis, the 5th to 11th Street 7:00 AM to 6:00 PM average, per side, per block was 7,200 pedestrians, virtually the same as 1976 despite additional Skyways. The most closely parallel Skyways crossing 6th through 10th Streets, five Skyways in total, averaged 11,500 pedestrians. If one adds the Skyway and block face averages, an approach that presumes Skyway volumes to each side of the Nicollet Mall to be roughly equal, the average 2002 pedestrian volume per side of the Nicollet corridor is found to be 18,700 pedestrians.[94] This is on the order of 50 percent more than the 1958 pre-mall, pre-Skyway, 11-hour pedestrian flow. Nicollet corridor counts over time are summarized in Table 16-131.

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[94] In developing the average parallel Skyway volume, only the one nearest Skyway per cross-street was included, as counts are not available for some second-nearest parallel Skyways. Counts are primarily 11-hour, September counts, with some 12-hour counts at retail centers. The assumption that Skyway volumes to each side of the Nicollet Mall are roughly equal to the nearest-Skyway 11,500-pedestrian average is rather crude. Three of 10 block-pair combinations bordering the Nicollet Mall between 5th and 11th Streets have two north-south Skyway connections instead of one, while one block-pair has none. The two second-nearest parallel Skyways for which counts are available average only 5,400 pedestrians. If one utilizes this figure as the "other side of the mall" Skyway average, then the corridor pedestrian count increase since 1958 is on the order of 25 percent. The lower figure is the basis for the low-end-of-the-range entry for 2002 in Table 16-131.

Table 16-131 Nicollet Corridor Pedestrian Flows—1958–2002—Six-Block, Per-Side Averages

Year	Count Parameters/*Events*	Avg. Nicollet Sidewalk Count (per Side)	Avg. Parallel Skyway Count (to One Side)	Avg. Nicollet Corridor Count (per Side)
1958	Nicollet Ave., 4th to 10th Sts., 12 hrs.	12,800	0	12,800
1958	Same, 11-hour count, 7 AM - 6 PM	12,400	0	12,400
1962-69	*First 5 Skyways opened*			
1966-67	*Nicollet Mall opened for 8 blocks*			
1973	Nicollet Mall, 4th to 10th Sts., 12 hrs.	13,600	n/a	n/a
1973-75	*5 additional Skyways opened*			
1976	Nicollet Mall, 4th to 10th Sts., 11 hrs.	7,400	1,800 - 7,400+ [a]	9,200 - 14,800+
1976-2002	*81 additional Skyways opened for a Minneapolis system total of 82 crossings*			
1982, '91	*Nicollet Mall extended, refurbished*			
2002	Nicollet Mall, 5th to 11th Sts., 11 hrs.	7,200	8,400 - 11,500	15,600 - 18,700

Note: See preceding text, including Footnote 94, for data limitations, assumptions, and discussion.

[a] Calculated at 1/3 - 2/3+ of corridor total per side, but then discounted by 50 percent for two to three cross-street Skyway coverage (parallel and adjacent to Nicollet) out of five cross-streets total.

Vehicle volumes displaced from Nicollet Avenue averaged 6,800 per direction per hour. There was essentially no congestion accompanying this shift. Peak hour bus volumes increased from 20 to 60 per hour in each direction. Two-way, 12-hour Nicollet Avenue bus volumes at the cordon line increased by 422, from 188 in 1964 to 623 after transit mall construction and subsequent bus reroutings. This was only partially counterbalanced by a reduction of 138 buses on Hennepin Avenue to the northwest and 33 buses on Marquette and Second Avenues to the southeast. The Nicollet Mall bus count at 12th Street in 2003 was 580 buses of all types.

As measured at the cordon line north of 12th Street, the total 12-hour person-flow on Nicollet Avenue (walking, biking, and riding in buses, cars, and other vehicles) increased from 17,246 persons in 1964 to 23,708 persons in 1970 after opening of the mall, increasing further to 25,184 in 1975. Person-volumes on nearby parallel streets declined. With extension of the transit mall in 1982, almost all persons recorded at the Nicollet count station are walking, bicycling, or riding on buses, a travel mode almost always involving NMT access at least one end of the trip if not both. Cordon counts in 1998 and 2003 show the Nicollet Avenue 12-hour person volumes at 12th Street under these more recent conditions to have been 23,223 and 24,140, respectively.

Six published financial/office district 2002–2007 Skyway count comparisons show 5-year increases ranging from 12 to 39 percent and averaging 24 percent. City of Minneapolis Nicollet Mall pedestrian data for 2007 suggest typical variation but no growth in at-grade sidewalk counts. Between 6th and 7th Streets 13,415 pedestrians were counted during 12 hours in 2007 versus 13,000 for 11 hours in 2002, and between 11th and 12th Streets 7,228 pedestrians were counted during 11-3/4 hours in 2007 versus 8,686 for 12 hours in 2003. Bicycle count increases from 2003 to 2007 at nine locations in downtown ranged from 13 to 96 percent, with a weighted average of 51 percent.[95] These indicators in combination suggest a return, following recovery from the post-9/11 downturn, to the irregular but overall gradual upward trend in Minneapolis downtown NMT volumes (roughly 1/2 of 1 percent per year) since the mid-1960s. Economic downturns and upturns exhibit the strongest influence, but Minneapolis has clearly succeeded in stabilizing and enhancing its downtown area and its NMT attractiveness. Circumstantial evidence supports a likely correlation with development of the Skyway system, and more recently with implementation of the various downtown-focused bicycle facilities, while the Nicollet Mall has presumably played a supporting role.

Sources. Alliance for Biking & Walking, "Bicycling and Walking in the United States: 2010 Benchmarking Report." Washington, DC. http://peoplepoweredmovement.org/site/index. php/site/memberservices/alliance_2010_benchmarking_report_information_findings (2010) • City of Minneapolis Public Works Department, "Minneapolis Pedestrian Master Plan." Draft for Public Review. Minneapolis, MN (June 8, 2009). • City of Minneapolis, MN, "Report on Bicycle & Pedestrian Counts." City of Minneapolis Department of Public Works (October 22, 2007). • Corbett, M. J., Xie, F., and Levinson, D., "Evaluation of the Second-Story City: The Minneapolis Skyway System." *TRB 87th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 13–17, 2008). • Barnes, G., Thompson, K., and Krizek, K., "A Longitudinal Analysis of the Effect of Bicycle Facilities on Commute Mode Share." *TRB 85th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 22–26, 2006). • Koffman, D., and Edminster, R., *Streets for Pedestrians and Transit: Examples of Transit Malls in the United States.* Final Report—Phase I. Prepared for the Urban Mass Transportation Administration, U.S. Department of Transportation, by Crain and Associates, Menlo Park, CA (August, 1977). • Edminster, R., and Koffman, D., *Streets for Pedestrians and Transit: An Evaluation of Three Transit Malls in the United States.* Final Report—Phase II. Prepared for the Urban Mass Transportation Administration, U.S. Department of Transportation, by Crain and Associates, Menlo Park, CA (February, 1979). • Robertson, K. A., *Pedestrian Malls and Skywalks—Traffic separation strategies in American downtowns.* Avebury—Ashgate Publishing Limited, Brookfield, Vermont (1994). • SRF Consulting Group, Inc., "2003 City of Minneapolis Central Business District Cordon Count." Prepared for the Public Works Department, Traffic & Parking Services Division, City of Minneapolis, MN (December, 2003). • Carlson, R., Metropolitan Council, email to the Handbook authors with attached table, "Minneapolis Downtown area covered employment" (August 24, 2004). • Bruce, P., *Nicollet Mall Pedestrian Count—September 2002 Daily Volumes.* Prepared by Community Enhancement/Pedestrian Studies/www.pedestrianstudies.com, Minneapolis, MN [2002c]. • Bruce, P., *2002 Minneapolis Downtown Pedestrian Count and Analysis.* Prepared by Community Enhancement/Pedestrian Studies/www.pedestrianstudies.com, Minneapolis, MN [2002a]. • SRF Consulting Group, Inc., "City of Minneapolis Central Business District 1998 Cordon Count." Prepared for the Department of Public Works, Transportation Division, City of Minneapolis, MN (November, 1998). • Bruce, P., Community Enhancement and Pedestrian Studies, email to the Handbook authors with attached map, "2007 Downtown Minneapolis Count Project—Skyway Level Daily Volumes—2002–2007 percent change" [redacted version] (July 27, 2009). • Summary computations for 2002, supplemental growth calculations, and overall conclusions by the Handbook authors.

[95] The collapse of the I-35W bridge across the Mississippi just in advance of the 2007 count program could conceivably have had some effect on bicycle counts, even though the freeway bridge itself did not accommodate cyclists. The 2002–2007 bicycle traffic increase at the three counted Mississippi River crossings was 62 percent while the increase at the other six downtown sites was 44 percent.

Bicycle Lanes in the Downtown Area—Toronto, Canada

Situation. Since 1993, the city of Toronto, Canada, has fine-tuned their established policy and process for implementing bicycle lanes along arterial streets mostly in the downtown area. The first bicycle lane in Toronto was installed in 1979 on Poplar Plains Road, a narrow residential street that had just been converted to one-way operation. Between 1990 and 1991, the city added approximately 5 miles of bicycle lanes along two arterial streets and one residential street, respectively: Queens Quay (1990), Bloor Street Viaduct (1991), and Russell Hill Road (1991), the one-way couplet to Poplar Plains Road. By 1993, bicycle traffic entering and leaving the downtown area appeared to be growing and had become a noticeable presence at about 17,000 bicycles per weekday. Bicyclists were also being over-represented in vehicle crashes, with nearly 15 percent of all reported collisions causing injuries involving bicyclists, compared to bicycle volumes representing 3 percent of wheeled traffic. At the same time, motor vehicle traffic levels appeared to be static. Given these factors and a strong, official plan in support of bicycling, the city of Toronto decided to embark on an expanded bicycle lane program.

Actions. In total, about 25 miles of bicycle lanes were constructed on six downtown arterial streets between 1993 and 1998. The bicycle lanes were added to an already congested street network (most arterial streets were carrying about 15,000 to 20,000 vehicles per day) to improve the safety of bicyclists and to encourage bicycling. Along many of these two-way, four-lane arterial streets, the motor vehicle lanes were reduced to one lane per direction, with left turn lane provisions at most signalized intersections. A bicycle lane and an all-day parking lane were introduced in each direction of travel.

Analysis. Before-and-after studies of bicycle and motor vehicle traffic volumes were conducted to gauge the potential changes after bicycle lanes were installed. The reported motor vehicle traffic volumes are expressed as annual average weekday traffic (AAWT). Bicycle volumes were seasonally adjusted to represent annual average weekday volumes. The "after" bicycle counts were typically performed 2 years after opening of the bicycle lane.

Results. Table 16-132 shows that, on average, bicycle volumes on the streets to which bicycle lanes were added increased by 23 percent while motor vehicle volumes remained static. The bicycle volume increases along the six routes with bike lanes ranged from 4 to 42 percent. For motor vehicles, there was one route where volumes dropped by 6 percent and another where volumes increased by 7 percent. Motor vehicle traffic volumes on the other four routes were unchanged after installation of bicycle lanes. Despite the cycling increases on the streets with bicycle lanes, bicycle traffic levels city-wide since 1994 appeared to have remained static or to have declined by as much as 4 percent in a year. This trend was attributed to either declining employment in the central area or an aging population less likely to bicycle. The authors note that the declines in bicycle traffic levels have been most noticeable on streets without bicycle lanes.

More . . . By paying careful attention to design details, the vehicle lane reductions (from two lanes to one through lane in each direction) resulted in only minor reductions in vehicular traffic capacity. For example, parking is prohibited near key intersections, permitting the addition of left-turn lanes. As indicated above and as illustrated in Table 16-132, the lane reductions did not significantly impact motor vehicle volumes on most arterial streets.

Table 16-132 Before and After Traffic Volumes for Selected Streets with Bicycle Lanes

Facility	Installation Date	Motor Vehicle Traffic [a]			Bicycle Traffic [b]		
		Before	After [c]	% Change	Before	After [c]	% Change
Davenport Road (North of Dupont Street)	May 1995	22,000	22,000	0%	600	850	42%
Gerrard Street (West of Sherbourne St.)	Aug. 1995	18,000	18,000	0%	800	900	13%
Sherbourne Street (North of Gerrard Street)	Sept. 1996	16,000	15,000	-6%	550	570	4%
Harbord Street (West of Bathurst Street)	Aug. 1997	15,000	16,000	7%	1,100	1,500	36%
St. George Street (North of College Street)	Aug. 1993	16,000	16,000	0%	1,500	1,650	10%
College Street (West of St. George Street)	Oct. 1993	20,000	20,000	0%	1,450	1,900	31%
Average		17,800	17,800	0%	1,000	1,230	23%

Notes: [a] Annual average weekday traffic volume.

[b] Seasonally adjusted (year-round) average weekday traffic volumes.

[c] Typically surveyed 2 years after installation.

Source. Macbeth, A. G., "Bicycle Lanes in Toronto." *ITE Journal,* Institute of Transportation Engineers, Washington, DC (April, 1999).

Anderson Road Bicycle Lanes—Davis, California

Situation. The city of Davis, California, has a well-established network of bicycle facilities and is home to a campus of the University of California. In the initial design of the city's bicycle lane system, a general travel grid for bicycles was laid over the existing street network. On-street bicycle lanes were placed on some, but not all, of the streets in the designated grid. Initial plans for Anderson Road included bicycle lanes but they were not immediately constructed. The addition of bicycle lanes in 1974 provided an opportunity to evaluate the impact on bicyclists' route choice. This opportunity along Anderson Road was unique for several reasons. Davis already had a relatively high percentage of bicycle commuters as compared to typical small college towns. A mature bicycle lane system was already in place, thereby lessening any novelty effect the Anderson Road bicycle lanes might have on bicycle trip generation, mode choice, or lane usage. Lastly, knowledge of the bicycle lane implementation was available enough in advance to design a behavioral experiment on bicyclists' route choices.

Actions. In 1974, the city of Davis converted Anderson Road from its original configuration (four lanes plus parking on 64 feet of pavement) to two motor vehicle lanes, a center two-way left-turn lane, and two bicycle lanes, one on each side. The on-street parking remained in the new configuration.

Analysis. A total of 254 bicyclists living within two blocks of Anderson Road were interviewed in their homes, before installation of the Anderson Road bicycle lanes, about their route choice selection. Based on the results, a partially different set of 108 bicyclists were home-interviewed after installation. Bicyclists living further from Anderson road were added, as far out as the parallel roads with previously installed bicycle lanes. This provided survey coverage equivalent to roughly five normal city blocks on each side of Anderson Road. A group of bicyclists living very close to Anderson Road were omitted, as they had been shown to already exhibit approximately 90 percent use of Anderson Road in the before condition. The subjects were categorized by gender and age group to discern differences in route selection among these groups. Route choices were determined both for the after condition and, retrospectively, for the before condition. Respondents were also asked to rank bicycling conditions before and after.

Bicycle traffic volumes were also collected along Anderson Road as well as the two parallel alternate routes with existing bicycle lanes, Sycamore Lane and Oak Avenue. The bicyclist volumes were counted manually on all three streets for two consecutive days several weeks before and 1 week after installation of the bicycle lanes. The counts were taken from 7:30 to 8:30 AM and 3:30 to 5:30 PM. The traffic observers also categorized each bicyclist by gender and age group as best possible.

Results. Interviews conducted with 108 bicyclists after installation of the bicycle lanes revealed that 44 percent (25 of 57) of the surveyed bicyclists previously using other streets in the Anderson Road area shifted to the Anderson Road bicycle lanes. No cyclist reported changing from Anderson Road to other streets. The route choice shift to Anderson Road was most pronounced in the 25 and older age category, which accounted for the majority of the surveyed bicyclists. Interview results are detailed in Table 16-133.

The actual counts, on the other hand, showed increases in bicycle volumes on all major routes. These increases, seen in the count data presentation of Table 16-134, were ascribed to seasonal variations related to weather and school schedules. The counts indicated that total bicyclist volumes along Anderson Road did not increase proportionately more than on nearby alternate routes after addition of the Anderson Road bicycle lanes; indeed, they increased slightly less. The 25-and-older age category did, however, show a significantly greater increase in bicyclist volumes (87 percent as compared to 52 percent on Oak Avenue or 8 percent on Sycamore Lane). The majority of the bicyclists counted appeared to be in the 18 to 24 age category, but the changes in total bicyclist volumes after implementation of the bicycle lanes show no clear pattern for Anderson Road or the two alternate routes.

Table 16-133 "After" Survey Interview Data on Selection of Anderson Road as a Travel Route Before and After Bicycle Lane Installation

	Age and Sex Class										
	0 to 11		12 to 17		18 to 24		25 and up		Total		
Route Selection	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**All**
Residence East of Anderson											
Using other routes before	2	–	–	–	3	1	7	10	12	11	23
Using Anderson before	1	3	3	5	1	1	4	5	9	14	23
Using Anderson after	1	3	3	5	1	2	8	9	13	19	32
Change from other route to Anderson [a]	–	–	–	–	–	+1	+4	+4	+4	+5	+9 of 23 (39%)
Residence West of Anderson											
Using other routes before	2	6	3	1	3	1	7	11	15	19	34
Using Anderson before	1	2	3	–	2	3	12	7	18	12	30
Using Anderson after	1	4	6	–	3	4	16	12	26	20	46
Change from other route to Anderson [a]	–	+2 [b]	+3 [b]	–	+1	+1	+4	+5	+8	+8	+16 of 34 (47%)
Total (East and West of Anderson)											
Using other routes before	4	6	3	1	6	2	14	21	27	30	57
Using Anderson before	2	5	6	5	3	4	16	12	27	26	53
Using Anderson after	2	7	9	5	4	6	24	21	39	39	78
Change from other route to Anderson [a]	-	+2 [b]	+3 [b]	-	+1	+2	+8	+9	+12	+13	+25 of 57 (44%)

Notes: The interviewees lived between Anderson Road and the next-over parallel bike lanes. Bicyclists living very close to Anderson Road were omitted. For additional background see text under "Analysis."

[a] Percentages calculated relative to those using other routes before. No one reported changing from Anderson Road to another route.

[b] These children changed from using the Anderson Road sidewalks to using the Anderson Road bicycle lanes.

Source: Lott, Tardiff, and Lott (1979).

Table 16-134 Bicyclist Volume Count Data on Three Parallel Routes Before and After Installation of Anderson Road Bicycle Lanes

	Age and Gender Class												
	0 to 11			12 to 17			18 to 24			25 and up			
Route Selection	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	**Grand Total**
Sycamore Lane													
Before	82	13	95	28	14	42	526	389	915	118	16	134	1,186
After	98	33	131	26	31	57	552	443	995	130	15	145	1,298
Change	+20%	+154%	+38%	-7%	+121%	+36%	+5%	+14%	+9%	+10%	-6%	+8%	+9%
Anderson Road													
Before	6	3	9	29	14	43	617	550	1,167	223	32	255	1,474
After	2	5	7	33	8	41	488	564	1,052	395	82	477	1,577
Change	-60%	+67%	-22%	+14%	-43%	-5%	-21%	+3%	-10%	+77%	+156%	+87%	+7%
Oak Avenue													
Before	2	1	3	27	18	45	277	139	416	206	34	240	704
After	5	1	6	24	16	40	232	157	389	284	80	364	789
Change	+150%	0%	+100%	-11%	-11%	-11%	-16%	+13%	-6%	+38%	+135%	+52%	+12%

Notes: Bicyclist volumes are from 7:30 to 8:30 a.m. and 3:30 to 5:30 p.m. and are average values for two days.

Age and gender class estimated by count crew.

Source: Lott, Tardiff, and Lott (1979).

More . . . The interviews showed no primary route shifts for bicyclists under age 18, but five of 23 children (22 percent) reporting use of the Anderson Road bicycle lanes had formerly used the sidewalk. All interviewees were asked to rate Anderson Road for bicycle use before and after bicycle lane implementation. The rating scale ran from 7 (very bad conditions) to 1 (very good conditions). The average ranking was lowered 3.7 points between the before and after conditions, more than three-fifths the span of the scale, indicating substantial perceived improvement. There was a rough correspondence between perception of improvement and the decision to change route, the other factor in play apparently being directness of travel route.

Source. Lott, D. F., Tardiff, T. and Lott, D. Y., "Evaluation by Experienced Riders of a New Bicycle Lane in an Established Bikeway System." *Transportation Research Record 683* (1979).

Six Urban, Suburban, and Semi-Rural Trails—Indiana Trails Study

Situation. Indiana is among the states that have committed significant federal and state funds to shared use, off-road trail development in local communities. The Indiana Trails Study was undertaken to address decision-maker need for comprehensive information on trail use and attitudes of users and trail neighbors. Six urban, suburban, and rural trails were studied. Although facilities classified as "rural" are generally beyond the scope of this "Traveler Response to Transportation System Changes" Handbook, the trails deemed rural in the Indiana study are included not only for comparison purposes but also because part of their alignments lie within small cities.

Actions. Table 16-135 lists the location, trail type, pavement type, width, and construction dates for each of the six trails. From the construction dates one may infer the time the trails were in service prior to the year 2000 counts and surveys.

Table 16-135 Locations, Characteristics, and Construction Dates for Studied Indiana Trails

Location	Trail Name	Type	Pavement	Length, Width	Construction Dates
Fort Wayne	Rivergreenway Trail	riverfront	hard surface	15 mi., 8-12′	1980′s
Goshen	Maple City Greenway	mill-race [a]	crushed stone	10 mi., 10′ ±	1996, 2000
Greenfield	Pennsy Trail	rail-trail	asphalt	3 mi., 12′	1998
Indianapolis	Monon Trail	rail-trail	asphalt	7½ mi., 10-12′	1995, 1997
Muncie	Cardinal Greenway	rail-trail	asphalt	10 mi., 12′	1998
Portage	Prairie Duneland	rail-trail	asphalt	6 mi., 12′	1996

Note: Trail characteristics and extent are as of the survey/study timeframe.

The Rivergreenway Trail (Ft. Wayne) and Monon Trail (Indianapolis) are classified urban, the Maple City Greenway (Goshen) and Prairie Duneland trail (Portage) are classified suburban, and the Pennsy Trail (Greenfield) and Cardinal Greenway (Muncie) are classified rural.

[a] The Maple City Greenway is a trail network that includes rail-trails, trails built in parkland and utility easements, a trail alongside an 1860′s mill race (man-made open water conduit), and city street segments. The Goshen study concentrated on Mill Race Trail use.

Analysis. Study methods applied on each of the six trails included user counts at selected trail segments made with infrared trail counters, entering/exiting user interviews with follow-up mail-back questionnaires, a mail survey of "trail neighbors" (adjacent property owners), and telephone interviews with local realtors. A counter was positioned on each trail: at one location on the 3-mile Pennsy Trail, two locations on the 6-mile Prairie Duneland Trail, and three locations on the other, longer trails. They were in place during August and September, 2000, and on each trail were rotated among locations every 10 days. Infrared counter results were adjusted on the basis of "hand" counting done for validation purposes.

Trail user surveys were conducted at four locations on each trail for 1 week each in July and August. One location at a time was surveyed, with 4-hour rotation so that 7:00 AM to 7:00 PM coverage was obtained. Every nth adult was asked to participate in a 3-minute interview with a mail-back questionnaire covering additional detail. Mail-back survey response rates were high, ranging from 70 to 97 percent for all trails except in Portage (50 percent) and Fort Wayne (39 percent). The sample of trail users intercepted ranged from 108 in Muncie to 585 in Fort Wayne. Totals of usable survey returns ranged from 72 in Greenfield to 200 in Fort Wayne.

Even with the excellent survey return rate, the response for minorities may have been below average, most notably among urban blacks and populations for whom English would likely be a second language (see comparative data provided in the bottom rows of Table 16-137). An important detail to note is that the trail user surveys were conducted at trail access points, and the interviews/surveys were of trail users entering or leaving the trail.[96]

Results. Table 16-136 presents the volume data obtained, with population and trail distance listed first as a point of reference. All count-based information in the table is shown as ranges where the first number is based on the September 2000 count and the second number is based on the October count. The Indianapolis Monon Trail October count information involved extrapolation to cover about 2 weeks when actual counts were not successfully obtained. There was a shift forward of peak hours and a general reduction in total trail traffic as the days shortened in October relative to September. For example, the monthly total Fort Wayne Rivergreenway trail count dropped 10 percent from 26,914 to 24,231 while the weekday peak hour moved forward 1 hour on weekdays and 2 hours on weekends. However, the peaks sharpened as the daylight hours for trail activity compressed. It can be seen that in some cities the count for the highest single hour of the month actually increased in October.

As discussed elsewhere, new facilities such as those covered in the Indiana Trails Study present an analytical problem in that there is no "before" data with which to compare. Impacts must be either determined from screenline data (not done here and rarely obtained) or from retrospective questions asked in surveys (see below).

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[96] This process of interviewing and handing-out of surveys to persons beginning and ending trail use rather than persons intercepted on the main trail itself has important implications. It means that, as a survey of users, it obtained results not biased by trip length differentials. If an on-trail intercept had been used, given that average bicycle trip distances are longer than walk trip distances, a typical bicycle trip would have been more likely to have been picked up than a typical walk trip. The generally available classification counts taken on trails reflect user mix at points along the trail, useful for operational analyses, whereas interception of persons starting or ending trail use is best for analysis of the mix of users taking advantage of a trail. In transportation planning terms, the method used in these Indiana surveys provides actual trip-based user data, as would a trip attraction survey.

The demographic information obtained for users of the Indiana trails is contained within Table 16-137. The distribution of males versus females on the trails ranges all the way from 68 percent male and 32 percent female on the rural Cardinal Greenway Trail radiating out from Muncie to 46 percent male and 54 percent female on the urban Monon Trail within Indianapolis. The Muncie trail is very bicyclist oriented, while the Monon Trail has many more walkers and runners than cyclists in terms of individual trail users. Other trail user demographics also vary among locations, with a definite slant toward the most educated and highest income users in Indianapolis.

Table 16-138 gives trail use characteristics for the Indiana trails. As indicated in the "Analysis" section above and Footnote 96, these data are derived from actual trip-based user attraction surveys taken of persons entering or leaving the trails, rather than from classification count observations or mainline-trail-based survey results. Distributions of uses normally involving less or more mileage, such as walk trips versus bicycle trips, are best represented by trip-based data such as presented here. It is also important to recall that the information covers all days of the week, including weekdays and weekend days.

Table 16-136 Indiana Trails NMT Traffic Count Information (September–October 2000)

	Fort Wayne	Goshen	Greenfield	Indianapolis	Muncie	Portage
Population	205,727	29,383	14,600	1-½ million [MSA]	67,430	33,496
Trail Length	15 miles	10 miles	3 miles	7-½ miles	10 miles	6 miles
Sept. – Oct. Count	26,914 – 24,231	10,530 – 9,107	5,218 – 6,108	55,148 – 45,606	9,275 – 9,063	12,766 – 8,430
Average Weekday	835 – 684	310 – 251	166 – 175	1,618 – 1,133	270 – 252	376 – 243
Peak 1 Hour Starts:	6 PM – 5 PM	5 PM – 5 PM	6 PM – 5 PM	6 PM – 5 PM	5 PM – 4 PM	6 PM – 5 PM
Percentage of Day	13.2% – 14.2%	11.6% – 14.9%	15.0% – 12.5%	17.9% – 19.4%	10.7% – 11.0%	12.5% – 14.0%
Avg. Weekend Day	1,025 – 1,017	447 – 430	192 – 252	2,352 – 2,181	408 – 372	541 – 398
Peak 1 Hour Starts:	4 PM – 2 PM	4 PM – 2 PM	6 PM – 4 PM	4 PM – 4 PM	3 PM – 3 PM	5 PM – 11 AM
Percentage of Day	9.9% – 11.5%	11.2% – 14.2%	11.5% – 13.9%	10.0% – 12.6%	12.0% – 15.3%	9.4% – 11.3%
Highest Single Hour	377 – 247	162 – 148	74 – 108	554 – 635	114 – 192	109 – 94

Note: Peak 1 hour start times are the average per city/trail for all weekday or weekend days surveyed, as appropriate.

Table 16-137 Indiana Trails Demographic Percentage Distributions from Intercept Interviews and Mail-back Survey

	Fort Wayne	Goshen	Greenfield	Indianapolis	Muncie	Portage
Male / Female Distribution	57% / 43%	57% / 43%	50% / 50%	46% / 54%	68% / 32%	51% / 49%
Age Dist.: ≤25/26-45/46-65/≥66	11/49/32/8	19/34/37/10	16/39/36/9	12/50/32/6	18/36/35/11	18/36/36/10
Income Dist.: <$40K/$40-80K/>80K [a]	35/48/17	39/45/16	33/46/21	22/45/33	33/51/16	33/48/18
Percent College Graduates [a]	60	57	33	79	52	32
Race Dist.: White/Black/Hispanic	86/10/4	92/1/7	98/1/1	92/6/2	95/5/0	92/3/5
Pct. White from Mail-back Survey [a]	94%	98%	100%	97%	96%	96%

Notes: [a] From mail-back survey responses.

Both intercept observations and survey determinations of white race are listed to illustrate possible bias despite high mail-back rates.

Table 16-138 Indiana Trail-Use Information from Entry/Exit Intercept Interviews

	Fort Wayne	Goshen	Greenfield	Indianapolis	Muncie	Portage
Trail activities						
Walk	49%	39%	54%	51%	11%	39%
Run	15%	20%	14%	13%	5%	11%
Bicycle	30%	40%	25%	23%	77%	40%
Skate/other	6%	1%	7%	13%	7%	10%
Mean distance on trail	6 miles	3 miles	4 miles	8 miles	15 miles	7 miles
Median time	35 min.	35 min.	40 min.	60 min.	90 min.	60 min.
Purpose of trail use						
Health/exercise	66%	64%	79%	71%	56%	74%
Recreation	32%	32%	19%	23%	39%	26%
Commute	2%	4%	1%	5%	3%	–
Other	–	–	1%	1%	1%	–
Entry/exit points same	88%	81%	89%	91%	93%	98%
Mode of access						
Walk	24%	27%	19%	29%	6%	9%
Bicycle	17%	30%	19%	14%	27%	15%
Auto	56%	40%	61%	52%	66%	71%
Other	3%	3%	1%	5%	1%	5%
Median access distance from home	2 miles	1 mile	1-½ miles	1 mile	2 miles	2 miles

Note: Seeming discrepancies between distance and time on trail may result from one being reported as the mean and the other being reported as the median.

Users on foot dominate especially on the urban trails, with walkers and runners totaling 64 percent in both Fort Wayne and Indianapolis. Wheeled users (bicyclists and skaters) constitute the 36 percent remainder. The percentages shift somewhat for the trails classified as suburban, those in Goshen and Portage, with a simple average of 54 percent users on foot. The dearth of skaters in Goshen—the "1%" of Table 16-138 is identified as "other"—may simply be reflective of trail surface conditions (crushed limestone). The trend continues on the mostly rural trail in Muncie, with only 16 percent users on foot. The Greenfield rural trail is a statistical outlier, with 68 percent users on foot, perhaps because it is only 3 miles long and fails to reach wide-open country in that distance.

All six trails have uniformly high use for fitness and recreational activities. Use for utilitarian transportation purposes may be somewhat higher than meets the eye, however, a possibility explored below under "More . . ." Responses identifying whether the user's trail entry and exit points are identical give an alternative indicator of utilitarian use. The 2 to 19 percent of trail respondents for whom entry and exit points were not the same are likely, although not certain, to have been using the trail at least in part for utilitarian travel purposes. It is notable that the majority of access is via auto except in Goshen, even though 50 percent or more of trail users were found to live within 2 miles of their trail.

Behavioral impacts of all-new facilities such as these shared-use trails typically must be determined from retrospective queries, or "what if?" questions, asked in interviews and surveys. While there are reliability issues with such survey approaches, they at least offer some insight. The first part of Table 16-139 contains response data suggesting that 14 to 19 percent of walkers, runners, cyclists, and skaters on the trails are engaging in their chosen activity only by virtue of the presence of the trail. From 70 to 87 percent believe they are walking, running, cycling, or skating more because of the trail. (Less than definitive clarity is suggested by the fact that the two percentages for Muncie add to more than 100 percent.) In general, responses such as these suggest a substantive positive effect on incidence and frequency of physical activity. Alternative activity possibilities must be taken into account, however, as is done next in the "More . . ." subsection using findings from the second half of the table.

Table 16-139 Impact of Indiana Trails on User Activity as Reported in Intercept Interviews and Mail-back Survey

	Fort Wayne	Goshen	Greenfield	Indianapolis	Muncie	Portage
First-time trail users [a]	9%	7%	11%	4%	9%	6%
W/r/c/s now because of trail	19%	14%	14%	16%	19%	17%
W/r/c/s more with trail available	79%	70%	74%	81%	87%	82%
W/r/c/s time spent because of trail availability (median, weekly)	120 min.	100 min.	120 min.	180 min.	200 min.	180 min.
Without the trail available would have participated in the same activity: [b]						
On streets or sidewalks	68%	68%	86%	59%	62%	59%
In park or other outdoor place [c]	18%	15%	1%	16%	7%	12%
In gym, mall, or other	2%	1%	0%	3%	2%	6%
No, would have done something different	12%	6%	13%	2%	29%	22%
Remainder [d]	–	10%	0%	20%	–	1%

Note: W/r/c/s = walk, run, cycle, or skate.

[a] Users who, on the survey day, had never been on the trail before.

[b] From mail-back survey responses as tabulated in the individual trail reports (values not so indicated are from intercept interviews as tabulated in the Summary Report).

[c] Including other trails or linear greenways.

[d] "Stay Home" for Goshen and Greenfield, not explained for Indianapolis or Portage.

More . . . Some of the Indiana Trails user survey questions offer a look behind effects observed "on the surface." The second half of Table 16-139 covers responses from probing what activities trail users would have engaged in had the trail not been there. Some 71 to 88 percent of survey respondents advised that they would have walked, run, cycled or skated somewhere else, mainly on streets or sidewalks. This indicates a high level of commitment to the chosen activity, although it is not to say respondents would have been active to the same extent. Another 2 to 29 percent would have done something different. It is not clear how much transportation or physical activity that would have involved. Finally, there were those who would have remained at home (10 percent in Goshen) or whose alternative activity was not accounted for in the survey response reporting (20 percent in Indianapolis). Overall, there is imprecise but strong indication that many trail users became more physically active as a result of trail development.

In addition, the user survey asked about both "main" and "other" purposes of visiting the trail. The purpose information in Table 16-138 pertains to the main use. As an example, among users of the Monon Trail in Indianapolis, 5 percent reported "commute" as their main purpose. Of those who answered the other-purpose question, 12 percent reported "commute," and another 3 percent reported various utilitarian secondary purposes ranging from dining to business. Although many users undoubtedly combine health/exercise with recreation, it nevertheless appears that combinations of health/exercise or recreation with commuting and other utilitarian transportation must be taken into account when interpreting trail use. The proportion of trips on the Monon Trail that serve to accomplish the work commute could, for example, theoretically lie somewhere between the raw figure of 5 percent and a maximum of 17 percent (5 percent primary-purpose plus 12 percent secondary-purpose) if assessed solely on the basis of "main" and "other" purposes. However, it would seem illogical for trips with a commute purpose to enter and exit at the same trail access point. Thus in the Monon trail example, with 91 percent of users reporting the same entry and exit points, no more than 9 percent can reasonably be true commute trips unless, perhaps, the entry/exit point question was misunderstood.

The trail user surveys also included attitudinal questions. The median attitude toward the trail on all six facilities was one of being "very satisfied" (5 on a 6-point scale). The city was viewed more favorably by 76 to 100 percent of users as a result of the trail, with no report of viewing the city less favorably. Only a minority of users, however, found the trail to be a reason for choice of housing location. Surveyed persons living adjacent to the trail were more guarded in their responses, but were nevertheless satisfied (five cities, 5 on a 7-point scale, median ranking) or neutral (one city, 4 on a 7-point scale) with regard to having the trail as a neighbor. Among those having purchased their home after trail opening, the reaction was one of being "very supportive" (6 on a 7-point scale) or, in one city, "extremely supportive." Estimated household trail use by trail neighbors was 117 to 139 days annually. Roughly 90 percent perceived that the trail had modestly added to or not affected their property value. Interviewed realtors were just slightly more circumspect, advising that they saw no major increases in property value or ease of making sales.

Sources. Patten, R. S., Derry, A., Hiemstra, H., and Fowler, M., "ISTEA and Trails: Merging Transportation Needs and Recreation Values." Published by Rails-to-Trails Conservancy and American Trails for the 12th National Trails Symposium, Anchorage, Alaska. http://ntl.bts.gov/DOCS/mtn.html (September, 1994). • Indiana University, "Indiana Trails Study—A Study of Trails in 6 Indiana Cities." Summary Report and individual trail reports (Rivergreenway Trail—Ft. Wayne, IN; Maple City Greenway Trail—Goshen, IN; Pennsy Rail Trail—Greenfield, IN; Monon Trail—Indianapolis, IN; Cardinal Greenway Trail—Muncie, IN; Prairie Duneland Trail—Portage, IN). Prepared by Epply Institute for Parks & Public Lands, Indiana University, Bloomington, IN (November/December, 2001). • "Without trail" distributions in Table 16-139 and certain interpretations in the activity and purpose discussions include elaborations by the Handbook authors.

Variations on Individualized Marketing in the Northwest United States

Situation. "Individualized marketing" seeks to modify travel choices by delivering tailored information on walking, bicycling, and public transit options for meeting daily travel needs. The "Individualized Transit Marketing in Europe" case study in Chapter 11, "Transit Information and Promotion," describes procedures and outcomes for the original IndiMark™ individualized transit-marketing protocol developed by Socialdata GmbH. Chapter 16's "Response by Type of NMT Strategy" section provides an update keyed to active transportation applications in the United States, the United Kingdom, and Australia (see "Individualized Marketing" within the "Walking/Bicycling Promotion and Information" subsection). Over one-half of these applications have followed the essential IndiMark protocol while the remainder are variants.

Programs in Northern California and the Pacific Northwest illustrate newer developments that range from major departures from the original protocol to incremental but substantive enhancements to the IndiMark approach. In adjudged order of increasing interactivity of personalized intervention, the four programs covered below are the "In Motion" demonstrations in Seattle; the "Way to Go Sausalito" pilot program within Marin County, California; the post-2004 SmartTrips campaigns in Portland, Oregon; and the Whatcom Smart Trips IndiMark application in Bellingham, Whatcom County, Washington.

Actions. Seattle's "In Motion" campaign was initiated in 2004 with demonstration programs situated in neighborhoods with reasonable sidewalk availability, access to nearby services, and at least half-hourly bus frequencies all day. The demonstrations, in terms of a "passive," "active," and "interactive" classification system, exhibited characteristics of a passive targeted marketing campaign. Individualized information materials and incentives were innovatively advertised and delivered, but the intended recipients had to proactively react to receive them. They had to react again, more or less on their own, to put alternative travel mode use into practice. The "In Motion" approach put substantial emphasis on blanket neighborhood promotion, such as catchy telephone-pole posters and direct mail, to prompt inquiries about the additional information available. Those choosing to respond received materials typical of individualized marketing programs, via mail, and also were asked to take an alternative-mode-use pledge. A website, neighborhood displays, a neighborhood Transportation Action Team, and local events were part of the community-focused effort.

The "Way to Go Sausalito" pilot program of 2008 was an element of "Walk Bike Marin," the Marin County component of the multi-faceted national Nonmotorized Transportation Pilot Program. Sausalito is an historic, mostly upscale, waterfront city of some 7,000 residents in the San Francisco commutershed. The Sausalito approach was arguably intermediate between "passive" and "active" in character. To obtain their "Go Kit" of customized information, residents had to respond to a mass-mailed newsletter, reminder postcard, other conventional community communication media, or the project website. "Go Kits" were delivered by bicycle in "Way to Go" tote bags. The Sausalito program is perhaps most notable for having a full menu of events, though as quantified below under the "More . . ." heading, attendance at many was quite small.

Portland, following a demonstration in 2003 and their first full-scale sector program in 2004 (both IndiMark based), worked to handle subsequent programs with mostly in-house staff and volunteers and to broaden enticements and events. (Table 16-143 under "More . . ." illustrates the array of materials and activities offered.) At the same time, conduct of any one-on-one alternative mode assistance sessions at the residence was apparently dropped. Portland's post-2004, annual, sector-by-sector SmartTrips campaigns thus probably fall in the "active" category of individualized marketing, with contact calls and personalized delivery of materials, but with almost full reliance on the receiver for ultimate action.

The 2008 "Neighborhood Smart Trips" component of Whatcom Smart Trips was an enhanced IndiMark application. It targeted the central area and coastal corridors of Bellingham between Bellingham Bay and the I-5 freeway. Extending from north to south city limits, some newer suburban-style development was included, but coverage was dominated by older areas with grid streets, sidewalks and/or light traffic, and substantial shared use trail and bike lane infrastructure. Just over 10,000 households were included, representing about 1/3 of the city's population. This IndiMark application was the first large-scale use of three different contact methods to address decline in listed land-line telephone numbers and ensure all possible target area households were reached. Telephoning, after an introductory mailing, was the preferred initial contact. If telephone contact proved impossible and outreach via U.S. Mail produced no response, dwelling-to-dwelling door knocking was employed in selected walkable areas. In all areas, "diffusion" was also relied upon, counting on residents to see the involvement of neighbors and become interested themselves. Representative of the "interactive" approach, dialogue was established, requested materials were delivered, and follow-up interaction—both group and one-on-one—was encouraged.

The overall ongoing Whatcom Smart Trips program includes an interactive web-based Smart Trips Diary where adults living or working in Whatcom County (including British Columbia residents) can maintain a record of walking, cycling, transit, and ridesharing trips made. The diary automatically calculates statistics such as pollution prevented and is tied to a system of rewards (gift certificates and the like) and recognition for reaching Smart Trips milestones. An emergency ride home program (a.k.a. guaranteed ride home or GRH) is provided for commute trips, and a Smart Trips Employer Partners program offers assistance to state-mandated and volunteer worksite trip reduction programs. Targeted outreach to seniors and women provides education in the use of the bus system and bicycles, respectively, while School Smart Trips offers middle school classroom activities. An EverybodyBIKE educational program provides cycling mentors, skill rodeos for children, and safety classes.

Analysis. Table 16-140 lists the primary evaluation parameters for each of the four programs. Seattle's "In Motion" demonstrations did not include surveys of target area residents overall. The only response data are for the 6 to 10 percent who actually became participants in the initial three demonstrations and thus are not included here for lack of compatibility with the survey information from other cities. Target-neighborhood bus boarding increases were compared with boarding statistics for a control neighborhood.

Table 16-140 Seattle "In Motion," "Way to Go Sausalito," Portland "SmartTrips," and Whatcom "Smart Trips" Target Group Evaluation Parameters

Program	Before Sampl e	After Sampl e	Before/After Response Rate	Control Group	External Evidence
Seattle "In Motion"	None	— [a]	n/a	Bus boardings	Bus boardings
"Way to Go Sausalito"	1,525	1,500	18%/11% [b]	None reported	None reported
Portland (2005) E Hub	300 [c]	300 [c]	n/a	1/2 of samples	Walk, bike counts
Portland (2006) NE Hub	600 [c]	600 [c]	n/a	1/2 of samples	None reported
Portland (2007) SE	600 [c]	600 [c]	n/a	None reported	Bike counts
Portland (2008) SW	692 [d]	288 [d]	n/a/64% [d]	None reported	Bike counts
Portland (2009) N/NW	No specifics reported on the before and after surveys				None reported
Whatcom Smart Trips	7,495 [e]	3,863 [e]	76%/78%	Yes – included	Anecdotal

Note: [a] A self-assessment survey was conducted of "In Motion" participants only.

[b] The self-administered-survey response rate drop-off in the randomly-selected Sausalito samples, to the notably low 11% "after" survey response rate, introduces above-average concerns of possible response bias (Handbook authors' assessment).

[c] Number of randomly selected telephone interviews completed.

[d] Of 692 respondents to September 2007 and April 2008 surveys prior to the 2008 TravelSmart, 449 households agreed to participate in a September 2008 follow-up panel survey, and 288 (64%) were reached and did so.

[e] Number of actual respondents, not the entire randomly selected target group sample.

The Sausalito evaluation surveys covered in Table 16-140, including Note B, were conducted immediately preceding and after the individualized marketing and related activities. Therefore, effects identified may or may not have been short term only. There was no control group or collection of external evidence.

The Portland Table 16-140 entries do not include the 2003 and 2004 IndiMark-based programs. The variety of post-2004 evaluation approaches and reporting in Portland may be judged from both Table 16-140 and the results descriptions to follow. It is rather obvious from the statistics in Table 16-140 that the most robust survey-based analysis potential is offered by the large Whatcom Smart Trips before and after surveys with their 76 and 78 percent response rates.

The Whatcom Smart Trips application in Bellingham followed the basic IndiMark protocol including follow-up prompts to increase response rates for the relatively large surveys. These surveys were scheduled roughly 1 year before and 1 year after the 2008 individualized marketing. Both the before and after survey samples were random picks, as contrasted to the panel approach less often used. The high response rate, use of trip diaries, lack of reference to the Smart Trips endeavor, and response rate factoring supported the minimization of potential for bias in the findings. Factoring was separately done for the standard IndiMark "Interested," "Regular [user]," and "Not Interested" individualized marketing groupings.

The control sample component of the survey populations was used to identify trends, which were in turn employed to project mode shares for a hypothetical "without IndiMark" target population. These were then used as a base to compare "with IndiMark" outcomes against. For example, control-group public transportation bus riding increased 29 percent from 2007 to 2009 in presumed response to increased service and a Western Washington University bus pass. Thus the target group 2007 public bus mode share of 3 percent was adjusted to 4 percent before comparing 2009 "with IndiMark" outcomes against it.

Results. Results documentation for these innovative Northwest U.S. and Northern California programs has mostly been too limited, and lacking in discernible outcome differentials relative to other individualized marketing projects, to allow firm conclusions as to effectiveness of the broadening of information and activity menus. Portland auto driver trip reductions have not varied from the norm established prior to the 2005 addition of tours and workshops, except in 2006 during marked increases in gasoline prices. The Whatcom Smart Trips undertaking comes with extensive survey data and very favorable comparisons, but caution should be used in transferring findings to other areas, given Bellingham's location in the midst of the environmentally conscious Pacific Northwest. In any case, broadened menus of support actions are unlikely to detract from the individualized marketing core approach—unless they replace proven protocols—and may support other community objectives.

Overall target area mode shifts were not surveyed in Seattle, but the demonstration study-area bus-boarding increase of 11 percent for up to 9 months after program implementation—compared to 1 percent in a control area—was notable. The percentage of target area households actually participating in the initial "In Motion" demonstrations was, however, only 6 to 10 percent. The lesser emphasis on proactive contact and interactive, dialogue-based follow-up may have shifted outcomes toward the lesser response typically found with mass marketing approaches.

The "Way to Go Sausalito" program results, where the proportion of households requesting "Go Kit" information packets was just over 15 percent, may similarly reflect an emphasis shift toward event- and website-based mass marketing techniques as compared to priority emphasis on highly proactive multi-pronged individualized dialogue/contact. Based on the before-and-after surveys addressed in Table 16-140, including Note B, the effect on Sausalito trip making was reported as a 9.5 percent relative increase in resident share of trips via active transportation (12.8 percent for walking and bicycling and no change in transit riding) and a 4.7 percent resident decrease in auto share. The absolute mode shift equivalents were +3.3 percentage points for walk/bike, zero shift for transit use, and –3.0 percentage points for auto use. Given the survey timing, these were short-term effects, with longer-term effects unknown.

Portland's IndiMark individualized marketing results for 2003 and 2004 were covered in the "Response by Type of NMT Strategy" section along with selected information for subsequent years (see "Walking/Bicycling Promotion and Information"—"Individualized Marketing"—"U.S. Home/Community-Based Program Mode Share Results.") Following post-2004 program changes, full mode shift detail has been reported only for certain years, but auto driver trip reduction results are available for each annual program.

The 2005 Eastside Hub "Options" project resulted in before-and-after survey-based *relative* mode share changes of +7 percent for walking, +41 percent for transit use, –8.6 percent for auto driving, no change in carpooling, and an insignificant shift for bicycling. Before-and-after two-hour AM, midday, and PM peak counts at selected Eastside Hub intersections showed a 7 percent walking increase in confirmation of the survey results. Corresponding 10-intersection bicycle counts indicated a 23 percent increase in average cycling volumes.[97]

The 2006 program covered the Northeast Hub area, introducing the city of Portland's own "SmartTrips" branding. The 2006 results were explicitly adjusted for rather significant mode shifts, identified in control group survey findings, thought likely to be the result of gasoline price increases. The adjusted *absolute* gains for environmentally friendly modes were 5 percentage points walk mode share gain, 2 percentage points bike share gain, and 1 percentage point bus- and light-rail-transit-share gain. The drive-alone adjusted shift was an 8 percentage points *absolute* decline (with carpooling increasing 3 percentage points) or a 12.8 percent decline in *relative* terms.

The 2007 SmartTrips Southeast project reported a 17.5 percent overall *relative* increase in use of environmentally friendly travel modes among southeast residents. Peak-hour 3-day AM, Noon, and PM bicycle counts at four key southeast intersections, obtained in September of 2006 and again in 2007, averaged a 26.5 percent increase. This was higher than the 18 percent citywide increase seen in the annual reporting of bicycle counts.

The 2008 SmartTrips Southwest project found weekday walking shares to have increased 36 percent, from 8.3 percent before individualized marketing to 11.3 percent after. Drive alone trips decreased 9.0 percent in relative terms. Bicycle work-purpose trips increased 38 percent, from 3.1 to 4.3 percent, but across all trip purposes the bike mode share remained constant. However, a count program similar to the previous year, covering three southwest intersections, found a 42 percent average growth in bicycle volumes—one-and-one-half times the citywide annual increase of 28 percent.

In Portland's 2009 North/Northwest project, approximately 7,500 target area households (about 25 percent) ordered materials, participated in one or more of the program events, or stopped by tables manned at other neighborhood events. The percentage specifically ordering materials was 12 to 13 percent. A survey-based relative increase estimate of 10.5 percent in environmentally friendly mode usage was accompanied by a 9.3 percent decrease in drive-alone trips.

As indicated in the "Response by Type of NMT Strategy" section, Portland appears to have achieved somewhat larger environmentally friendly mode shifts than observed in the 2003–2006 FTA IMDP National Demonstrations, which did not include Portland. Comparing 2005–2009 Portland results with the earlier 2003–2004 Portland outcomes, however, there is no sound basis for concluding that the protocol changes and innovations introduced in 2005 and enhanced in suc-

[97] City-wide secular trends were not reported in connection with the pedestrian and bicycle count results for the 2005 Eastside Hub individualized marketing analysis.

ceeding years have either increased or decreased program effectiveness as measured by travel mode shift outcomes.

The Whatcom Smart Trips 2008 Bellingham application of an enhanced IndiMark protocol has produced among the largest, if not the largest, of shifts to environmentally sustainable travel modes of any major individualized marketing project to date. The results have included substantial shifts to walking and bicycling. A 15 percent reduction in auto vehicle miles of travel (VMT) has been computed.

Of 10,037 households targeted in the individualized marketing outreach, 8,880 (88 percent) were successfully contacted. Among these, 356 (4 percent) were regular environmentally friendly mode users with no information needs, 847 (9 percent) were regular users who wanted more information, 3,963 (45 percent) were interested in exploring use of environmentally friendly modes, and 3,714 (42 percent) were not interested. With 90 percent of interested households following up with an individualized marketing materials request, combined with regular users who wanted more information, roughly 50 percent of households reached and 44 percent of target area population obtained offered materials.

Table 16-141 presents the changes in mode shares measured in the control group. As noted earlier, the increase in public transit use from 2007 to 2009 is thought to reflect effects of bus service increases and Western Washington University bus pass availability and use. The control group changes observed were applied to the 2007 target group shares, as previously explained, to obtain adjusted "before" shares as shown in Table 16-142. The "after" shares in Table 16-142 are best compared with the adjusted "before" shares. That is how the relative and absolute mode shifts attributable to the Smart Trips project (last two columns) are computed.

Table 16-141 Whatcom Smart Trips 2007 to 2009 Bellingham Control Group Mode Changes

Travel Mode	2007 Mode Shares	2009 Mode Shares	Relative Changes (Percent Up/Down)	Absolute Changes (Percentage Points)
Walk	7%	7%	-1%	0
Bicycle	3%	3%	+2%	0
Public Transit	2%	3%	+29%	+1%
Auto Driver	63%	62%	-1%	-1%
Auto Passenger	24%	23%	-3%	-1%

Notes: Absolute changes calculated by the Handbook authors from before/after mode share percentages reported in integers.

Motorcycle mode omitted (1 percent or less).

School bus mode omitted (1 percent throughout).

Table 16-142 Whatcom Smart Trips 2007 to 2009 Bellingham Target Group Mode Shifts

Travel Mode	2007 Target Group Shares	Adjusted "Before" IndiMark Shares	2009 Target Group "After" Shares	Relative Mode Shifts (Percent Up/Down)	Absolute Mode Shifts (Percentage Points)
Walk	16%	16%	20%	+22%	+4%
Bicycle	8%	8%	11%	+35%	+3%
Public Transit	3%	4%	4%	+11%	<+1%
Auto Driver	51%	50%	44%	-13%	-6%
Auto Passenger	21%	20%	19%	-3%	-1%

Notes: Absolute changes calculated by the Handbook authors from before/after mode share percentages reported in integers.

Motorcycle mode omitted (1 percent or less).

School bus mode omitted (1 percent throughout).

Target group shifts to active transportation modes were fairly evenly distributed across all purposes of travel, including leisure, judging by auto trip reductions by trip purpose. There was perhaps a moderately elevated impact on education and "other" purpose trips. Quantification of physical activity effects is provided in the "Response by Type of NMT Strategy" section (see "Walking/Bicycling Promotion and Information"—"Individualized Marketing"—"Home/Community-Based Program Effects on Physical Activity").

More . . . Portland's annual SmartTrips materials distribution and event participation tallies offer an indication of participant interest levels in different forms of information and outreach. A core element of the distributions has been the "Ten Toe Express" walking campaign kit. A popular item in the kit is a discount coupon book for and supported by businesses within walking distance. Local businesses are said, anecdotally, to have gained new customers from this outreach. The city has also succeeded in attracting health maintenance organization support in the form of pedestrian/bicycle map, "Ten Toe Express" kit, and guided walk sponsorship. Table 16-143 lists items and activities made available to interested individuals in the 2009 campaign and gives the number of requests or participants for each. The numbers reflect more than one distribution protocol and some event participation overlap, thus the indication of interest levels is imprecise. Nevertheless, the requests/distributions for walk/bike maps covering neighborhoods outside of the 2009 North/Northwest target area clearly suggest that such maps are very much in demand.

Table 16-143 Portland 2009 SmartTrips North/Northwest Campaign Transportation Materials, Incentives, and Activities and Acceptance/Attendance Totals

Materials/Activities	Number	Materials/Activities	Number
Ten Toe Express walking kits	5,500 [a]	TriMet transit info., maps, sched., etc.	5,940 [d]
Portland by Cycle kits	4,700 [a]	Transit Tracker™ bus stop IDs	1,005
NW Portland Walk/Bike Map	3,000 [b]	CarpoolMatchNW.org materials	270
N Portland Walk/Bike Map	4,000 [b]	Zipcar brochure	506
NE Portland Walk/Bike Map	1,000	Smart Driver brochure	652
SE Portland Walk/Bike Map	860	AAA Safe Driving for Seniors booklet	376
Outer SE Portland Walk/Bike Map	590	SmartTrips umbrellas (incentives)	1,483
SW Portland Walk/Bike Map	840	Bandana bicycle maps (incentives)	1,106
Citywide Bicycle Map	6,000 [c]	Walk There! booklets (incentives)	872
Downtown Bike Map	1,300	Ten Toe Express walks (17 walks)	~200
Portland by Cycle flyer	8,000 [c]	Senior Strolls (22 strolls)	n/a [e]
Portland by Cycle Guide	6,000 [c]	Portland by Cycle rides (19 rides)	230 [f]
Women on Bikes flyer	5,500 [c]	Portland by Cycle workshops (12)	~100
Senior Stroll flyer	2,750	Women on Bikes clinics and rides	190 [g]

Notes: Order forms were mailed to some 28,000 of the 29,500 Northwest and North neighborhood households. A total of 3,656 households ordered materials. This 12 to 13 percent rate was smaller than previous campaigns, thought to reflect bundling of order forms with junk mail at the numerous apartments and condominiums. To compensate, Ten Toe Express and Portland by Cycle kits were also distributed through libraries, schools, community events, and other venues. The numbers of kits and items contained in the kits reflect this augmentation.

[a] Of Ten Toe Express walking kits, 3,900 were ordered or distributed at neighborhood events, 1,100 were made available to libraries, schools, and non-profit groups, and 500 were not accounted for in the documentation. The Portland by Cycle kits were distributed similarly.

[b] Distribution included those inserted in Ten Toe Express and Portland by Cycle kits.

[c] Distribution included those inserted in Portland by Cycle kits.

[d] Number appears to be a count of items distributed. Some kind of transit information was ordered by 2,048 individual households. A popular item separately listed/counted is the personalized Transit Tracker™ card with the ID numbers of nearby bus stops, with which real-time bus arrival times can be obtained via telephone or a number of web-based options.

[e] Attendance in 2008 (SmartTrips Southwest) for 22 Senior Strolls averaged 20 persons per stroll, with many repeat attendees from prior years and other neighborhoods. There were 50 first-time strollers overall.

[f] Attendee total for 19 rides was 230, representing 136 different riders.

[g] Signup total for rides and clinics was 190, representing 175 individuals.

Comparable information for the "Way to Go Sausalito" pilot program of 2008 reflects a much smaller-scale operation, but is of interest because all reported distributions were apparently upon participant request only. Respondent interest levels are thus more directly represented. Order forms for materials were mailed to 5,402 households and 844 orders were received.

Materials and activities requested or participated in were (listed in decreasing order of interest with number of requests or participants in parenthesis): Way to Go (WTG) Sausalito map (701), WTG event calendar (675), WTG coupon book (673), Golden Gate Bus and Ferry Guide (498), pocket ferry brochure (474), 511 Getting There on Transit Guide (453), WTG Guide to Your Ride

(396), Muir Woods Shuttle brochure (391), Stagecoach brochure (388), WTG tote bag (358), Golden Gate Bike to Transit Guide (351), Seniors Transit Guide (338), 511 Service Guide (305), 511 Rideshare Guide (298), bike light (284), Marin County Safe Routes to School brochure (205), transit tickets (164), Tuesday evening guided walks (52 total, 6 events), Saturday walks and rides (42 total, 7 events), Thursday evening classes and workshops (10 total, 6 events), Tuesday evening guided bicycle rides (1 total, 4 events). Aside from the 30 percent of events that had no participants, individual event participation ranged from one to 14 persons.

Sources. Overall observations including judgment of relative intervention intensities and program assignment to approach categories (utilizing categories set forth in Horst and Brög, 2010) are by the Handbook authors. • Tools of Change, "Seattle Neighborhoods In Motion." Case study. Prepared by Cullbridge Marketing and Communications on behalf of Health Canada and Natural Resources Canada. http://www.toolsofchange.com/en/case-studies/detail/186/ (Website accessed November 2, 2010). • Alta Planning + Design, "Way to Go Sausalito—Program Report & Evaluation" (May, 2009b). • City of Portland, "Eastside Hub Target Area Program Comprehensive Evaluation Report—Options for Portland Transportation." Office of Transportation, Portland, OR (the following web address applies to all Portland reports) http://www.portlandonline.com/transportation/index.cfm?c=43819 (December, 2005a). • Portland Office of Transportation, "Appendix A—Eastside Hub Target Area Program Measurement Tools and Results Report." Portland, OR (December, 2005). • Portland Office of Transportation, "Appendices—SmartTrips Northeast Hub." Portland, OR (December, 2006). • Portland Office of Transportation, "Appendices—SmartTrips Southeast." Portland, OR (December, 2007). • Portland Bureau of Transportation, "Appendices—SmartTrips Southwest." Portland, OR (February, 2009). • City of Portland, "SmartTrips North/Northwest." Final Report. Bureau of Transportation, Portland, OR (March, 2010). • Hofbauer, D., Socialdata America Ltd. Personal Interview (July 3, 2007). • Whatcom Council of Governments, "Whatcom Smart Trips—A Transferable Model of Vehicle Trip Reduction for US Cities." Bellingham, WA (October, 2010). • Horst, S., and Brög, W., "Neighborhood Smart Trips: How Individualized Marketing Can Work in Your Community." PowerPoint notes (Horst only) and slides. Session 54, Pro Walk/Pro Bike® 2010 Chattanooga (September 13–16, 2010). • Horst, S., Whatcom Council of Governments. Telephone and personal interviews (December 2, 20, and 22, 2010b).

REFERENCES

Special Note: This "References" listing includes only Primary sources cited in this chapter. A number of the chapter's summary tables start with a "Study (Date)" column that provides either the primary source(s) for information in corresponding rows or, where applicable, secondary source(s). The secondary (original) source is listed first, if there is one, and a dash ("—") separates the author(s) and the date instead of having the date in parentheses. For example, in the case of the fourth entry in summary Table 16-1, there is a secondary source. It is indicated in the "Study (Date)" column as "Painter—1996" while the primary sources are identified as "Cao, Mokhtarian, and Handy (2007) and Heath et al. (2006)." In some tables this information is provided instead in the "Source" entry under the table. In any case, where there is a secondary source, the primary source(s) will need to be consulted for full secondary source bibliographic information, as well as for further background.

Aarts, H., Verplanken, B., and van Knippenberg, A., "Habit and Information Use in Travel Mode Choices." *Acta Psychologica,* Vol. 96, Issue 1–2 (1997).

AASHTO (American Association of State Highway and Transportation Officials), "A Policy on Geometric Design of Highways and Streets." Washington, DC (2001).

AASHTO (American Association of State Highway and Transportation Officials), "Guide for the Development of Bicycle Facilities." Washington, DC (1999).

AASHTO (American Association of State Highway and Transportation Officials), "Guide for the Planning, Design, and Operation of Pedestrian Facilities." Washington, DC (2004).

Abdel-Aty, M., and Abdelwahab, H., "Calibration of Nested-Logit Mode-Choice Models for Florida." Final Report. Department of Civil & Environmental Engineering, University of Central Florida, Orlando, FL. http://www.fsutmsonline.net/images/uploads/reports/FDOT_BC415rpta.pdf (November, 2001).

Aboelata, M. J., Mikkelsen, L., Cohen, L., Fernandes, S., Silver, M., and Parks, L. F., *The Built Environment and Health—11 Profiles of Neighborhood Transformation.* Prepared for National Center for Environmental Health, Centers for Disease Control and Prevention, by Prevention Institute, Oakland, CA (July, 2004).

Abrahams, H., *Has the Goodwill Bridge Induced Walking and Cycling Trips for Commuting to Brisbane's Central Business District?* Post Graduate Dissertation. University of New England, Armidale, New South Wales, Australia (October, 2002).

Agrawal, A. Weinstein, and Schimek, P., "Extent and correlates of walking in the USA." *Transportation Research Part D,* Vol. 12, Issue 8 (December, 2007).

Alan M. Voorhees & Associates, Inc., "Traffic Forecast—Proposed Interim RF&P Railroad Commuter Demonstration Project." Prepared for Washington Metropolitan Area Transit Authority (January, 1968).

Alliance for Biking & Walking, "Bicycling and Walking in the United States: 2010 Benchmarking Report." Washington, DC. http://peoplepoweredmovement.org/site/index. php/site/member services/alliance_2010_benchmarking_report_information_findings (2010).

Alta Planning + Design, "Fundamentals of Bicycle Boulevard Planning & Design." Prepared for Initiative for Bicycle & Pedestrian Innovation, Portland State University, OR, http://www.ibpi.usp.pdx.edu/guidebook.php (July, 2009a).

Alta Planning + Design, "National Bicycle and Pedestrian Project—Summary Report." Portland, OR (December 18, 2008).

Alta Planning + Design, "Way to Go Sausalito—Program Report & Evaluation" (May, 2009b).

American Public Health Association, "Backgrounder—The Hidden Health Costs of Transportation." http://www.apha.org/NR/rdonlyres/B96B32A2-FA00-4D79-99AB-F0446 C63B254/0/TheHidden HealthCostsofTransportationBackgrounder.pdf (February, 2010).

American Public Transportation Association, "2010 Public Transportation Fact Book." Washington, DC http://www.apta.com/resources/statistics/Documents/FactBook/APTA_2010_Fact_Book.pdf (April, 2010).

American Public Transit Association, "SunLine Bike Racks Attract New Riders." *Passenger Transport.* Newsletter of American Public Transit (now Transportation) Association, Washington, DC (February 10, 1997).

Antonakos, C. L., "Environmental and Travel Preferences of Cyclists." *Transportation Research Record 1438* (1994).

Ashton-Graham, C., and John, G., "TravelSmart Household Program: Frequently Asked Questions in Travel Demand Management and Dialogue Marketing." Department of Transport Working Paper, Government of Western Australia (April, 2006).

Aultman-Hall, L., and Adams, M. F., "Sidewalk Bicycling Safety Issues." *Transportation Research Record 1636* (1998).

Aultman-Hall, L., and LaMondia, J., "Evaluating the Safety of Shared-Use Paths: Results from Three Corridors in Connecticut." *Transportation Research Record 1939* (2005).

Aultman-Hall, L., Hall, F. L., and Baetz, B. B., "Analysis of Bicycle Commuter Routes Using Geographic Information Systems: Implications for Bicycle Planning." *Transportation Research Record 1578* (1997).

Australian Government, "Evaluation of Australian TravelSmart Projects in the ACT, South Australia, Queensland, Victoria, and Western Australia 2001–2005." Australian Greenhouse Office, Department of the Environment and Heritage, Parkes ACT, Australia. www.travelsmart.gov.au/publications/pubs/evaluation-2005.pdf (2005).

Bandara, S., Wirasinghe, S. C., Gurofsky, D., and Chan, P., "Grade-Separated Pedestrian Circulation Systems." *Transportation Research Record 1438* (1994).

Barnes, G., Thompson, K., and Krizek, K., "A Longitudinal Analysis of the Effect of Bicycle Facilities on Commute Mode Share." *TRB 85th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 22–26, 2006).

Barton-Aschman Associates, Inc., "Extending the Skyway System into Gateway Center." Prepared for the Minneapolis Housing & Redevelopment Authority. Minneapolis, MN (1978).

Bassett, D. R., Pucher, J., Buehler, R., Thompson, D. L., and Crouter, S. E., "Walking, Cycling, and Obesity Rates in Europe, North America, and Australia." *Journal of Physical Activity and Health,* Vol. 5, Issue 6 (November, 2008).

Beck, L. F., Dellinger, A. M., and O'Neil, M. E., "Motor Vehicle Crash Injury Rates by Mode of Travel, United States: Using Exposure-Based Methods to Quantify Differences." *American Journal of Epidemiology,* Vol. 166, No. 2, Advance Access publication (April 21, 2007).

Bennett, G. G., McNeill, L. H., Wolin, K. Y., Duncan, D. T., Puleo, E., and Emmons, K. M., "Safe to Walk? Neighborhood Safety and Physical Activity Among Public Housing Residents." *PLoS Medicine* 4(10) http://medicine.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pmed.0040306 (October 23, 2007).

Berrigan, D., and Troiano, R. P., "The Association between Urban Form and Physical Activity in U.S. Adults." *American Journal of Preventative Medicine,* Vol. 23, No. 2, Supplement 1 (August, 2002).

Berke, E. M., Gottlieb, L. M., Moudon, A. V., and Larson, E. B., "Protective Association Between Neighborhood Walkability and Depression in Older Men." *Journal of the American Geriatric Association,* Vol. 55, No. 4 (April, 2007a).

Berke, E. M., Koepsell, T. D., Moudon, A. V., Hoskins, R. E., and Larson, E. B., "Association of the Built Environment With Physical Activity and Obesity in Older Persons." *American Journal of Public Health,* Vol. 97, No. 3 (March, 2007b).

Berry, B. J. L., *Geography of Market Centers and Retail Distribution.* Prentice-Hall, Englewood Cliffs, NJ (1967).

Besser, L. M., and Dannenberg, A. L., "Walking to Public Transit: Steps to Help Meet Physical Activity Recommendations." *American Journal of Preventive Medicine,* Vol. 29, Issue 4 (November, 2005).

Bhatia, R., and Wier, M., "'Safety in Numbers' re-examined: Can we make valid or practical inferences from available evidence?" *Accident Analysis and Prevention*, Vol. 43, Issue 1 (January, 2011).

Bicycle Federation of America, "Case Study No. 18—Analyses of Successful Provincial, State, and Local Bicycle and Pedestrian Programs in Canada and the United States." *National Bicycling And Walking Study.* Prepared for Federal Highway Administration, U.S. Department of Transportation, Washington, DC (1993).

Bikestation. "Bikestation© Long Beach." http://www.bikestation.org/longbeach/index.asp (Website accessed August 15, 2003).

Bikesummer '99, "SF's Valencia Street: Two Lanes Better Than Four." *Bikesummer '99 Zine* (1999).

Birk, M., *A Tale of Portland Bridges.* Alta Planning + Design, Portland, Oregon. (Accessed May 10, 2010 as BIKESAFE Bicycle Countermeasure Selection System Case Study #2) http://www.bicyclinginfo.org/bikesafe/case_studies.cfm [2003].

Birk, M., and Geller, R., "Bridging the Gaps: How the Quality and Quantity of a Connected Bikeway Network Correlates with Increasing Bicycle Use." *TRB 85th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 22–26, 2006).

Boarnet, M. G., Anderson, C. L., Day, K., McMillan, T., and Alfonzo, M., "Evaluation of the California Safe Routes to School Legislation—Urban Form Changes and Children's Active Transportation to School." *American Journal of Preventative Medicine,* Vol. 28, Issue 2, Supplement 2 (February, 2005a).

Boarnet, M. G., Day, K., Anderson, C., McMillan, T., and Alfonzo, M., "California's Safe Routes to School Program—Impacts on Walking, Bicycling, and Pedestrian Safety." *Journal of the American Planning Association,* Vol. 71, No. 3 (Summer, 2005b).

Booz Allen Hamilton, "International Approaches to Tackling Transport Congestion—Paper 5 (Final): Walking and Cycling." Prepared for the Victorian Competition and Efficiency Commission, Australia. http://www.vcec.vic.gov.au/CA256EAF001C7B21/0/DEED6E489A0E8F33CA2571470008CE9B?OpenDocument (April, 2006).

Bowker, J. M., Bergstrom, J. C., Gill, J., and Lemanski, U., *The Washington & Old Dominion Trail: An Assessment of User Demographics, Preferences, and Economics.* Final Report. Prepared for the Virginia Department of Conservation by the Southern Forest Research Station, the University of Georgia, and the National Park Service (December 9, 2004).

Boyle, J., *RTD bike-n-ride Survey Overview.* Web article summarizing 1999 bike survey prepared by Kent Epperson of the Denver RTD. http://www.bikemap.com/transit/rtdsurvey.htm accessed July 11, 2003 (Article dated September 9, 2002).

Bricka, S. G., Sen, S., Paleti, R., and Bhat, C. R., "An Analysis of the Factors Influencing Differences in Survey-Reported and GPS-Recorded Trips." *TRB 90th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 23–27, 2011).

Brisbane City Council, "Bikeway maps." http://www.brisbane.qld.gov.au (Webpage accessed January 22, 2009a).

Brisbane City Council, "Brisbane Active Transport Strategy: Walking and Cycling Plan 2005–2010." http://www.jcu.edu.au/soc/bug/resources/BCC%20Active%20Transport%20Strategy%202 005-2010.pdf (Webpages accessed January 22, 2009b).

Broach, J., Gliebe, J., and Dill, J., "Bicycle Route Choice Model Developed Using Revealed Preference GPS Data." *TRB 90th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 23–27, 2011).

Broach, J., Gliebe, J., and Dill, J., *Development of a Multi-class Bicyclist Route Choice Model Using Revealed Preference Data.* Paper submitted to the 12th International Conference on Travel Behavior Research, Jaipur, India (December 13–18, 2009a).

Broach, J., Gliebe, J., and Dill, J., *Development of a Multi-class Bicyclist Route Choice Model Using Revealed Preference Data.* PowerPoint presentation, Session S27, 12th International Conference on Travel Behavior Research, Jaipur, India (December 13–18, 2009b).

Brög, W., and Barta, F., "National Demonstration Project (FTA): Individualized Marketing Demonstration Program." *TRB 86th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 21–25, 2007).

Brög, W., and Ker, I., "Myths, (Mis)perceptions and Reality in Measuring Voluntary Behavior Change." *Workshop on Surveys for Behavioural Experiments.* Resource Paper, 8th International Conference on Survey Methods in Transport. Annecy, France (May 25–31, 2008).

Brög, W., Erl, E., Ker, I., Ryle, J., and Wall, R., "Evaluation of voluntary travel behaviour change: Experiences from three continents." *Transport Policy,* Vol. 16, Issue 6 (2009).

Bruce, P., *2002 Minneapolis Downtown Pedestrian Count and Analysis*. Report and Work Files. Prepared by Community Enhancement/Pedestrian Studies, Minneapolis, MN [2002a].

Bruce, P., *2002 Pedestrian Traffic Count in Downtown Minneapolis Public Ramp Areas.* Prepared for Minneapolis Public Works Transportation Section by Community Enhancement & Organizing, Minneapolis, MN (July, 2002b).

Bruce, P., Community Enhancement/Pedestrian Studies/www.pedestrianstudies.com, email to the Handbook authors with attached map, "2007 Downtown Minneapolis Count Project—Skyway Level Daily Volumes—2002–2007 percent change" [redacted version] (July 27, 2009).

Bruce, P., *Nicollet Mall Pedestrian Count—September 2002 Daily Volumes.* Report and Work Files. Prepared by Community Enhancement/Pedestrian Studies, Minneapolis, MN [2002c].

Bruce, P., "Special Conditions Should Not Be Hidden on Data Record." *Pedestrian Studies News,* Issue 12, Community Enhancement and Organizing, Minneapolis, MN (Summer, 2004a).

Bruce, P., "Sporting Event Impacts Around an Entertainment Center." *Pedestrian Studies News,* Issue 11, Community Enhancement and Organizing, Minneapolis, MN (March, 2004b).

Buehler, T., and Handy, S., "Fifty years of bicycle policy in Davis, California." *Transportation Research Record 2074* (2008).

Buehler, H., and Pucher, J., "Impacts of Bike Paths and Lanes on Cycling in Large American Cities." *TRB 90th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 23–27, 2011).

Burbidge, S. K., and Goulias, K. G., "Evaluating the Impact of Neighborhood Trail Development on Active Travel Behavior and Overall Physical Activity of Suburban Residents." *Transportation Research Record 2135* (2009).

Bureau of Transportation Statistics, "Highlights of the 2001 National Household Travel Survey." U.S. Department of Transportation, Washington, DC, http://www.bts.gov/publications/highlights_of_the_2001_national_household_travel_survey/ (2003a).

Bureau of Transportation Statistics, "Omnibus Household Survey Results April 2003." Washington, DC (April, 2003b).

Bureau of Transportation Statistics, *OmniStats.* Vol. 2, Issues 6 and 8, Washington, DC (December, 2002).

Burgess, D. F., and Zerbe, R. O., "Appropriate Discounting for Benefit-Cost Analysis." *Journal of Benefit-Cost Analysis,* Vol. 2, Issue 2, Article 2 (2011).

Burnier, C. V., *Pedestrian-Vehicular Crashes: The Influence of Personal and Environmental Factors.* Masters Thesis. University of Maryland, College Park, MD. http://drum.lib.umd.edu/bitstream/1903/2551/1/umi-umd-2435.pdf (2005).

Caltrain Bicycle Master Plan Technical Advisory Group, Agenda with Attachment: "2007 Caltrain Online Bicycle Survey: Selected Preliminary Results." http://bikesiliconvalley.org/files/documents/caltrain/july112007-agendadocs.pdf (July 11, 2007).

Calvert, S., "For Howard Street, it's been rough road." *Baltimore Sun,* Baltimore, Maryland, (July 29, 2001).

Cambridge Community Development, The Department of, "Safety Benefits of Bike Lanes." Cambridge, Massachusetts. http://www2.cambridgema.gov/cdd/et/bike/bike_safety.html (Webpages accessed August 2, 2011).

Cambridge Systematics, Inc., Parsons Brinckerhoff, Mark Bradley Research & Consulting, CCS Planning & Engineering, Inc., Hausrath Economics Group, Hunt Analytics Incorporated, Lawton Consulting, and Corey, Canapary & Galanis, "San Francisco Travel Demand Forecasting Model Development." Final Report. Prepared for San Francisco County Transportation Authority, San Francisco, CA (2002).

Cambridge Systematics, S. H. Putman Associates, and Calthorpe Associates, "Model Modifications." LUTRAQ Project, Vol. 4, 1000 Friends of Oregon, Portland, OR (1992).

Cambridge Systematics, Inc., Vanasse Hangen Brustlin, Inc., Gallop Corporation, Dr. Chandra R. Bhat, Shapiro Transportation Consulting, LLC, and Martin/Alexiou/Bryson, PLLC, "Travel Demand Forecasting: Parameters and Techniques." Preliminary Draft Final Report. Prepared for NCHRP Project 8-61, Transportation Research Board. Washington, DC (October, 2011).

Cambridge Systematics, Inc. with Deakin, Harvey, Skabardonis, Inc., "The Effects of Land Use and Travel Demand Management Strategies on Commuting Behavior." Prepared for the U.S. Department of Transportation and the U.S. Environmental Protection Agency (November, 1994).

Campbell, A., "More people are bringing bicycles along on their mass transit commutes." *South Florida Sun-Sentinal.com.* http://www.sun-sentinel.com (Online article dated June 24, 2008).

Campbell, B. J., Zegeer, C. V., Huang, H. H., and Cynecki, M. J., *A Review of Pedestrian Safety Research in the United States and Abroad.* Prepared for the Office of Safety Research and Development, Federal Highway Administration, by the University of North Carolina Highway Safety Research Center, Chapel Hill, NC (January, 2004).

Cao, X., Handy, S. L., and Mokhtarian, P. L., "The influences of the built environment and residential self-selection on pedestrian behavior: Evidence from Austin, TX." *Transportation,* Vol. 33, No. 1 (2006).

Cao, X., Mokhtarian, P. L., and Handy, S. L., "Examining the Impacts of Residential Self-Selection on Travel Behaviour: A focus on Empirical Findings." *Transport Reviews,* Vol. 29, Issue 3 (2009).

Cao, X., Mokhtarian, P. L., and Handy, S. L., *Examining the Impacts of Residential Self-Selection on Travel Behavior: Methodologies and Empirical Findings.* Research Report. Institute of Transportation Studies, University of California, Davis, CA (Revised March, 2007).

Capital Bikeshare Dashboard, "Trips by Municipality and Month—System-Wide" and "System-Wide Bicycle in Service by Month—Available." Charts. A partnership between the District of Columbia Department of Transportation, Arlington County, and Alta Bicycle Share. http://cabidashboard.ddot.dc.gov/cabiDashboard/#Home (Webpages accessed September 13, 2011).

Capital Crossroads Special Improvement District, "Downtown Columbus Retail Market Data." Columbus, Ohio [2003].

Carlson, R., [Twin Cities] Metropolitan Council, email to the Handbook authors with attached table, "Minneapolis Downtown area covered employment" (August 24, 2004).

Case, R. B., *Improving the Mobility of Non-Drivers Using Proximity to Destinations and Bus Routes.* Prepared by Hampton Roads Planning District Commission. http://www.hrtpo.org/Documents/Reports/Improving%20Mobility.pdf (June, 2007).

Centers for Disease Control and Prevention, "CDC Recommendations for Improving Health through Transportation Policy." http://www.cdc.gov/transportation/recommendation.htm (April 28, 2010).

Centers for Disease Control and Prevention, "Neighborhood Safety and the Prevalence of Physical Inactivity—Selected States, 1996." *Morbidity and Mortality Weekly Report,* Vol. 48, No. 7. http://www.cdc.gov/mmwr/preview/mmwrhtml/00056582.htm (February 26, 1999).

Centers for Disease Control and Prevention, "Prevalence and Trends Data—Physical Activity 2009." National Center for Chronic Disease Prevention & Health Promotion; Office of Surveillance, Epidemiology, and Laboratory Services; Behavioral Risk Factor Surveillance System. http://apps.nccd.cdc.gov/BRFSS/list.asp?cat=PA&yr=2009&qkey=4418&state=All (Webpages accessed January 8, 2011).

Cervero, R., *America's Suburban Centers: A Study of the Land Use—Transportation Link.* Urban Mass Transit Administration, U.S. Department of Transportation, Washington, DC (1988).

Cervero, R., *Ridership Impacts of Transit-Focused Development in California.* Monograph 45. Institute of Urban and Regional Development, University of California at Berkeley (1993).

Cervero, R., and Duncan, M., "Walking, Bicycling, and Urban Landscapes: Evidence From the San Francisco Bay Area." *American Journal of Public Health,* Vol. 93, No. 9 (September, 2003).

Cervero, R., and Radisch, C., *Travel Choices in Pedestrian Versus Automobile Oriented Neighborhoods.* Institute of Urban and Regional Development, University of California. Working Paper 644. Berkeley, CA (1995).

Chaney, H., *A Review of Before and After Usage Documentation of Pedestrian and Bicycle Facilities.* Draft Version. Pedestrian and Bicycle Information Center, Highway Research Center, Chapel Hill, NC (January 4, 2005).

Chu, X., "The Fatality Risk of Walking in America: A Time-Based Comparative Approach." *Walk21 IV Proceedings.* The Fourth International Conference on Walking in the 21st Century, Portland, Oregon, http://www.walk21.com/papers/Chu.pdf (May 1–3, 2003).

Chu, X., Guttenplan, M., and Kourtellis, A., "Considering Usage and Safety Effects in Guidelines for Uncontrolled Midblock Crosswalks." *TRB 86th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 21–25, 2007).

Ciccarelli, J., "Bicycle Boulevards—Bryant Street Example—Palo Alto, California." *BIKESAFE Bicycle Countermeasure Selection System—Case Studies.* Case Study #32. http://www.bicyclinginfo.org/bikesafe/case_studies.cfm (Webpage accessed August 4, 2010).

City of Boulder, "TMP 2003—Transportation Master Plan." Boulder, CO (2003).

City of Minneapolis Public Works Department, "Minneapolis Pedestrian Master Plan." Draft for Public Review. Minneapolis, MN (June 8, 2009).

City of Minneapolis, "Report on Bicycle & Pedestrian Counts." City of Minneapolis Department of Public Works (October 22, 2007).

City of Palo Alto, "Bicycle Transportation Plan." Prepared by Wilbur Smith Associates. (May, 2001). Expanded version by Wilbur Smith Associates et al. available at http://www.cityofpaloalto.org/civica/filebank/blobdload.asp?BlobID=7293 (May, 2003).

City of Portland, "Bicycle Master Plan—Portland [OR] Bicycle Program History." http://www.trans.ci.portland.or.us/Plans/BicycleMasterPlan/into.htm (Webpages accessed July 29, 2004).

City of Portland, "Bicycling in Portland [OR]." Slide Presentation. Office of Transportation. http://www.trans.ci.portland.or.us/bicycles/presentations/BicyclinginPortland/frame.htm (Webpage accessed June 9, 2003; dated April 11, 2001).

City of Portland, "Eastside Hub Target Area Program Comprehensive Evaluation Report—Options for Portland Transportation." Office of Transportation, Portland, OR. http://www.portlandonline.com/transportation/index.cfm?c=43819 (December, 2005a).

City of Portland, "SmartTrips North/Northwest." Final Report. Bureau of Transportation, Portland, OR. http://www.portlandonline.com/transportation/index.cfm?c=43819 (March, 2010).

City of Portland, "TravelSmart—Interstate Avenue 2004 target area project." Portland, OR. http://www.portlandonline.com/transportation/index.cfm?c=43819 [2005b].

City of Seattle, "Comparison of Old and Recently Adopted LUC Requirements for Sidewalks." http://www.seattle.gov/DPD/static/Comparison%20old%20and%20new%20sidewalk%20code%20011108_LatestReleased_DPDP_021071.pdf (Webpage dated January 11, 2008).

City of Seattle, "Seattle Urban Mobility Plan—Fact Sheet—Bicycle Routes and Volumes." http://cityofseattle.net/dpd/cms/groups/pan/@pan/@plan/@proj/documents/web_informational/dpds017347.pdf (January, 2008).

City of Toronto, "2. Cycling in Toronto." *City of Toronto Bike Plan—Shifting Gears.* Toronto, ON, Canada. http://www.toronto.ca/cycling/bikeplan/ (June, 2001).

City of Vancouver, "Burrard Bridge Bike Lanes Status Report, Fall 2009." Administrative Report. Vancouver, BC, Canada. http://vancouver.ca/projects/burrard/index.htm ["Read report to Council" button] (October 27, 2009a).

City of Vancouver, "Burrard Bridge Lane Reallocation Trial." Various linked webpages [all same main heading]. Vancouver, BC. http://vancouver.ca/projects/burrard/index.htm (Webpages last modified November 12, 2009b).

City of Vancouver, "Burrard Bridge Lane Reallocation Trial—Statistics." Vancouver, BC, Canada. http://vancouver.ca/projects/burrard/statistics.htm (Webpage last modified May 12, 2010).

City of Vancouver, "Cycling"—"Bike route profiles." Vancouver, BC, Canada. http://vancouver.ca/engsvcs/transport/cycling/bikeways/routes/ (Webpage last modified October 8, 2009c).

Circella, G., Mokhtarian, P. L., and Handy, S. L., "Land Use, Attitudes, and Travel Behavior Relationships: A Cross-sectional Structural Equations Model for Northern California." *TRB 87th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 13–17, 2008).

Cleaveland, F., and Douma, F., "The Impact of Bicycling Facilities on Commute Mode Share." *TRB 88th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 11–15, 2009).

Clifton, K. J., and Krizek, K. J., "The Utility of the NHTS in Understanding Bicycle and Pedestrian Travel." Prepared for: *National Household Travel Survey Conference: Understanding our Nation's Travel.* Washington, DC (November 1–2, 2004).

Committee for Determination of the State of the Practice in Metropolitan Area Travel Forecasting, *TRB Special Report 288: Metropolitan Travel Forecasting—Current Practice and Future Direction.* Transportation Research Board, Washington, DC (2007).

Committee on Physical Activity, Health, Transportation, and Land Use, *TRB Special Report 282: Does the Built Environment Influence Physical Activity?—Examining the Evidence.* Transportation Research Board and Institute of Medicine, Washington, DC (2005).

Committee on Prevention of Obesity in Children and Youth, *Preventing Childhood Obesity: Health in the Balance.* Institute of Medicine, Washington, DC (2005).

Committee on School Transportation Safety, *TRB Special Report 269: The Relative Risks of School Travel—A National Perspective and Guidance for Local Community Risk Assessment.* Transportation Research Board, Washington, DC (2002).

Comsis Corporation, "A Survey and Analysis of Employee Responses to Employer-Sponsored Trip Reduction Incentive Programs—Technical Appendix A—Model Calibration Report." Draft Final Report. Prepared for California Air Resources Board (1993).

Corbett, M. J., Xie, F., and Levinson, D., "Evaluation of the Second-Story City: The Minneapolis Skyway System." *TRB 87th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 13–17, 2008).

Coverly, L., "Bike and Bus Program—Santa Barbara, California." *BIKESAFE Bicycle Countermeasure Selection System—Case Studies.* Case Study #50. http://www.bicyclinginfo.org/bikesafe/case_studies.cfm (Webpage accessed August 4, 2010).

C.R.O.W., "Sign up for the bike: Design for a cycle-friendly infrastructure." Record 10. Prepared by Centre for Research and Contract Standardization in Civil and Traffic Engineering (C.R.O.W.), The Netherlands (August, 1993).

Cycle City Odense, http://www.odense.dk/web4/cyklisternesby/cycle%20city%20odense.aspx [Click "Expo 2010"] (Webpages accessed April 19, 2011).

Cynecki, M. J., "Bike Lane Safety Evaluation—Phoenix, Arizona." *BIKESAFE Bicycle Countermeasure Selection System—Case Studies.* Case Study #8. http://www.bicyclinginfo.org/bikesafe/case_studies.cfm (Webpages accessed August 3, 2011).

Dannenberg, A. L., "Panel 2: A Focus on Public Health and Physical Activity—Overview and Context." *Integrating health and Physical Activity Goals Into Transportation Planning: Building the Capacity of Planners and Practitioners—Proceedings of the Portland Roundtable—January 22, 2004.* Prepared for the Federal Highway Administration and Federal Transit Administration by the Volpe National Transportation Systems Center (April, 2004).

Dannenberg, A. L., "Where Does Transportation Infrastructure Fit into the Causes and Control of Obesity?" Session 117: *Transportation Infrastructure and Obesity: Emerging National Issue—Science to Solutions.* Presentation Slides. Transportation Research Board 84th Annual Meeting, Washington, DC (January 9–13, 2005).

David C., "Capital Bikeshare's first year results exceed expectations." *Greater Greater Washington.* http://greatergreaterwashington.org/post/12176/capital-bikeshares-first-year-results-exceed-expectations (Posted September 28, 2011).

David Evans and Associates, Inc., "Case Study No. 3—What Needs to be Done to Promote Bicycling and Walking?" *National Bicycling and Walking Study.* Prepared for Federal Highway Administration, U.S. Department of Transportation, Washington, DC (1992).

Davies, R., Department of Main Roads, Queensland, Australia, email to the Handbook authors with attached Brisbane walk and bicycle mode share maps and data, 1986–2006 (January 18, 2008).

Davies, R., Department of Transport and Main Roads, Queensland, Australia, email to the Handbook authors with M.J. Langdon review comments (November 18, 2010).

Davies, R., "Implementing the Main Roads Cycling Policy: Case studies, impacts, and future directions." *Main Roads Technology Forum,* Queensland, Australia (August, 2007).

Davis, G. A., "Relating Severity of Pedestrian Injury to Impact Speed in Vehicle-Pedestrian Crashes: Simple Threshold Model." *Transportation Research Record 1773* (2001).

Davison, K. K., and Lawson, C. T., "Do attributes in the physical environment influence children's physical activity? A review of the literature." *International Journal of Behavioral Nutrition and Physical Activity.* Vol. 3:19 (July 27, 2006).

DeMaio, P., "Bike-sharing: History, Impacts, Models of Provision, and Future." *Journal of Public Transportation,* Vol. 12, No. 4. Center for Urban Transportation Research, Tampa, FL (2009).

DeMaio, P., and Meddin, R., "Nice Ride Minnesota Survey Results" and "2010 Year-end Wrap-up." *The Bike-sharing Blog.* http://bike-sharing.blogspot.com/ (Webpage postings of November 9 and December 31, 2010).

DeMaio, P., Simmons, J. L., and Meddin, R., "Tenders" and "Contracts." *The Bike-sharing Blog.* http://bike-sharing.blogspot.com/ (Webpages accessed July 18, 2011).

de Nazelle, A., Nieuwenhuijsen, M. J., Antó, J. M., Brauer, M., Briggs, D., Braun-Fahrlander, C., Cavill, N., Cooper, A., R., Desqueyroux, H., Fruin, S., Hoek, G., Panis, L. I., Janssen, N., Jerrett, M., Joffe, M., Andersen, Z. J., van Kempen, E., Kingham, S., Kubesch, N., Leyden, K. M., Marshall, J. D., Matamala, J., Mellios, G., Mendez, M., Nassif, H., Ogilvie, D., Peiró, R., Pérez, K., Rabl, A., Ragettli, M., Rodríguez, D., Rojas, D., Ruiz, P., Sallis, J. F., Terwoert, J., Toussaint, J.-F., Tuomisto, J., Zuurbier, M., and Lebret, E., "Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment." *Environment International,* Vol. 37, Issue 4 (May, 2011).

Department for Transport, "Personalised travel planning: evaluation of 14 pilots part funded by DfT." Prepared by the Operational Research Unit, DfT, for the Sustainable Travel Branch, DfT, London, UK (June 22, 2005).

Department of Health and Human Services (HHS), "2008 Physical Activity Guidelines for Americans." Washington, DC. http://www.health.gov/paguidelines/ [2008].

Department of Transport W.A., "TravelSmart—South Perth Large Scale Individualized Marketing Project." Slides and notes, Government of Western Australia (August, 2000).

Design, Community & Environment, Ewing, R., Lawrence Frank and Company, Inc., and Kreutzer, R., "Understanding the Relationship Between Public Health and the Built Environment." Prepared for the LEED-ND Core Committee of the U.S. Green Building Council, Congress for the New Urbanism, and the Natural Resources Defense Council (May, 2006).

Dill, J., Portland State University, email to the Handbook authors (July 30, 2010).

Dill, J., Portland State University, email to the Handbook authors and attachment "Old Primary Commute Mode [vs.] Current Primary Commute Mode Crosstabulation." Portland, OR (October 4 and 6, 2006a).

Dill, J., *Travel and Transit Use at Portland Area Transit-Oriented Developments (TODs).* Prepared for Transportation Northwest (TransNow), Seattle, WA (May, 2006b).

Dill, J., and Carr, T., "Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them." *Transportation Research Record 1828* (2003).

Dill, J., and Gliebe, J., *Understanding and Measuring Bicycle Behavior: A Focus on Travel Time and Route Choice.* Final Report. Prepared by Portland State University for Oregon Transportation Research and Education Consortium (OTREC), http://www.ibpi.usp.pdx.edu/bikegps.php (December, 2008).

Doolittle, J. T., and Porter, E. K., *TCRP Synthesis of Transit Practice 4: Integration of Bicycles and Transit.* Transportation Research Board, National Research Council, Washington, DC (1994).

Dossett, B., "Nice Ride Minnesota Celebrates 1-Year Anniversary." https://www.niceridemn.org/news/(Webpage posting of June 9, 2011).

Dowling, R., Reinke, D., Flannery, A., Ryus, P., Vandehey, M., Petritsch, T., Landis, B., Rouphail, N., and Bonneson, J., "Multimodal Level of Service Analysis for Urban Streets." *NCHRP Report 616.* Washington, DC (2008).

Dueker, K. J., Pendleton, P., and Luder, P., *The Portland Mall Impact Study.* Final Report. Prepared for the Urban Mass Transportation Administration, U.S. Department of Transportation, by the Center for Urban Studies, Portland State University, Portland, OR (December, 1982).

Dunphy, R. T., and Fisher, K., "Transportation, Congestion, and Density: New Insights." *Transportation Research Record 1552* (1996).

East Bay Regional Park District, "Iron Horse Regional Trail—Trail Use Study, Summer 1997." Oakland, CA (January, 1998).

Edminster, R., and Koffman, D., *Streets for Pedestrians and Transit: An Evaluation of Three Transit Malls in the United States.* Final Report—Phase II. Prepared for the Urban Mass Transportation Administration, U.S. Department of Transportation, by Crain and Associates, Menlo Park, CA (February, 1979).

Eisen|Letunic and Fehr & Peers Transportation Consultants, "Caltrain Bicycle Access and Parking Plan." Prepared for Caltrain Peninsula Corridor Joint Powers Board. Berkeley, CA (October 2, 2008).

El-Geneidy, A., McGill University, email to the Handbook authors. Montreal, Quebec, Canada (September 19, 2011).

Emond, C. R., Tang, W., Handy, S. L., "Explaining Gender Difference in Bicycling Behavior." *Transportation Research Record 2125* (2009).

Energy Information Administration, "U.S. Regular All Formulations Retail Gasoline Prices (Cents per Gallon)." http://www.eia.doe.gov/ (Webpages accessed June 26, 2008).

Engelen, R. E., Barton-Aschman Associates, Inc. (retired), email to the Handbook authors (October 12, 2004).

Environmental Working Group, Surface Transportation Policy Project, and Bicycle Federation of America, "Share the Road: Let's Make America Bicycle Friendly." Report published by Environmental Working Group (1997).

Epperson, B., Hendricks, S. J., and York, M., "Estimation of Bicycle Transportation Demand from Limited Data." *1995 Compendium of Technical Papers.* Institute of Transportation Engineers 65th Annual Meeting (1995).

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., Kim, J. S., Heo, S., Alves, H., White, S. M., Wojcicki, T. R., Mailey, E., Vieira, V. J., Martin, S. A., Pence, B. D., Woods, J. A., McAuley, E., and Kramer, A. F., "Exercise training increases size of hippocampus and improves memory." *Proceedings of the National Academy of Sciences.* http://www.pnas.org/content/early/2011/01/25/1015950108.abstract (January 31, 2011).

Erlanger, S., and De La Baume, M., "Paris's Tour de Incivility." *International Herald Tribune.* (Saturday/Sunday October 31-November 1, 2009).

Evans, J. E., IV, and Stryker, A., "TCRP Project B-12B—Technical Report 1." Prepared for Richard H. Pratt, Consultant, Inc. by Jay Evans Consulting LLC and PB Consult Inc. Unpublished report available in pdf format through TCRP Project B-12A webpage. http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=1034 (March 21, 2005).

Evenson, K. R., Herring, A. H., and Huston, S. L., "Evaluating Change in Physical Activity with the Building of a Multi-Use Trail." *American Journal of Preventative Medicine*, Vol. 28, Issue 2, Supplement 2 (February, 2005).

Everett, M.D. "The Determinants of Mass Bicycle Commuting Revisited." *Journal of the Transportation Research Forum,* Vol. 30, No. 2 (1990).

Ewing, R., *Pedestrian- and Transit-Friendly Design.* Prepared for the Public Transit Office, Florida Department of Transportation (March, 1996).

Ewing, R., "Traffic calming in the United States: are we following Europe's lead?" *Urban Design International,* Vol. 13, Issue 2 (Summer, 2008).

Ewing, R., *Transportation & Land Use Innovations: When You Can't Pave Your Way Out of Congestion.* Cosponsored by Florida Department of Community Affairs, FAU/FIU Joint Center for Environmental and Urban Problems, Florida Metropolitan Planning Organization Advisory Council, Surface Transportation Policy Project (STPP) with funding from the Florida Department of Transportation. American Planning Association, Chicago, IL (1997).

Ewing, R., Brownson, R. C., and Berrigan, D., "Relationship Between Urban Sprawl and Weight of United States Youth." *American Journal of Preventative Medicine,* Vol. 31, No. 6 (December, 2006).

Ewing, R., and Cervero, R., "Travel and the Built Environment—A Meta-Analysis." *Journal of the American Planning Association,* Vol. 6, No. 3 (Summer, 2010).

Ewing, R., and Cervero, R., "Travel and the Built Environment — A Synthesis." *Transportation Research Record 1780* (2001).

Ewing, R., Connors, M. B., and Neckerman, K. M., email to the Handbook authors with partial draft paper "Validating Urban Design" and "Parameter Estimates" tabulation, with follow-up personal correspondence (November 30–December 6, 2011).

Ewing, R., and Handy, S., "Measuring the Unmeasureable: Urban Design Qualities Related to Walkability." *Journal of Urban Design,* Vol. 14, Issue 1 (2009).

Ewing, R., Handy, S. L., and McCann, B., "Effect of Infrastructure Investments on Bicycling and Walking in Two Metropolitan Areas." *TRB 89th Annual Meeting Compendium of Papers DVD*. Washington, DC (January 10–14, 2010).

Ewing, R., Schmid, T., Killingsworth, R., Zlot, A., and Raudenbush, S., " Relationship between Urban Sprawl and Physical Activity, Obesity, and Morbidity." *American Journal of Health Promotion,* Vol. 18, No. 1 (September/October, 2003).

Federal Highway Administration, "Asset Management: Economic Analysis Primer." http://www.fhwa.dot.gov/infrastructure/asstmgmt/primer03.cfm (Webpages accessed October 11, 2011).

Federal Highway Administration, "Design Guidance – Accommodating Bicycle and Pedestrian Travel: A Recommended Approach." U.S. Department of Transportation, Washington, DC. http://www.fhwa.dot.gov/environment/bikeped/design.htm (Webpage accessed September 7, 2004).

Federal Highway Administration, "Design of Procedures to Evaluate Traveler Responses to Changes in Transportation System Supply: Conference Summary and White Papers." NTIS PB-240-003/AS, Washington, DC, (September, 1974).

Federal Highway Administration, "Integration of Bicycles and Transit." Undated [ca. 1997]. http://safety.fhwa.dot.gov/ped_bike/docs/bike_bus.pdf (Accessed August 2, 2010).

Federal Highway Administration, "Interim Report to the U.S. Congress on the Nonmotorized Transportation Pilot Program SAFETEA-LU Section 1807." Washington, DC (2007).

Federal Highway Administration, "Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations Final Report and Recommended Guidelines." http://www.fhwa.dot.gov/publications/research/safety/04100/01.cfm (September, 2005).

Ferguson, L., City of Boulder, "Boulder Bike Data" email to the Handbook authors with attached Excel file "1990_2006_Boulder.xls" (October 16, 2009).

Fertig, R., *Bicyclist Numbers Increase in the City of Santa Barbara.* Santa Barbara Bicycle Coalition, Santa Barbara, CA (November, 1996).

Filipi, M., [Twin Cities] Metropolitan Council, "Non-Motorized Trips in the 2000 TBI" email to the Handbook authors (October 1, 2011).

Fisher, M., "So Arlington Really Is For Walkers." *http://washingtonpost.com* (Online article dated April 28, 2005).

Fitzpatrick, K., Turner, S., Brewer, M., Carlson, P., Ullman, B., Trout, N., Park, E. S., Whitacre, J., Lalani, N., and Lord, D., "Improving Pedestrian Safety at Unsignalized Intersections." *TCRP Report 112/NCHRP Report 562.* Washington, DC (2006).

Fitzpatrick, K., Ullman, B., and Trout, N., "On-Street Pedestrian Surveys of Pedestrian Crossing Treatments." *TRB 83rd Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 11–15, 2004).

Flegal, K. M., Carroll, M. D., Ogden, C. L., and Curtin, L. R., "Prevalence and Trends in Obesity among US Adults, 1999–2008." *Journal of the American Medical Association,* Vol. 303, No. 3 (January 20, 2010).

Flegal, K. M., Graubard, B. I., Williamson, D. F., and Gail, M. H., "Excess Deaths Associated with Underweight, Overweight, and Obesity." *Journal of the American Medical Association,* Vol. 293, No. 15 (April 20, 2005).

Frank, L. D., *An Analysis of Relationships between Urban Form (Density, Mix and Jobs: Housing Balance) and Travel Behavior (Mode Choice, Trip Generation, Trip Length and Travel Time)*. Prepared for the Washington State DOT by the Washington State Transportation Center, University of Washington, Seattle, WA (1994).

Frank, L. D., and Engelke, P., "Multiple Impacts of the Built Environment on Public Health: Walkable Places and the Exposure to Air Pollution." *International Science Review,* Vol. 28, No. 2 (2005).

Frank, L. D., "Resource Paper—Land Use and Transportation." *Environmental Research Needs in Transportation. Conference Proceedings 28.* Transportation Research Board, Washington, DC, (March 21–23, 2002).

Frank, L. D., Andresen, M. A., and Schmid, T. L., "Obesity Relationships with Community Design, Physical Activity, and Time Spent in Cars." *American Journal of Preventative Medicine,* Vol. 27, No. 2 (August, 2004).

Frank, L. D., Greenwald, M. J., Kavage, S., and Devlin, A., "An Assessment of Urban Form and Pedestrian and Transit Improvements as an Integrated GHG Reduction Strategy." Prepared for the Washington State DOT by Urban Design 4 Health, Inc., Seattle, WA http://www.wsdot.wa.gov/research/reports/fullreports/765.1.pdf (April 1, 2011).

Frank, L. D., Saelens, B. E., Powell, K. E., and Chapman, J. E., "Stepping toward causation: Do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity?" *Social Science and Medicine,* Vol. 65, Issue 9 (November, 2007).

Gårder, P., Leden, L., and Pulkkinen, U., "Measuring the Safety Effect of Raised Bicycle Crossings Using a New Research Methodology." *Transportation Research Record 1636* (1998).

Garrick, N. W., "Land Use Planning and Network Design in a Bicycle Friendly American City." *TRB 84th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 9–13, 2005).

Giles-Corti, B., and Donovan, R. J., "Relative Influences of Individual, Social Environmental, and Physical Environmental Correlates of Walking." *American Journal of Public Health,* Vol. 93, No. 9 (September, 2003).

Giles-Corti, B., Macintyre, S., Clarkson, J. P., Picora, T., and Donovan, R. J., "Environmental and Lifestyle Factors Associated with Overweight and Obesity in Perth, Australia." *American Journal of Health Promotion*, Vol. 18, No. 1 (September/October, 2003).

Goldsmith, S. A., "Case Study No. 1—Reasons Why Bicycling and Walking Are and Are Not Being Used More Extensively as Travel Modes." *National Bicycling and Walking Study*. Federal Highway Administration, U.S. Department of Transportation, Washington, DC (1992).

Gonzales, L., Hanumara, R. C., Overdeep, C., and Church, S., *2002 Bicycle Transportation Survey; Developing Intermodal Connections for the 21st Century*. University of Rhode Island, Department of Computer Science and Statistics, Kingston, RI (February, 2004).

Goodwill, J. A., and Carapella, H., "Creative Ways to Manage Paratransit Costs." Prepared for the Florida Department of Transportation by the Center for Urban Transportation Research, University of South Florida, Tampa, FL (July, 2008).

Gordon, P. M., Zizzi, S. J., and Pauline, J., "Use of a Community Trail Among New and Habitual Exercisers: A Preliminary Assessment." *Preventing Chronic Disease,* Vol. 1, No. 4 (October, 2004).

Gossen, R., *Characteristics of Rail and Ferry Station Residents in the San Francisco Bay Area: Evidence from the 2000 Bay Area Travel Survey*. Planning Section, Metropolitan Transportation Commission, Oakland, CA (September, 2006).

Gotschi, T., "Costs and Benefits of Bicycling Investments in Portland, Oregon." *Journal of Physical Activity and Health,* Vol. 8, Supplement 1 (January, 2011).

Goulias, K. G., *Audit of South Perth Individualized Marketing Evaluation Survey*. Final Report. Submitted to Western Australia Transport (April 2, 2001).

Grant, M., Kuzmyak, R., Shoup, L., Hsu, E., Krolik, T., and Ernst, D., *SAFETEA-LU 1808: Congestion Mitigation and Air Quality Improvement Program Evaluation and Assessment—Phase I Final Report.* Prepared for the Office of Natural and Human Environment, Federal Highway Administration, by ICF International, Fairfax, VA (October, 2008).

Greenwald, M. J., and Boarnet, M. G., "Built Environment as Determinant of Walking Behavior—Analyzing Nonwork Pedestrian Travel in Portland, Oregon." *Transportation Research Record 1780* (2001).

Greenways Incorporated, "Case Study No. 7—Transportation Potential and Other Benefits of Off-Road Bicycle and Pedestrian Facilities." *National Bicycling and Walking Study.* Federal Highway Administration, U.S. Department of Transportation, Washington, DC (1992).

Griffiths, R. E., "Changes in Daily Travel Patterns based on the Results of the 1994 and 2007/2008 Regional Household Travel Surveys." Memorandum to the National Capital Region Transportation Planning Board, Washington, DC. http://www.mwcog.org/uploads/committee-documents/Z15ZXVhY20100311140703.pdf (March 11, 2010).

Grynbaum, M. M., "Broadway is Busy, with Pedestrians, if Not Car Traffic." *The New York Times.* (With map/diagram, "Not So Broadway.") http://www.nytimes.com/2010/09/06/nyregion/06broadway.html?pagewanted=1&_r=1&ref=nyregion (Online article dated September 6, 2010).

Guttenplan, M., and Patten, R., "Off-Road but On Track: Using Bicycle and Pedestrian Trails for Transportation." *TR News 178.* Transportation Research Board, Washington, DC (May-June, 1995).

Hagelin, C. A., "A Return on Investment Analysis of Bikes-on-Bus Programs." Prepared for the Florida Department of Transportation by the Center for Urban Transportation Research, University of South Florida, Tampa, FL (May, 2005).

Hagelin, C. A., "Bicycle Parking Plan For Miami-Dade Transit." Prepared for the Miami-Dade Metropolitan Planning Organization by the Center for Urban Transportation Research, University of South Florida, Tampa, FL. http://www.cutr.usf.edu/pub/files/MPO_bpp_report_2002.pdf (2002).

Handy, S., *Critical Assessment of the Literature on the Relationships Among Transportation, Land Use, and Physical Activity.* Prepared for the Transportation Research Board and the Institute of Medicine Committee on Physical Activity, Health, Transportation, and Land Use in connection with TRB *Special Report 282*. Department of Environmental Science and Policy, University of California, Davis, CA (July, 2004).

Handy, S. L., Cao, X., and Mokhtarian, P. L., "The Causal Influence of Neighborhood Design on Physical Activity Within the Neighborhood: Evidence from Northern California." *American Journal of Health Promotion,* Vol. 22, No. 2 (November/December, 2007).

Handy, S. L., Clifton, K., and Fisher, J., *The Effectiveness of Land Use Policies as a Strategy for Reducing Automobile Dependence: A Study of Austin Neighborhoods.* Research Report. Southwest Region University Transportation Center, The University of Texas at Austin. http://www.des.ucdavis.edu/faculty/handy/Austin_Report.pdf (October, 1998).

Hansen, W. G., "How Accessibility Shapes Land Use." *Journal of the American Planning Association,* Vol. 25, No. 2 (1959).

Harkey, D. L., and Zegeer, C. V., *PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System.* Prepared for the Federal Highway Administration by the University of North Carolina, Highway Safety Research Center, Chapel Hill, NC (September, 2004).

Harkey, D. L., Reinfurt, D. W., and Sorton, A., T*he Bicycle Compatibility Index: A Level of Service Concept, Implementation Manual.* FHWA-RD-98-095, U.S. Department of Transportation, Federal Highway Administration, Washington, DC (December, 1998a).

Harkey, D. L., Reinfurt, D. W., Knuiman, M., Stewart, J. R., and Sorton, A., *Development of the Bicycle Compatibility Index: A Level of Service Concept, Final Report.* FHWA-RD-98-072, U.S. Department of Transportation, Federal Highway Administration, Washington, DC (December 1998b).

Harkey, D. L., Stewart, J. R., and Rodgman, E. A., *Evaluation of Shared-Use Facilities for Bicycles and Motor Vehicles.* Prepared for Florida Department of Transportation, Tallahassee, FL (March, 1996).

Harvey, P., "Pedestrian education continues in Silver Spring." *Gazette Regional News.* Montgomery County, MD (July 14, 2004).

Heath, G. W., Brownson, R. C., Kruger, J., Miles, R., Powell, K. E., Ramsey, L. T., and the Task Force on Community Preventative Services, "The Effectiveness of Urban Design and Land Use and Transport Policies and Practices to Increase Physical Activity: A Systematic Review." *Journal of Physical Activity and Health,* Vol. 3, Supplement 1 (February, 2006).

Heglund, C. T., Barton-Aschman Associates, Inc. (retired), email to the Handbook authors (October 11, 2004).

Heglund, C. T., *The Des Moines Skywalk System.* American Society of Civil Engineers Preprint 80-557, ASCE Convention & Exposition, Florida (October 27–31, 1980).

Hennepin County, "Hennepin County Trail User Survey—Summer 2005." Department of Housing, Community Works & Transit, Minneapolis, MN [2005].

Herman, M., *Bicycle Blueprint: A Plan to Bring Bicycling into the Mainstream in New York City.* New York: Transportation Alternatives (1993).

Hess, P. M., Moudon, A. V., Snyder, M. C., and Stanilov, K., "Site Design and Pedestrian Travel." *Transportation Research Record 1636* (1998).

Hillman, M., "Reconciling Transport and Environmental Policy." *Public Roads,* Vol. 70 (Summer, 1992).

Historical Marker Database, "Maine (Androscoggin County)—Cities of the Androscoggin—Lewiston-Auburn." *Maine Markers.* Article/Map. http://hmdb.org?Results.asp?State=Maine (Webpages accessed May 18, 2010).

Hofbauer, D., Socialdata America Ltd. Personal Interview (July 3, 2007).

Horning, J., El-Geneidy, A. M., and Krizek, K. J., "Perceptions of Walking Distance to Neighborhood Retail and Other Public Services." *TRB 87th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 13–17, 2008).

Horst, S., *Achieving Mode Shift in Washington State.* Prepared by Whatcom Council of Governments for CTR Board Workshop (August 10, 2010a).

Horst, S., Whatcom Council of Governments. Telephone and personal interviews (December 2, 20, and 22, 2010b).

Horst, S., and Brög, W., "Neighborhood Smart Trips: How Individualized Marketing Can Work in Your Community." PowerPoint notes (Horst only) and slides. Session 54, Pro Walk/Pro Bike® 2010 Chattanooga (September 13–16, 2010).

Hottenstein, A., Turner, S., and Shunk, G., *Bicycle and Pedestrian Travel Demand Forecasting: Summary of Data Collection Activities.* Prepared by Texas Transportation Institute, College Station, TX (September, 1997).

Huston, S. L., Evenson, K. R., Bors, P., and Gizlice, Z., "Neighborhood Environment, Access to Places for Activity, and Leisure-time Physical Activity in a Diverse North Carolina Population." *American Journal of Health Promotion*, Vol. 18, No. 1 (September/October, 2003).

Hsiao, S., Lu, J., Sterling, J., and Weatherford, M., "Use of Geographic Information Systems for Analysis of Transit Pedestrian Access." *Transportation Research Record 1604* (1997).

Hu, P. S., and Reuscher, T. R., "Summary of Travel Trends—2001 National Household Travel Survey." Prepared for the Federal Highway Administration, U. S. Department of Transportation, Washington, DC. http://nhts.ornl.gov/2001/pub/STT.pdf (December, 2004).

Hunter, W. W., Stewart, J. R., Stutts, J. C., Huang, H. H., and Pein, W. E., *A Comparative Analysis of Bicycle Lanes Versus Wide Curb Lanes: Final Report.* Prepared by the University of North Carolina Highway Safety Research Center for the U.S. Federal Highway Administration, Office of Safety and Traffic Operations (December, 1999).

Hunt, J. D., and Abraham, J. E., "Influences on bicycle use." *Transportation,* Vol. 34, No. 4 (2007).

Iacono, M., University of Minnesota, Minneapolis, MN, email to the Handbook authors (October 4, 2011).

Iacono, M., Krizek, K., and El-Geneidy, A., *Access to Destinations: How Close is Close Enough? Estimating Accurate Distance Decay Functions for Multiple Modes and Different Purposes.* Final Report. Prepared by Hubert H. Humphrey Institute of Public Affairs, University of Minnesota, for the Minnesota Department of Transportation, St. Paul, MN (May, 2008).

Indiana University, "Indiana Trails Study—A Study of Trails in 6 Indiana Cities." Summary Report and individual trail reports (Rivergreenway Trail—Ft. Wayne, IN; Maple City Greenway Trail—Goshen, IN; Pennsy Rail Trail—Greenfield, IN; Monon Trail—Indianapolis, IN; Cardinal Greenway Trail—Muncie, IN; Prairie Duneland Trail—Portage, IN). Prepared by Epply Institute for Parks & Public Lands, Indiana University, Bloomington, IN (November/December, 2001).

Institute of Transportation Studies, "Crosswalk Markings for Better or Worse?" *Technology Transfer Program Newsletter.* University of California, Berkeley, CA (Spring, 2003).

ITE (Institute of Transportation Engineers), "State DOTs Award 80 Percent of Available Safe Routes to School Federal Funds to Encourage Safe Walking and Bicycling to School." *ITE e-newsletter,* http://www.ite.org/enewsletters/enewsletter1208.htm (dated December, 2008).

Jacobsen, P. L., "Safety in numbers: more walkers and bicyclists, safer walking and bicycling." *Injury Prevention,* Vol. 9 (2003).

Jensen, S. U., Rosenkilde, C., Jensen, N., *Road safety and perceived risk of cycle facilities in Copenhagen.* Prepared for the Municipality of Copenhagen, Denmark http://www.vehicularcyclist.com/copenhagen1.pdf (April, 2007).

Jones, M., "National Bicycle and Pedestrian Documentation Project." PowerPoint presentation to the TRB Pedestrian Committee, TRB 88th Annual Meeting, Washington, DC (January 11–15, 2009).

Kamin, B., "State Street's revival through Boston eyes: Killing the transit mall opened the door to the street's rebirth." Cityscapes blog. *chicagotribune.com* (Blogged March 10, 2009).

Kell, J. H., "Transportation Planning Studies." *Transportation Planning Handbook,* John D. Edwards, Jr., P.E., Editor, Institute of Transportation Engineers. Prentice Hall, Englewood Cliffs, NJ (1992).

Ker, I., "Too Good to be True? A Response to Morton and Mees (2010)." *World Transport Policy & Practice,* Vol. 17, No. 1, http://www.eco-logica.co.uk/pdf/wtpp17.1.pdf (May, 2011).

Khisty, C. J., "Evaluation of Pedestrian Facilities: Beyond the Level-of-Service Concept." *Transportation Research Record 1438* (1994).

King, W. C., Brach, J. S., Belle, S., Killingsworth, R., Fenton, M., and Kriska, A. M., "The Relationship Between Convenience of Destinations and Walking Levels in Older Women." *American Journal of Health Promotion,* Vol. 18, No. 1 (September/October, 2003).

Kitamura, R., Mokhtarian, P. L., and Laidet, L., *A Micro-Analysis of Land Use and Travel in Five Neighborhoods in the San Francisco Bay Area.* Prepared for the California Air Resources Board by the University of California at Davis, CA (November, 1994).

Knoblauch, R. L., Nitzburg, M., and Seifert, R. F., *Pedestrian Crosswalk Case Studies: Sacramento, California; Richmond, Virginia; Buffalo, New York; Stillwater, Minnesota.* Prepared for the Office of Safety R&D, Federal Highway Administration, by the Center for Applied Research, Inc., Great Falls, VA (August, 2001).

Kockelman, K. M., *Travel Behavior as a Function of Accessibility, Land Use Mixing, and Land Use Balance: Evidence from the San Francisco Bay Area.* Thesis. University of California, Berkeley, CA (1996).

Koffman, D., and Edminster, R., *Streets for Pedestrians and Transit: Examples of Transit Malls in the United States.* Final Report—Phase I. Prepared for the Urban Mass Transportation Administration, U.S. Department of Transportation, by Crain and Associates, Menlo Park, CA (August, 1977).

Krizek, K. J., "Pretest-Posttest Strategy for Researching Neighborhood Scale Urban Form and Travel Behavior." *Transportation Research Record 1722* (2000).

Krizek, K. J., "Residential Relocation and Changes in Urban Travel: Does Neighborhood-Scale Urban Form Matter?" *Journal of the American Planning Association,* Vol. 69, No. 3 (Summer, 2003).

Krizek, K. J., and Johnson, P. J., "Proximity to Trails and Retail: Effects on Urban Cycling and Walking." *Journal of the American Planning Association,* Vol. 72, No. 1 (Winter, 2006).

Krizek, K. J., Barnes, G., Poindexter, G., Mogush, P., Thompson, K., Levinson, D., Tilahun, N., Loutzenheiser, D., Kidston, D., Hunter, W., Tharpe, D., Gillenwater, Z., Killingsworth, R., "Guidelines for Analysis of Investments in Bicycle Facilities." *NCHRP Report 552.* Washington, DC (2006).

Krizek, K. J., Barnes, G., Wilson, R., Johns, B., McGinnis, L., NuStats International, Forsyth, A., Handy, S. L., and Clifton, K. J., *Nonmotorized Transportation Pilot Program Evaluation Study.* Final Report. Prepared by the University of Minnesota for the Minnesota Department of Transportation, St. Paul, MN (June, 2007).

Krizek, K. J., El-Geneidy, A., and Thompson, K., "A detailed analysis of how an urban trail system affects cyclists' travel." *Transportation,* Vol. 34, No. 5 (2007).

Kuzmyak, J. R., Babor, C., and Savory, D., "Use of a Walk Opportunities Index to Quantify Local Accessibility." *Transportation Research Record 1977* (2006).

Kuzmyak, J. Richard, Transportation Consultant, LLC, Fehr & Peers, NuStats, LLC, University of Texas at Austin, John L. Bowman Research and Consulting, Mark Bradley Research & Consulting, Kieth Lawton Consulting, Inc., and Richard H. Pratt, Consultant, Inc., "NCHRP Project No. 08-78, Estimating Bicycling and Walking for Planning and Project Development, Interim Report." Approved draft. Prepared for the National Cooperative Highway Research Program, Transportation Research Board, Washington, DC (March, 2011).

LaHood, R., "United States Department of Transportation Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations." Signed on March 11, 2010. http://www.fhwa.dot.gov/environment/bikeped/policy_accom.htm (March 15, 2010).

Landis, B. W., Vattikuti, V. R., and Brannick, M. T., "Real-Time Human Perceptions: Toward a Level of Service." *Transportation Research Record 1578,* (1997).

Landis, B. W., Vattikuti, V. R., Ottenberg, R. M., McLeod, D. S., and Guttenplan, M., "Modeling the Roadside Walking Environment: Pedestrian Level of Service." *Transportation Research Record 1773,* (2001).

Langdon, M. J., Department of Transport and Main Roads, Queensland, Australia, telephone interview and email with attached bikeway and count location maps (December 6–7, 2010).

Lawrence Frank & Co., Inc., The Sacramento Council of Governments (SACOG), and Mark Bradley Associates, "I-PLACE3S Health & Climate Enhancements and Their Application in King County." Prepared for King County HealthScape, Seattle, WA (April 7, 2008). Update available at http://www.kingcounty.gov/transportation/HealthScape.aspx (June 1, 2009).

League of American Bicyclists, "Bicycle Friendly America." http://www.bikeleague.org/programs/bicyclefriendlyamerica/ (Webpages accessed January 26, 2009).

Lee, C., and Moudon, A. V., "Correlates of Walking for Transportation or Recreation Purposes." *Journal of Physical Activity and Health,* Vol. 3, Supplement 1 (February, 2006a).

Lee, C., and Moudon, A. V., "The 3Ds + R: Quantifying land use and urban form correlates of walking." *Transportation Research Part D,* Vol. 11, Issue 3 (May, 2006b).

Lemer, A. C., Bellomo, S. J., and Liff, S. D., "Planning for Pedestrians—Demand Estimating Techniques." *Pedestrian Planning and Design Seminar Proceedings.* MAUDEP (Metropolitan Association of Urban Designers and Environmental Planners), New York, NY (February, 1972).

Levine, J., and Frank, L. D., "Transportation and land use preferences and residents' neighborhood choices: the sufficiency of compact development in the Atlanta region." *Transportation,* Vol. 34, No. 2 (March, 2007).

Levinson, H. S., "Pedestrian Circulation Planning: Concepts and Case Studies." *Pedestrian Planning and Design Seminar Proceedings.* MAUDEP (Metropolitan Association of Urban Designers and Environmental Planners), New York, NY (February, 1972).

Levinson, H. S., "Streets for People and Transit." *Transportation Quarterly,* Vol. 40, No. 4 (October, 1986).

Levinson, H. S., "Urban Travel Characteristics," in *Transportation and Traffic Engineering Handbook,* Second Edition, Editors Homburger, W. S., Keefer, L. E., and McGrath, W. R., Institute of Transportation Engineers, Prentice Hall, Englewood Cliffs, NJ (1982).

Levinson, H. S., and Brown-West, O., "Estimating Bus Ridership." *Transportation Research Record 994* (1984).

Lindsey, G., Han, Y., Wilson, J., and Yang, J., "Neighborhood Correlates of Urban Trail Use." *Journal of Physical Activity and Health,* Vol. 3, Supplement 1. http://www.activelivingresearch.org/files/jpah_10_lindsey.pdf (February, 2006).

Lindsey, G., Man, J., Payton, S., and Dickson, K., "Property Values, Recreation Values, and Urban Greenways." *Journal of Park and Recreation Administration,* Vol. 22, No. 3 (Fall, 2004).

Lindsey, G., Maraj, M., and Kuan, S.-C., "Access, Equity, and Urban Greenways: An Exploratory Investigation." *The Professional Geographer,* Vol. 53, Issue 3 (August, 2001).

Lindsey, G., Payton, S., Man, J., Ottensmann, J., "Public Choices and Property Values—Evidence for Greenways in Indianapolis." *Central Indiana.* Center for Urban Policy and the Environment, Indianapolis, IN (December, 2003).

Lipton, S. G., "Evaluating the Eugene, Oregon, Greenway Bicycle Bridge." *Transportation Research Record 739* (1979).

Liss, S., McGuckin, N., Moore, S., Reuscher, T., "Our Nation's Travel: Current Issues—2001 National Household Travel Survey (NHTS)." Federal Highway Administration, U.S. Department of Transportation, Washington, DC http://www.bts.gov/publications/highlights_of_the_2001_national_household_travel_survey/ (2003).

Litman, T., "Bicycling and Transportation Demand Management." *Transportation Research Record 1441* (1994).

Litman, T., *Evaluating Non-Motorized Transportation Benefits and Costs.* Victoria Transport Policy Institute, Victoria, BC, Canada, http://www.vtpi.org/nmt-tdm.pdf (March 18, 2011a).

Litman, T., *Quantifying the Benefits of Non-Motorized Transport for Achieving TDM Objectives.* Victoria Transport Policy Institute, Victoria, BC, Canada (December, 1999).

Litman, T., Victoria Transport Policy Institute, email to the Handbook Authors with "Accessibility Index" revision for next post-12/26/11 update of "Roadway Connectivity—Creating More Connected Roadway and Pathway Networks" (http://www.vtpi.org/tdm/tdm116.htm). Victoria, BC, Canada (December 27, 2011b).

Lott, D. F., Tardiff, T., and Lott, D. Y., "Evaluation by Experienced Riders of a New Bicycle Lane in an Established Bikeway System." *Transportation Research Record 683* (1979).

Loutzenheiser, D., "Pedestrian Access to Transit: Model of Walk Trips and their Design and Urban Form Determinants around Bay Area Rapid Transit Stations." *Transportation Research Record 1604* (1997).

Lund, H. M., Cervero, R., and Willson, R. W., *Travel Characteristics of Transit-Oriented Development in California.* Prepared by Project Team Members from Cal Poly Pomona, UC Berkeley, and San Francisco Bay Area Rapid Transit under a Caltrans "Statewide Planning Studies" Transportation Grant, Sacramento, CA (January, 2004).

Lusk, A. C., Furth, P. G., Morency, P., Miranda-Moreno, L. F., Willett, W. C., and Dennerlein, J. T., "Risk of Injury for bicycling on cycle tracks versus in the street." *Injury Prevention* http://injuryprevention.bmj.com/content/early/2011/02/02/ip.2010.028696.full (published online, doi: 10.1136/ip.2010.028696, February 9, 2011).

Luton, J., "Bike to Work Week—Victoria, British Columbia." *Case Study Compendium.* Pedestrian and Bicycle Information Center, University of North Carolina Highway Safety Research Center, http://www.walkinginfo.org/case_studies (July, 2010).

Macbeth, A. G., "Bicycle Lanes in Toronto." *ITE Journal,* Vol. 69, No. 4, Institute of Transportation Engineers, Washington, DC (April, 1999).

Mackett, R., Banister, D., Batty, M., Einon, D., Brown, B., Gong, Y., Kitazawa, K., Marshall, S., and Paskins, J., "Final report on 'Children's Activities, Perceptions and Behavior in the Local Environment (CAPABLE).' " University College London (UCL), UK (April, 2007a).

Mackett, R., Brown, B., Gong, Y., Kitazawa, K., and Paskins, J., "Setting children free: children's independent movement in the local environment." Working Papers Series Paper 118, UCL Centre for Advanced Spatial Analysis, University College London, UK. http://www.casa.ucl.ac.uk/publications/workingpapers.asp (March, 2007b).

Mackett, R. L., Lucas, L., Paskins, J., and Turbin, J., "The therapeutic value of children's everyday travel." *Transportation Research Part A,* Vol. 39, Issues 2–3 (February–March, 2005a).

Mackett, R., Lucas, L., Paskins, J., and Turbin, J., "Walking Buses in Hertfordshire: Impacts and Lessons." Centre for Transport Studies, University College London (UCL), UK (November, 2005b).

MacLachlan, S., and Badgett, S., *An Exploration of Bicycle Use in the U.S.: National Findings and Local Implications.* Washington State Transportation Commission Innovations Unit, Olympia, Washington (June, 1995).

Marchetti, L., "National Safe Routes to School Program: Initial Results." Presentation visuals. http://www.bikeleague.org/conferences/summit10/srts_initial_results.pdf National Bike Summit, Washington, DC (March 10, 2010).

Maryland-National Capital Park and Planning Commission, "Interim Capital Crescent/Georgetown Branch Trail Survey Report." Countywide Park Planning and Resources Analysis Division, Silver Spring, MD (2001).

McCahill, C., and Garrick, N. W., "The Applicability of Space Syntax to Bicycle Facility Planning." *TRB 87th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 13–17, 2008).

McCarthy, D., *Wonder's Way Bike Pedestrian Pathway on the Arthur Ravenel, Jr. Bridge: A Successful Model for Facilitating Active Living in Lowcountry South Carolina.* Final Report. Prepared by the College of Charleston for the Berkeley, Charleston, Dorchester Council of Governments, Charleston, SC (February 23, 2009).

McCollom Management Consulting, "Transit Performance Monitoring System—First Phase Testing," Draft Final Report. Prepared for American Public Transit Association (April, 1999).

McDonald, N. C., "Children's mode choice for the school trip: the role of distance and school location in walking to school." *Transportation,* Vol. 35, No. 1 (2008).

McGuckin, N., and Srinivasan, N., "The Journey-to-Work in the Context of Daily Travel." *Decennial Census Data for Transportation Planning: Conference Proceedings 4,* Transportation Research Board, Washington, DC (2005).

McNally, M. G., and Kulkarni, A., "Assessment of Influence of Land Use–Transportation System on Travel Behavior." *Transportation Research Record 1607* (1997).

Merom, D., Bauman, A., Vita, P., and Close, G., "An environmental intervention to promote walking and cycling—the impact of a newly constructed Rail Trail in Western Sydney." *Preventative Medicine,* Vol. 36, Issue 2 (February 2003).

Mitman, M. F., Ragland, D. R., and Zegeer, C. V., "Marked-Crosswalk Dilemma—Uncovering Some Missing Links in a 35-Year Debate." *Transportation Research Record 2073* (2008).

Monsere, C., McNeil, N., and Dill, J., "Evaluation of Innovative Bicycle Facilities: SW Broadway Cycle Track & SW Stark/Oak Street Buffered Bike Lanes." Final Report. Prepared by Portland State University for the Bureau of Transportation, City of Portland, OR http://www.its.pdx.edu/project.php?id=2011-BBL (January 14, 2011).

Moore, R. L., and Older, S. J., "Pedestrians and Motor Vehicles are Compatible in Today's World." *Traffic Engineering,* Vol. 35, No. 12, Institute of Traffic Engineers. (Now *ITE Journal,* Institute of Transportation Engineers, Washington, DC) (September, 1965).

Moritz, W. E., "Adult Bicyclists in the United States: Characteristics and Riding Experience in 1996." *Transportation Research Record 1636* (1998).

Moritz, W. E., *Bicycle Facilities and Use.* Prepared for the Washington State Department of Transportation by the Washington State Transportation Center (TRAC), Seattle, WA (May, 1995).

Moritz, W. E., *Burke-Gilman/Sammamish River Trails Surveys—Summary Report 2005.* Seattle, WA (June, 2005a).

Moritz, W. E., *Burke-Gilman/Sammamish River Trails—User Counts and Survey Results—1980, 1985, 1990, 1995, and 2000.* Summary Report. Seattle, WA (April, 2005b).

Morris, H., *Getting the Most out of Bicycle Commuting in the United States.* For presentation at the Canadian Institute of Transportation Engineers Conference, Alberta, Canada (May 13, 2001).

Morton, A., and Mees, P., "Too Good to be True? An Assessment of the Melbourne Travel Behavior Modification Pilot." *World Transport Policy & Practice,* Vol. 16, No. 2, http://www.eco-logica.co.uk/pdf/wtpp16.2.pdf (August, 2010).

Moudon, A. V., Hess, P. M., Snyder, M. C., and Stanilov, K., "Effects of Site Design on Pedestrian Travel in Mixed-Use, Medium-Density Environments." *Transportation Research Record 1578* (1997).

Moudon, A. V., Lee, C., Cheadle, A. D., Collier, C. W., Johnson, D., Schmid, T. L., and Weathers, R. D., "Cycling and the built environment, a US perspective." *Transportation Research Part D,* Vol. 10, Issue 3 (May, 2005).

Moudon, A. V., Lee, C., Cheadle, A. D., Garvin, C., Johnson, D. B., Schmid, T. L., Weathers, R. D., "Attributes of Environments Supporting Walking." *American Journal of Health Promotion,* Vol. 21, Issue 5 (May/June, 2007).

Moudon, A. V., Stewart, O., and Lin, L., *Safe Routes to School (SRTS) Statewide Mobility Assessment Study.* Phase I Report. Appendix A, "Literature Review." Prepared for the Research Office, Washington State Department of Transportation, by the Washington State Transportation Center, University of Washington, Seattle, WA. http://www.wsdot.wa.gov/research/reports/fullreports/743.1.pdf (January, 2010).

Mustel Group Market Research, "City of Vancouver Burrard Bridge Lane Reallocation Residents Surveys—Mid-Trial Report." Presented to City of Vancouver, BC, Canada. http://vancouver.ca/projects/burrard/index.htm ["Read report to Council" button] (September, 2009).

Nabors, D., Gibbs, M., Sandt, L., Rocchi, S., Wilson, E., and Lipinski, M., *Pedestrian Road Safety Audit Guidelines and Prompt Lists.* Prepared for the Federal Highway Administration, Office of Safety, by Vanasse Hangen Brustlin, Inc., Silver Spring, MD (July, 2007).

Nabors, D., Schneider, R., Leven, D., Lieberman, K., and Mitchell, C., *Pedestrian Safety Guide for Transit Agencies.* Prepared for the Federal Highway Administration, Office of Safety, by Vanasse Hangen Brustlin, Inc., Silver Spring, MD (February, 2008).

(NACTO) National Association of City Transportation Officials, "NACTO Urban Bikeway Design Guide," Washington, DC. http://nacto.org/cities-for-cycling/design-guide/ (Webpages accessed March 17, 2011).

National Center for Safe Routes to School, "Federal Safe Routes to School Program Evaluation Plan." Prepared for the Federal Highway Administration, Washington, DC. http://www.saferoutesinfo.org/sites/default/files/resources/NationalEvaluationPlan.pdf (August, 2011).

National Center for Safe Routes to School, "Safe Routes to School Case Studies—From Around the Country." http://www.saferoutesinfo.org/sites/default/files/resources/srts_case_studies.pdf (April, 2010).

National Highway Traffic Safety Administration (NHTSA), "Traffic Safety Facts—2009 Data—Pedestrians" and "Traffic Safety Facts—2009 Data—Bicyclists and Other Cyclists." DOT HS 811 394 and DOT HS 811 386. U.S. Department of Transportation, Washington, DC [2010].

National Highway Traffic Safety Administration (NHTSA) and the Bureau of Transportation Statistics (BTS), "National Survey of Pedestrian & Bicyclist Attitudes and Behaviors: Highlights Report." Sponsored by NHTSA and BTS, U.S. Department of Transportation, and administered by The Gallup Organization. Washington, DC (2002).

National Research Center, Inc., "2005 Boulder Valley Employee Survey for Transportation." Prepared for the City of Boulder, CO (July, 2006a).

National Research Center, Inc., "Modal Shift in the Boulder Valley—1990 to 2006." Prepared for the City of Boulder, CO (July, 2007).

National Research Center, Inc., "University of Colorado: Boulder Campus Student Transportation Survey—Report of Results." Boulder, CO (March, 2006b).

National Safe Routes to School Task Force, "Safe Routes to School: A Transportation Legacy—A National Strategy to Increase Safety and Physical Activity among American Youth." http://www.saferoutesinfo.org/task_force/collateral/task_force_report.web.pdf (July, 2008).

Navin, F. P. D., Synectics Road Safety Research, and Anderson, M., City of Vancouver, BC, Canada. Individual telephone interviews (November 24, 2009).

Nelson, A. C., and Allen, D., "If You Build Them, Commuters Will Use Them: Association Between Bicycle Facilities and Bicycle Commuting." *Transportation Research Record 1578* (1997).

Newman, D. A., and Bebendorf, M., *Integrating Bicycles and Transit in Santa Barbara, California*. Final Report, September 1978—June 1981. Prepared by Systan, Inc., Los Altos, CA (March, 1983).

New York City Department of Transportation, "Green Light for Midtown Evaluation Report." http://www.nyc.gov/html/dot/downloads/pdf/broadway_report_final2010_web.pdf (January, 2010).

NHTSA (see National Highway Traffic Safety Administration).

NHTSA and BTS (see National Highway Traffic Safety Administration and Bureau of Transportation Statistics).

Niemeier, D., Rutherford, G. S., and Ishimaru, J. M., *Analysis of Bicyclist Counts in the Puget Sound Area and Spokane*. Report 95.3. Washington State Transportation Commission Innovations Unit, Olympia, Washington (June, 1995a).

Niemeier, D., Rutherford, G. S., and Ishimaru, J. M., *An Analysis of Bicyclist Survey Responses from the Puget Sound Area and Spokane.* Report 95.4. Washington State Transportation Commission Innovations Unit, Olympia, Washington (June, 1995b).

Nice Ride MN, "How it Works." https://www.niceridemn.org/how_it_works (Webpage accessed July 19, 2011).

Nice Ride MN, "Nice Ride Subscriber Survey." Summary Report. http://appv3.sgizmo.com/reportsview/?key=102593-416326-6d13ea0276ea0822c9f59f4411b6c779 (Nov. 1, 2010).

NuStats, "2007 Origin and Destination Study." Final Report. Prepared for Valley Metro Regional Public Transportation Authority (RPTA), Phoenix, AZ. http://www.valleymetro. org/images/uploads/projects/2007_Origins_and_Destinations_Study_Final_Report.pdf (February, 2009).

NuStats International, "Bicycle and Pedestrian Travel: Exploration of Collision Exposure in Florida." Final Paper prepared for Florida Department of Transportation, Office of Policy Planning, Tallahassee, FL (December, 1998).

O'Fallon, C., "Developing School-based Cycle Trains in New Zealand." *Land Transport New Zealand Research Report 338,* Prepared by Pinnacle Research & Policy Ltd, Wellington, New Zealand (2007).

Office of Management and Budget, "Memorandum for Heads of Executive Departments and Establishments: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs." Circular No. A-94 Revised. http://www.whitehouse.gov/omb/circulars_a094/ (October 29, 1992).

Ogilvie, D., Foster, C. E., Rothnie, H., Cavill, N., Hamilton, V., Fitzsimons, C. F., and Mutrie, N., "Interventions to promote walking: systematic review." *BMJ (British Medical Journal),* doi:10.1136/bmj.39198.722720.BE; Vol. 334, No. 1204; and Data Supplement (June, 2007).

Ohio-Kentucky-Indiana Regional Council of Governments, "Little Miami Scenic Trail Users Study." Prepared for the Ohio Greenways Initiative (1999).

Ottensmann, J. R., and Lindsey, G., "A use-based measure of accessibility to linear features to predict urban trail use." *Journal of Transport and Land Use,* Vol. 1, Issue 1 (Summer, 2008).

Park, S., and Kang, J., "Factors That Influence Walking and Biking to the Station: Modeling Commuter Rail Users' Access Mode Choice." *TRB 87th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 13–17, 2008).

Parker, J. H., Harris, L., Chatterjee, K., Armitage, R., Cleary, J., and Goodwin, P., "Making Personal Travel Planning Work: Research Report." Prepared by Integrated Transport Planning Ltd for Department for Transport, London, United Kingdom (December, 2007).

Parsons Brinckerhoff Quade & Douglas, Inc., "Transit and Urban Form." Vol. 1, Part I, *TCRP Report 16.* Washington, DC (1996).

Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, R., Howard Stein-Hudson Associates, Inc., and Zupan, J., "Influence of Land Use Mix and Neighborhood Design on Transit Demand." TCRP Project H-1 Unpublished Research Findings, Transportation Research Board, Washington, DC, (1996a).

Parsons Brinckerhoff Quade & Douglas, Inc., Cervero, R., Howard Stein-Hudson Associates, Inc., and Zupan, J., "Mode of Access and Catchment Areas of Rail Transit." TCRP Project H-1 Unpublished Research Findings, Transportation Research Board, Washington, DC, (1996b).

Parsons Brinckerhoff, Richard H. Pratt, Consultant, Inc., and RJM Engineering, Inc., "Virginia Railway Express Commuter Rail Patronage Forecasts—Technical Memorandum: Fiscal Year 1996 Forecasts." Prepared for the Northern Virginia Transportation Commission (October, 1994).

Patten, R. S., Derry, A., Hiemstra, H., and Fowler, M., "ISTEA and Trails: Merging Transportation Needs and Recreation Values." Published by Rails-to-Trails Conservancy and American Trails for the 12th National Trails Symposium, Anchorage, Alaska. http://ntl.bts.gov/DOCS/mtn.html (September, 1994).

PBIC (Pedestrian and Bicycle Information Center) and APBP (Association of Pedestrian and Bicycle Professionals), "Case Study Compendium." University of North Carolina Highway Safety Research Center. http://www.walkinginfo.org/case_studies (Compendium dated January, 2009).

Peale, C., "Skywalk debate: Relic or amenity?" *The Cincinnati Post,* Cincinnati, Ohio (October 1, 1999).

Pecheux, K. K., Bauer, J., Miller, S., Rephlo, J., Saporta, H., Erickson, S., Knapp, S., and Quan, J., "Guidebook for Mitigating Fixed-Route Bus-and-Pedestrian Collisions." *TCRP Report 125.* Washington, DC (2008).

Pedestrian and Bicycle Information Center, "Case Study Compendium." University of North Carolina Highway Safety Research Center. http://www.walkinginfo.org/case_studies (Compendium dated July, 2010).

Pedestrian and Bicycle Information Center, "SRTS Guide—Encouragement." http://guide.saferoutesinfo.org/case_studies/encouragement.cfm (Webpages accessed November 8, 2011).

Petritsch, T. A., Landis, B. W., McLeod, P. S., Huang, H. F., and Scott, D., "Energy Savings Resulting from the Provision of Bicycle Facilities." *TRB 87th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 13–17, 2008).

Philip Habib & Associates, Inc., "Percent Growth in Pedestrian Counts—Aggregate of Selected Locations—Summer 1999–2010" and "2010 Summer Pedestrian Counts." http://www.timessquarenyc.org/do-business-here/market-facts/pedestrian-counts/index.aspx (Webpages accessed June 7–9, 2011).

Physical Activity Guidelines Advisory Committee, "Physical Activity Guidelines Advisory Committee Report." Prepared for the Department of Health and Human Services, Washington, DC. http://www.health.gov/paguidelines/Report/default.aspx (May, 2008).

Pinjari, A. R., Bhat, C. R., and Hensher, D. A., "Incorporating Residential Self-Selection Effects in Activity Time-use Behavior: Formulation and Application of a Joint Mixed Multinomial Logit—Multiple Discrete-Continuous Extreme Value Model." *TRB 87th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 13–17, 2008).

Pinsof, S. A., "Transportation Control Measure Analysis: Bicycle Facilities." *Transportation Research Record 847* (1982).

Podolski, R. C., and Heglund, C. T., "Skyways in Minneapolis/St. Paul: Prototypes for the Nation?" *Urban Land* (September, 1976).

Portland Bureau of Transportation, "Appendices—SmartTrips Southwest." Portland, OR. http://www.portlandonline.com/transportation/index.cfm?c=43819 (February, 2009).

Portland Office of Transportation, "Appendices—SmartTrips Northeast Hub." Portland, OR. http://www.portlandonline.com/transportation/index.cfm?c=43819 (December, 2006).

Portland Office of Transportation, "Appendices—SmartTrips Southeast." Portland, OR. http://www.portlandonline.com/transportation/index.cfm?c=43819 (December, 2007).

Portland Office of Transportation, "Appendix A—Eastside Hub Target Area Program Measurement Tools and Results Report." Portland, OR. http://www.portlandonline.com/transportation/index.cfm?c=43819 (December, 2005).

Pratt, L. A., "Serious Psychological Distress, as Measured by the K6, and Mortality." *Annals of Epidemiology,* Vol. 9, Issue 3 (March, 2009).

Pratt, M., Macera, C. A., and Wang, G., "Higher Direct Medical Costs Associated With Physical Inactivity." *The Physician and Sportsmedicine,* Vol. 28, No. 10 (October, 2000).

Pratt, R. H., "A Utilitarian Theory of Travel Mode Choice." *Highway Research Record 322,* Highway (now Transportation) Research Board, Washington, DC (1970).

Pratt, R. H., "Impact of Rail Transit on Bus Operations." *Transportation Engineering Journal—Proceedings of the American Society of Civil Engineers,* Vol. 97, No. TE1, Proc. Paper 7881 (February, 1971).

Pratt, R. H., Pedersen, N. J., and Mather, J. J., *Traveler Response to Transportation System Changes—A Handbook for Transportation Planners* [first edition]. Federal Highway Administration, Washington, DC (February, 1977).

Pratt, Richard H., Consultant, Inc., and Metropolitan Washington Council of Governments (MWCOG), "Patronage and Revenue Forecasts for the Virginia Railway Express." Prepared for the Northern Virginia Transportation Commission (May, 1987).

Project for Public Spaces, "Case Study No. 20—The Effects of Environmental Design on the Amount and Type of Bicycling and Walking." *National Bicycling and Walking Study.* Prepared for Federal Highway Administration, U.S. Department of Transportation, Washington, DC (1993).

Project for Public Spaces. "Transit-Friendly Streets: Design and Traffic Management Strategies to Support Livable Communities." *TCRP Report 33.* Washington, DC (1998).

Pucher, J., "Cycling Safety on Bikeways vs. Roads." *Transportation Quarterly,* Vol. 55, No. 4 (Fall, 2001).

Pucher, J., and Buehler, R., "Cycling for a Few or for Everyone: The Importance of Social Justice in Cycling Policy." *World Transport Policy & Practice,* Vol. 15, No. 1, Lancaster, UK (April, 2009a).

Pucher, J., and Buehler, R., "Cycling for Everyone—Lessons from Europe." *Transportation Research Record 2074* (2008a).

Pucher, J., and Buehler, R., "Integrating Bicycling and Public Transport in North America." *Journal of Public Transportation,* Vol. 12, No. 9. Center for Urban Transportation Research, Tampa, FL (2009b).

Pucher, J., and Buehler, R., "Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany." *Transport Reviews,* Vol. 28, Issue 4, London, UK (July, 2008b).

Pucher, J., and Dijkstra, L., "Making Walking and Cycling Safer: Lessons from Europe." *Transportation Quarterly,* Vol. 54, No. 3 (Summer, 2000).

Pucher, J., and Dijkstra, L., "Promoting Safe Walking and Cycling to Improve Public Health: Lessons From The Netherlands and Germany." *American Journal of Public Health,* Vol. 93, No. 9 (September, 2003).

Pucher, J., and Renne, J. L., "Socioeconomics of Urban Travel: Evidence from the 2001 NHTS." *Transportation Quarterly,* Vol. 57, No. 3 (Summer, 2003).

Pucher, J., Buehler, R., Bassett, D. R., and Dannenberg, A. L., "Walking and Cycling to Health: A Comparative Analysis of City, State, and International Data." *American Journal of Public Health,* Vol. 100, No. 10 (October, 2010).

Pucher, J., Dill, J., and Handy, S., "Infrastructure, programs, and policies to increase bicycling: An international review." *Preventative Medicine,* Vol. 50, Supplement 1 (January, 2010).

Puget Sound Regional Council, "Burke-Gilman/Sammamish River Trail Use." *Puget Sound Trends*, No. T14, Seattle, WA (November, 2000).

Pushkarev, B., and Zupan, J. N., "Pedestrian Travel Demand." *Highway Research Record 355,* Highway (now Transportation) Research Board, Washington, DC (1971).

Pushkarev, B., and Zupan, J. N., *Urban Space for Pedestrians—A Report of the Regional Plan Association.* MIT Press, Cambridge, MA (1975).

Queensland Transport, Transport Research and Analysis Centre (now Queensland Government, Transport and Main Roads, Modelling, Data and Analysis Centre), "Walk mode share to CBD and CBD Fringe 1986 to 2006" and "Bicycle mode share to CBD and CBD Fringe 1986 to 2006." Maps and data [2007].

Rails-to-Trails Conservancy, "Trail of the Month: January 2010—New York's Walkway Over the Hudson." http://www.railstotrails.org/news/recurringFeatures/trailMonth/index.html (Webpage accessed January 8, 2010).

Rails-to-Trails Conservancy (RTC) and the Association of Pedestrian and Bicycle Professionals (APBP), "Improving Conditions for Bicycling and Walking: A Best Practices Report." Prepared for the Federal Highway Administration, Washington, DC (January, 1998).

Raisman, G., Portland [Oregon] Bureau of Transportation, email to Andrew Dannenberg, Centers for Disease Control and Prevention, with attached table, "Cyclists per Day—Bikeway Miles" (2010).

Rathbone, D. B., "Editorial." *The Urban Transportation Monitor,* Vol. 20, No. 3 (February 17, 2006).

Ratzel, M., City of Boulder, email to the Handbook authors with facilities tabulation as of June-08 of "Grade separated crossings" and "Bikeway Corridors" (January 27, 2009).

Reiff, B., and Kim, K.-H., *Statistical Analysis of Urban Design Variables and Their Use in Travel Demand Models.* Prepared by Lane Council of Governments, Portland Metro, and Oregon Department of Transportation for Performance Measures Subcommittee of the Oregon Modeling Steering Committee (November, 2003).

Relyea, K., "Bikes help take heat off high gasoline prices—Commuter gear popular items at cycling shops." *The Bellingham Herald* (July 23, 2008).

Replogle, M., "Case Study No. 17—Bicycle and Pedestrian Policies and Programs in Asia, Australia, and New Zealand." *National Bicycling and Walking Study.* Prepared for Federal Highway Administration, U.S. Department of Transportation, Washington, DC (1993).

Replogle, M., "Integrating Pedestrian and Bicycle Factors into Regional Transportation Planning Models: Summary of the State-of-the-Art and Suggested Steps Forward." Report for the Environmental Defense Fund (July 20, 1995).

Replogle, M., and Parcells, H., "Case Study No. 9—Linking Bicycle/Pedestrian Facilities with Transit." *National Bicycling and Walking Study*. Prepared for Federal Highway Administration, U.S. Department of Transportation, Washington, DC (1992).

Reynolds, C. C. O., Winters, M., Ries, F. J., and Gouge, B., *Active Transportation in Urban Areas: Exploring Health Benefits and Risks.* Prepared for the National Collaborating Centre for Environmental Health, Vancouver, BC, Canada (June, 2010).

Rissotto, A., and Tonucci, F., "Freedom of Movement and Environmental Knowledge in Elementary School Children." *Journal of Environmental Psychology,* Vol. 22, Issues 1–2. www.lacittadeibambini.org/inglese/ricerca/allegati/articolo_eng.doc (March, 2002).

Roback, P., Community Development Educator, UW-Extension, *Ozaukee Interurban Trail Enhancement Project.* http://www.interurbantrail.us/TrailEnhancementProject/ProjectStudy-2_061504.pdf Ozaukee County, Wisconsin (March, 2004).

Roberts, C., University of Minnesota Architectural and Urban Studies student, "The Skyway System (twincitiespage.com)." http://www.angelfire.com/mn/dragonfire/skyways.html (blogged March 26, 2001).

Robertson, K. A., "Downtown Pedestrian Malls in Sweden and the United States," *Transportation Quarterly,* Vol. 46, No. 1 (January, 1992).

Robertson, K. A., "Downtown Redevelopment Strategies in the United States." *APA Journal,* Vol. 61, No. 4, American Planning Association, Chicago, Illinois (Autumn, 1995).

Robertson, K. A., "Pedestrianization Strategies for Downtown Planners: Skywalks versus Pedestrian Malls." *APA Journal,* Vol. 59, No. 3, American Planning Association, Chicago, Illinois (Summer, 1993).

Robertson, K. A., *Pedestrian Malls and Skywalks—Traffic separation strategies in American downtowns.* Avebury—Ashgate Publishing Limited, Brookfield, Vermont (1994).

Robertson, K. A., "Pedestrian Skywalk Systems: Downtown's Great Hope or Pathways to Ruin?" *Transportation Quarterly,* Vol. 17, No. 3 (July, 1988).

Roddin, M. F., "A Manual to Determine Benefits of Separating Pedestrians and Vehicles." *NCHRP Report 240.* Washington, DC (November, 1981).

Rose, G., "Combining intercept surveys and a self-completion questionnaire to understand cyclist use of off-road paths." *TRB 86th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 21–25, 2007).

Rose, G., and Marfurt, H., "Travel behavior change impacts of a major ride to work day event." *Transportation Research Part A,* Vol. 41, Issue 4 (May, 2007).

Rosén, E., and Sander, U., "Pedestrian fatality risk as a function of car impact speed." *Accident Analysis and Prevention,* Vol. 41, Issue 3 (May, 2009).

Roskowski, M., Ratzel, M., Gardner-Sweeney, M., and Winfree, T., "Development of Boulder's Multimodal System." *Case Study Compendium.* Pedestrian and Bicycle Information Center, University of North Carolina Highway Safety Research Center, http://www.walkinginfo.org/case_studies (July, 2010).

Rovio, S., Kåreholt, I., Helkala, E., Viitanen, M., Winblad, B., Tuomilehto, J., Soininen, H., Nissinen, A., and Kivipelto, M., "Leisure-time physical activity at midlife and the risk of dementia and Alzheimer's disease." *The Lancet Neurology,* Vol. 4, Issue 11 (2005).

RTC and APBP (see Rails-to-Trails Conservancy and the Association of Pedestrian and Bicycle Professionals).

Rutherford, G. S., McCormack, E., and Wilkinson, M., *Travel Impacts of Urban Form: Implications from an Analysis of Two Seattle Area Travel Diaries.* Urban Design, Telecommuting and Travel Forecasting Conference, Williamsburg, VA: Summary, Recommendations and Compendium of Papers. Prepared by Day, L., Texas Transportation Institute, for the U.S. Department of Transportation (1997).

Rutt, C. D., and Coleman, K. J., "Examining the relationships among the built environment, physical activity, and body mass index in El Paso, TX," *Preventative Medicine,* Vol. 40, No. 6 (June, 2005).

Saelens, B. E., and Handy, S. L., "Built Environment Correlates of Walking: A Review." *Medicine & Science in Sports & Exercise,* Vol. 40, Issue 7, Supplement 1, (July, 2008).

Saelens, B. E., Sallis, J. F., Black, J. B., and Chen, D., "Neighborhood-Based Differences in Physical Activity: An Environmental Scale Evaluation." *American Journal of Public Health,* Vol. 93, No. 9 (September, 2003).

Saelens, B., Sallis, J., and Frank, L., "Transportation, Human Health, and Physical Activity." Resource Paper. *Environmental Research Needs in Transportation—Report of a Conference.* Conference Proceedings 28. Transportation Research Board, Washington, DC (March 21–23, 2002).

San Francisco Bicycle Coalition, "Valencia St. Bike Lanes." Press Release. http://www.sfbike.org/news/press_release_archives/01-03-valencia.html (March 22, 2001).

S. B. Friedman & Company, Vlecides-Schroeder Associates, Nancy Seeger Associates, and Siim Soot, Ph.D., "Metra Rail Service and Residential Development Study: Summary of Findings." Prepared for Metra, Chicago, IL (2000a).

S. B. Friedman & Company, Vlecides-Schroeder Associates, Nancy Seeger Associates, and Siim Soot, Ph.D., "Metra Rail Service and Residential Development Study: Appendices: Rider Survey Findings." Prepared for Metra, Chicago, IL (2000b).

Schaller Consulting, "Curbing Cars: Shopping, Parking and Pedestrian Space in SoHo." http://www.transalt.org/files/newsroom/reports/soho_curbing_cars.pdf Prepared for Transportation Alternatives. New York, NY (December 14, 2006).

Schimek, P., email correspondence with the Handbook authors (May 8–June 20, 2008).

Schlossberg, M., Brown, N., Bossard, E., and Roemer, D., *Using Spatial Indicators for Pre- and Post-Development Analysis of TOD Areas: A Case Study of Portland and the Silicon Valley.* Mineta Transportation Institute, San Jose, CA (2004).

Schneider, R. J., *Understanding Sustainable Transportation Choices: Shifting Routine Automobile Travel to Walking and Bicycling.* PhD Dissertation. University of California Transportation Center, University of California, Berkeley, CA (Spring, 2011).

Schneider, R. J., University of California, email to the Handbook authors and attached review comments. Berkeley, CA (October 29, 2010).

Schneider, R. J., Arnold, L. S., and Ragland, D. R., "Methodology for Counting Pedestrians at Intersections—Use of Automated Counters to Extrapolate Weekly Volumes from Short Manual Counts." *Transportation Research Record 2140* (2009).

Schneider, R. J., Patton, R., Toole, J., Raborn, C., *Pedestrian and Bicycle Data Collection in United States Communities: Quantifying Use, Surveying Users, and Documenting Facility Extent.* Prepared for the Federal Highway Administration, U. S. Department of Transportation, by the Pedestrian and Bicycle Information Center, University of North Carolina at Chapel Hill, NC (January, 2005).

Schultz, G. W., and Pratt, R. H., "Estimating Multimode Transit Use in a Corridor Analysis." *Highway Research Record 369,* Highway (now Transportation) Research Board, Washington, DC (1971).

Schwanen, T., and Mokhtarian, P. L., "What affects commute mode choice: neighborhood physical structure or preferences toward neighborhoods?" *Journal of Transport Geography 13* (2005a).

Schwanen, T., and Mokhtarian, P. L., "What if you live in the wrong neighborhood? The impact of residential neighborhood type dissonance on distance traveled." *Transportation Research Part D,* Vol. 10, Issue 2 (March, 2005b).

Schwartz, W., and Porter, C., *Bicycle and Pedestrian Data: Sources, Needs, & Gaps.* Prepared by Cambridge Systematics, Inc., for the Bureau of Transportation Statistics, U.S. Department of Transportation, Washington, DC (2000).

Shafer, C. S., Lee, B., Turner, S., and Hughart, M., *Evaluation of Bicycle and Pedestrian Facilities: User Satisfaction and Perceptions on Three Shared Use Trails in Texas.* Texas Transportation Institute, College Station, TX (May, 1999).

Shafizadeh, K., and Niemeier, D., "Bicycle Journey-to-Work: Travel Behavior Characteristics and Spatial Attributes." *Transportation Research Record 1578* (1997).

Shaheen, S. A., Guzman, S., and Zhang, H., "Bikesharing in Europe, the Americas, and Asia: Past, Present, and Future." *TRB 89th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 10–14, 2010).

Shriver, K., "Influence of Environmental Design on Pedestrian Travel Behavior in Four Austin Neighborhoods." *Transportation Research Record 1578* (1997).

Shunk, G. A., "Urban Transportation Systems." *Transportation Planning Handbook,* John D. Edwards, Jr., P.E., Editor, Institute of Transportation Engineers. Prentice Hall, Englewood Cliffs, NJ (1992).

Silva, C., "$3 Gas Packs Riders on PSTA Buses," *St. Petersburg Times.* Accessed via MassTransitMag.com (Webpage accessed November 14, 2007).

Socialdata America Ltd., "City of Portland Individualized Marketing Pilot Project." Final Report. Prepared for City of Portland, OR (July, 2004).

Socialdata GmbH, "Active Living." Chart prepared for Whatcom Council of Governments, Bellingham, WA (March, 2008).

Sorton, A., and Walsh, T., "Bicycle Stress Level as a Tool to Evaluate Urban and Suburban Bicycle Compatibility." *Transportation Research Record 1438* (1994).

SR 282 (see Committee on Physical Activity, Health, Transportation, and Land Use).

SRF Consulting Group, Inc., "2003 City of Minneapolis Central Business District Cordon Count." Prepared for the Public Works Department, Traffic & Parking Services Division, City of Minneapolis, MN (December, 2003).

SRF Consulting Group, Inc., "City of Minneapolis Central Business District 1998 Cordon Count." Prepared for the Department of Public Works, Transportation Division, City of Minneapolis, MN (November, 1998).

Staunton, C. E., Hubsmith, D., and Kallins, W., "Promoting Safe Walking and Biking to School: The Marin County Success Story." *American Journal of Public Health,* Vol. 93, No. 9 (September, 2003).

Steiner, R. L., "Trip Generation and Parking Requirements in Traditional Shopping Districts." *Transportation Research Record 1617* (1998).

Steiner, R. L., Bejleri, I., Johnson, J. L., Boles, G., Cahill, M., and Perez, B. O., "Understanding and Mapping Institutional Impediments to Walking and Bicycling to School: A Case Study of Hillsborough County." *TRB 87th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 13–17, 2008).

Steve Spindler Cartography, "Bikes on Transit Ridership Statistics," *Bikes on Transit Database.* http://www.bikemap.com/bikesontransit/statistics.php (Webpage accessed August 1, 2010).

Stopher, P., Alsnih, R., Bullock, P., and Ampt, E., "Evaluating Voluntary Travel Behaviour Interventions." *27th Australasian Transport Research Forum,* Adelaide, Australia (September 29-October 1, 2004).

Stover, V. G., and Koepke, F. J., *Transportation and Land Development.* 2nd Edition. Institute of Transportation Engineers, Washington, DC (2002).

SunLine, "About SunLine—Organization." SunLine Transit Agency, Thousand Palms, California. http://www.sunline.org (Website accessed on August 16, 2003).

Switzer, C. R., *The Center Commons Transit Oriented Development: A Case Study.* Master of Urban and Regional Planning field area paper, Portland State University, Portland, OR (Fall, 2002).

Swords, A. R., Goldman, L. M., Feldman, W., Ehrlich, T. F., and Bird, W. J., Jr., "An Analytical Framework for Prioritizing Bicycle and Pedestrian Investments: New Jersey's Statewide Master Plan Update, Phase 2." *Transportation Research Record 1878* (2004).

Sztabinski, F., *Bike Lanes, On-Street Parking and Business—A Study of Bloor Street in Toronto's Annex Neighbourhood.* The Clean Air Partnership, Toronto, Ontario, Canada (February, 2009).

Tannen, P. S., "Bicycle Access on Caltrain, San Francisco Bay Area, California." *BIKESAFE Bicycle Countermeasure Selection System—Case Studies.* Case Study #49. http://www.bicyclinginfo.org/bikesafe/case_studies.cfm (Webpage accessed August 4, 2010).

Targa, F., and Clifton, K. J., *Built Environment and Trip Generation for Non-Motorized Travel.* Paper summary submitted for presentation. National Household Travel Survey Data Conference: Data for Understanding Our Nation's Travel, Washington, DC. http://www.trb.org/conferences/nhts/Clifton.pdf (November 1–2, 2004).

Taylor, D., and Mahmassani, H., "Analysis of Stated Preferences for Intermodal Bicycle-Transit Interfaces." *Transportation Research Record 1556* (1996).

Thunderhead Alliance, "Bicycling and Walking in the U.S.: Benchmarking Report 2007." Washington, DC. http://www.thunderheadalliance.org/benchmarking.htm (August, 2007).

Tilahun, N. Y., Levinson, D. M., and Krizek, K. J., "Trails, Lanes, or Traffic: The Value of Different Bicycle Facilities Using an Adaptive Stated Preference Survey." *TRB 84th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 9–13, 2005).

Tilahun, N. Y., Levinson, D. M., and Krizek, K. J., "Trails, Lanes, or Traffic: The Value of Different Bicycle Facilities Using an Adaptive Stated Preference Survey." *Transportation Research Part A: Policy and Practice.* Vol. 41, Issue 4 (May, 2007).

Tools of Change, "Seattle Neighborhoods In Motion." Case study. Prepared by Cullbridge Marketing and Communications on behalf of Health Canada and Natural Resources Canada. http://www.toolsofchange.com/en/case-studies/detail/186/ (Website accessed November 2, 2010).

Traffic Calming.org, "Effectiveness of Traffic Calming measures." Presented by Fehr & Peers, http://trafficcalming.org/effectiveness (Webpages accessed June 3, 2011).

TransNow, "The Effect of Light Rail Transit on Travel Mode Choice and Physical Activity: A Natural Experiment." *2009 Annual Report* [2009].

Transport and Main Roads, "Traffic Census—Bikeway Surveys." Queensland, Australia, (2004–2009).

TriMet, "What's New on the Portland Mall?—Big changes on 5th and 6th avenues downtown." http://trimet.org/portlandmall/index.htm (Webpages accessed July 24, 2009).

Troped, P. J., Saunders, R. P., Pate, R. R., Reininger, B., Ureda, J. R., and Thompson, S. J., "Associations between Self-Reported and Objective Physical Environmental Factors and Use of a Community Rail-Trail." *Preventative Medicine,* Vol. 32, Issue 2 (February, 2001).

Turner, S., Sandt, L., Toole, J., Benz, R., and Patten, R., *Federal Highway Administration University Course on Bicycle and Pedestrian Transportation.* Prepared by the Texas Transportation Institute and Toole Design Group, LLC, for Federal Highway Administration, U.S. Department of Transportation. Office of Safety Research and Development, Mclean, VA http://www.fhwa. dot.gov/publications/research/safety/pedbike/05085/pdf/combinedlo.pdf (July, 2006).

UITP (International Union of Public Transport) and Socialdata, "Switching to Public Transport." Brussels, Belgium (1998).

Ujifusa, A., "Officials want amenities added to Elm Street Park." *The Gazette.* Montgomery County, MD (March 18, 2009).

University of North Carolina, "A Compendium of Available Bicycle and Pedestrian Trip Generation Data in the United States." Prepared for the Federal Highway Administration, U.S. Department of Transportation, by the University of North Carolina Highway Safety Research Center (October, 1994).

Urban Transportation Monitor, "Omaha Ponders Issue of Pedestrian Bridges—Safety versus Cost in Question." Vol. 14, No. 14 (July 21, 2000).

Urban Transportation Monitor, "Pedestrian Space at Times and Herald Squares in New York City to be Permanent." Vol. 24, No. 2 (March 8, 2010).

Urban Transportation Monitor, "This Month's Survey Results (Survey 1)—Bike Station Characteristics." Vol. 23, No. 8 (October 5, 2009).

U.S. Census Bureau, "American Community Survey" (ACS). 2009. Transportation. Commuting Characteristics by Sex. http://factfinder.census.gov/servlet/STGeoSearchByList Servlet?ds_name= ACS_2009_1YR_G00_&_lang=en&_ts=331298619629 (Webpages accessed August 13, 2011).

U.S. Environmental Protection Agency, "Partnership for Sustainable Communities—A Year of Progress for American Communities." Washington, DC (October, 2010).

U.S. Environmental Protection Agency, "Travel and Environmental Implications of School Siting." Washington, DC (October, 2003).

Valley Metro, "Annual Ridership Report FY 2008–2009." http://www.valleymetro.org/valley_ metro/publications/ridership_reports/ (Webpage and linked pdf documents accessed August 3, 2010).

VanZerr, M., "Resident Perceptions of Bicycle Boulevards: A Portland, Oregon Case Study." *TRB 89th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 10–14, 2010).

Victoria Transport Policy Institute, "Evaluating Accessibility for Transportation Planning: Measuring People's Ability to Reach Desired Goods and Activities." *Online TDM Encyclopedia.* http://www.vtpi.org/access.pdf (Webpages updated November 28, 2010).

Victoria Transport Policy Institute, "Evaluating Nonmotorized Transport: Techniques for Measuring Walking and Cycling Activity and Conditions." *Online TDM Encyclopedia.* http://www.vtpi.org/ tdm/tdm63.htm (Webpages updated August 27, 2007).

Victoria Transport Policy Institute, "Multi-Modal Level-of-Service Indicators—Tools For Evaluating The Quality of Transport Services and Facilities." *Online TDM Encyclopedia.* http://www.vtpi.org/ tdm/tdm129.htm (Webpages updated October 7, 2011a).

Victoria Transport Policy Institute, "Roadway Connectivity—Creating More Connected Roadway and Pathway Networks." *Online TDM Encyclopedia.* http://www.vtpi.org/tdm/tdm116.htm (Webpages updated March 16, 2011b).

Virkler, M. R., "Prediction and Measurement of Travel Time Along Pedestrian Routes." *Transportation Research Record 1636* (1998).

Wachtel, A., and Lewiston, D., "Risk Factors for Bicycle-Motor Vehicle Collisions at Intersections." *ITE Journal,* Vol. 64, No. 9, Institute of Transportation Engineers, Washington, DC (September, 1994).

Washington State Department of Transportation, "Ferries—Bicycle Rules and Information." http://www.wsdot.wa.gov/Ferries (Webpage accessed July 15, 2011).

Watkins, C. K., State Highway Administration, Maryland Department of Transportation, letter to the Handbook authors Re. "US 29 (Georgia Avenue) at Ellsworth Drive Mid-block Pedestrian Crossing Studies" with attached 2001–2004 traffic counts at the Georgia Avenue intersections with Colesville Road, Ellsworth Drive, and Wayne Avenue (August 17, 2004).

Weinstein, A., and Schimek, P., "How Much do Americans Walk? An Analysis of the 2001 NHTS." *TRB 84th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 9–13, 2005).

Weinstein, A., Bekkouche, V., Irvin, K., and Schlossberg, M., "How Far, by Which Route, and Why? A Spatial Analysis of Pedestrian Preference." *TRB 86th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 21–25, 2007).

Weisbrod, G., and Loudon, W., *Downtown Crossing: Auto Restricted Zone in Boston.* Final Report. Prepared by Cambridge Systematics, Inc., for the Urban Mass Transit Administration, U.S. Department of Transportation, Washington, DC (July, 1982).

Welzenbach, K. D., *Analysis of the 1995 Bicycle Survey of Suburban Bike Trails.* Working Paper #96-08. Chicago Area Transportation Study, Chicago, Illinois (June, 1996).

Whatcom Council of Governments, "Whatcom Smart Trips—A Transferable Model of Vehicle Trip Reduction for U.S. Cities." Bellingham, WA (October, 2010).

Wikipedia, "Technology adoption lifecycle." http://en.wikipedia.org/wiki/Technology_adoption_lifecycle (Webpages accessed July 17, 2011).

Wikipedia, "Underground city—United States." http://en.wikipedia.org/wiki/Underground_city#United_States (Webpages accessed July 16, 2009).

Wilbur Smith and Associates, "Urban Transportation Concepts." City Center Transportation Study. Prepared for the Urban Mass Transportation Administration, Washington, DC (September, 1970).

Wilbur Smith and Associates, Resource Systems Group, Applied Real Estate Analysis, and League of American Bicyclists. "Final Report: Non-Motorized Access to Transit." Prepared for Regional Transportation Authority, Chicago, Illinois (1996a).

Wilbur Smith and Associates, Resource Systems Group, Applied Real Estate Analysis, and League of American Bicyclists. "Task 3, 4 and 5 Model Development and Application Report: Non-Motorized Access to Transit." Prepared for Regional Transportation Authority, Chicago, Illinois (1996b).

Wilbur Smith and Associates, Resource Systems Group, Applied Real Estate Analysis, and League of American Bicyclists. "Task 6 and 7 Prioritization of Station and Case Studies Report: Non-Motorized Access to Transit." Prepared for Regional Transportation Authority, Chicago, Illinois (1996c).

Wilbur Smith Associates, "Bicyclist and Pedestrian Data Collection and Analysis Project." Final Report, technical memoranda, and computer database. Prepared for the Metropolitan Transportation Commission in association with Traffic Research & Analysis, Inc. San Francisco, CA (April 9, 2003).

World Health Organization, "Global Database on Body Mass Index—BMI Classification." http://www.who.int/bmi/index.jsp?introPage=intro_3.html (Webpages accessed April 12, 2011).

Yan, J. H., Thomas, J. R., and Downing, J. H., "Locomotion Improves Children's Spatial Search: A Meta-Analytic Review." *Perceptual and Motor Skills,* Vol. 87 (1998).

Xing, Y., and Handy, S. L., "Bicycling Differences between Davis, California and Boulder, Colorado." *TRB 89th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 10–14, 2010).

Xing, Y., Handy, S. L., and Buehler, T. J, "Factors Associated with Bicycle Ownership and Use: A Study of 6 Small U.S. Cities." *TRB 87th Annual Meeting Compendium of Papers DVD.* Washington, DC (January 13–17, 2008).

Zegeer, C. V., UNC Highway Safety Research Center, email to the Handbook authors with review comments attachment. Chapel Hill, NC (January 11, 2011).

Zegeer, C. V., "Grade Separated Crossings." *Design and Safety of Pedestrian Facilities.* Prepared by Traffic Engineering Council Committee TENC-5A-5, Institute of Transportation Engineers, Washington, DC (March, 1998).

Zegeer, C. V., Stewart, J. R., Huang, H. H., Lagerwey, P. A., Feaganes, J., and Campbell, B. J., *Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines.* Prepared for the Office of Safety Research and Development, Federal Highway Administration, by the University of North Carolina Highway Safety Research Center, Chapel Hill, NC (August, 2005).

Zegeer, C. V., Stutts, J., Hunter, B., Pein, W., Feske, C. D., Cheeney, D., McCarville, P., and Geiger, C. *Final Report: The National Bicycling and Walking Study.* Prepared by the Highway Safety Research Center and HDR Engineering, Inc. for the Federal Highway Administration, Washington, DC (1994).

Zehnpfenning, G. H., Design Ventures, Inc., Cromar, J., and Maclennan, S. J., "Case Study No. 4—Measures to Overcome Impediments to Bicycling and Walking." *National Bicycling and Walking Study.* Federal Highway Administration, U.S. Department of Transportation, Washington, DC (1993).

Zein, S. R., Geddes, E., Hemsing, S., and Johnson, M., "Safety Benefits of Traffic Calming." *Transportation Research Record 1578* (1997).

Zhao, F., Li, M.-T., Chow, L.-F., Gan, A., and Shen, L. D., *FSUTMS Mode Choice Modeling: Factors Affecting Transit Use and Access.* Prepared for National Center for Transit Research (NCTR), University of South Florida, in cooperation with the Florida Department of Transportation, by the Lehman Center for Transportation Research, Florida International University, Miami, FL (July, 2002).

Zhou, B., and Kockelman, K. M., "Self-Selection in Home Choice: Use of Treatment Effects in Evaluating Relationship Between Built Environment and Travel Behavior." *Transportation Research Record 2077* (2008).

Zhou, N., Zhao, J., Hsu, P., and Rouse, J., "Identifying Factors Affecting the Number of Students Walking or Biking to School." *ITE Journal,* Vol. 79, No. 10, Institute of Transportation Engineers, Washington, DC (October, 2009).

Zwerts, E., and Wets, G., "Children's Travel Behavior: World of Difference." *TRB 85th Annual Meeting Compendium of Papers CD-ROM.* Washington, DC (January 22–26, 2006).

Cyclist on a "Bikeway" (a.k.a., bicycle boulevard) in Vancouver, British Columbia, Canada, illustrating a vehicle traffic diverter, bike cut-through, and arterial-crossing bicycle and pedestrian refuges

Courtesy of www.pedbikeimages.org, Carl Sundstrom, photographer

A state highway semi-mid-block ("T" intersection) signalized pedestrian crossing in combination with a pedestrian passageway provide town center access in Silver Spring, Maryland

Dick Pratt, photographer

Minneapolis Skyway and Nicollet Mall activity in a downtown core area where total pedestrian flows have crept upward on average for nearly half a century

Courtesy of Metropolitan Council, St. Paul, MN, Jeff Syme, photographer

An elementary school "Walking School Bus" in Montreal, with children grasping a cord held front and back by responsible adults

Courtesy of www.pedbikeimages.org, Dan Burden, photographer

In Montgomery County, MD, the on-road bike route, which parallels the trail (bottom) sees mostly avid cyclists

Dick Pratt, photographer

In Montgomery County, MD, the trail, which parallels the on-road bike route (top), is used by walkers, joggers, bicyclists-in-training, and more casual cyclists in general

Dick Pratt, photographer

ADA-compliant bus stops and adjoining sidewalk sections have been found in Maryland, in specific cases, to allow cost-effective reductions in special ADA-mandated paratransit services

Dick Pratt, photographer

The easterly sidewalk branch seen here on the right follows a former dirt path traced by Washington Metro passengers seeking directness in their walk to/from Grosvenor-Strathmore Station

Dick Pratt, photographer

Conventional bike lanes along the Embarcadero are part of a City of San Francisco program that has seen bicycle count increases averaging some 70 percent on individual streets studied

Courtesy of www.pedbikeimages.org, Dan Burden, photographer

A singular facility extension example is the "Downtown Trail" continuation of Florida's west coast Pinellas Trail through central St. Petersburg to Tampa Bay via the 1st Avenue South cycle track

Dick Pratt, photographer

Manhattan's elevated "High Line" rail trail is a classic example of a spectacular facility whose users are likely seeking "direct-benefit" enjoyment and exercise more than derived-benefit travel

Courtesy of Robert Pratt, photographer

Trail orientation affects which travel purposes are effectively served—the alignment of Florida's Pinellas Trail through several downtowns attracts relatively high use for commuting

Dick Pratt, photographer

The highly varied weekend traffic mix on the Capital Crescent Trail in Bethesda, MD, illustrates off-road path openness to multiple activities by users of all ages and capabilities

Dick Pratt, photographer

Improvement of MD 547, providing ADA-compliant sidewalks on both sides instead of a degraded walk on one side, was associated with nearly a 70 percent total pedestrian count increase

Dick Pratt, photographer

This Mesa, AZ, multi-use path signage illustrates well the variety of uses generally allowed on U.S. “bicycle” paths and trails

Courtesy of www.pedbikeimages.org, Jim Hash, photographer

Pedestrian and bicycle bridges on paths, if well connected like this Pinellas Trail bridging of Central Avenue in St. Petersburg, FL, can serve both local access and longer through trips

Dick Pratt, photographer

Bike racks such as these in Madison, WI, are preferred by potential cyclists over no parking at all but appear to rank lower than secure covered parking

Courtesy of www.pedbikeimages.org, Eric Lowry, photographer

This Durham, NH, streetscape illustrates pedestrian-friendly features such as store placement directly at the back of the broad sidewalk

Courtesy of www.pedbikeimages.org, Dan Burden, photographer

An "interested" participant receives an information packet as part of the 2008 Bellingham Smart Trips individualized marketing project

Courtesy of Socialdata GmbH and Whatcom Council of Governments, Bellingham, WA

Bicycling on quiet streets, including bicycle boulevards, is attractive to most user groups but especially female cyclists

Courtesy of www.pedbikeimages.org, Adam Darin, photographer

"Hawk Signals" are among the "active when present" traffic control devices being applied in an effort to reduce dangers of multiple-threat situations at marked but uncontrolled multi-lane crossings

Courtesy of www.pedbikeimages.org, Mike Cynecki, photographer

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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