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Traveler Response to Transportation System Changes: An Interim Introduction to the Handbook

This TCRP digest is one of a series of products from TCRP Projects B-12, B-12A, and B-12B, “Updating the ‘Traveler Response to Transportation System Changes’ Handbook (DOT-FH-11-9579).” This digest was written by Richard H. Pratt.

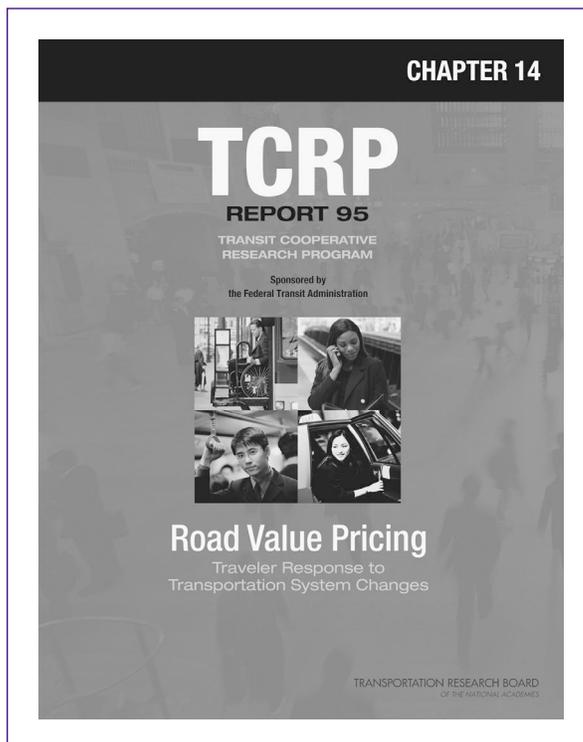
The objective of this project is to develop an up-to-date and expanded sourcebook on how travel demand is affected by transportation system changes and built environment options. This digest is structured to serve as an “Interim Introduction” for the evolving Traveler Response Handbook, replacing Chapter 1, “Introduction” of the “Interim Handbook” (available as *TCRP Web Document 12*), and facilitating the transition to final multi-volume publication as *TCRP Report 95*.

This digest describes the Traveler Response Handbook, contains the publication schedule and information on availability, provides guidance to the prospective

Handbook user, and includes two Handbook appendices. It should be saved for use with the printed chapters as they become available. The “Traveler Response to Transportation System Changes” Handbook update is being prepared by Richard H. Pratt, Consultant, Inc., in association with the Texas Transportation Institute; Jay Evans Consulting LLC; Parsons Brinckerhoff Quade & Douglas, Inc.; Cambridge Systematics, Inc.; J. Richard Kuzmyak, L.L.C.; SG Associates, Inc.; Gallop Corporation; McCollom Management Consulting, Inc.; Herbert S. Levinson, Transportation Consultant; and K.T. Analytics, Inc.

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Chapter 14 is the first of 19 stand-alone chapters to be published as TCRP Report 95.

Interim Introduction

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

HANDBOOK CONTEXT AND PREPARATION

In this first of the two major sections of the Introduction, the *Traveler Response Handbook* is placed in context with its origins, the current update, and companion reference documents; its staged publication is outlined in terms of chapter availability; and scope and key research steps are covered. The second major section, “Use of the Handbook,” offers information provided in support of informed and effective application of the work.

Genesis and Coverage of the Handbook

Earlier Editions

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

By the time of the Second Edition, shrinking transportation revenues, rising construction costs, and energy scarcity had made more effective use of existing transportation systems essential. There was expanded emphasis on traffic operations improvements, ridesharing, priority for high

occupancy vehicles (HOV), transit service enhancements, variable work hours, and other TSM actions. More experience had been gained in application of these types of actions. However, while the Second Edition reflected that advancement in practical knowledge and substantially expanded on each topic area retained from the First Edition, coverage was only provided for nine categories of system change—and that was over two decades ago.

Current Update

Further substantial innovations and advancements have occurred in transportation services provision and management since Second Edition *Traveler Response Handbook* publication, given impetus by the various Transportation Efficiency/Equity Acts of Congress. Electronic media have expanded fare, fee, and toll payment options; high occupancy toll (HOT) lanes have introduced value pricing to high occupancy vehicle facilities; federal interest in pedestrian and bicycle provisions has vastly increased; and new emphasis has been placed on land use and transportation interrelationships. More has been learned from approaches new or unseasoned two decades ago. Connecting people with their daily activities; meeting needs for mobility; and addressing congestion in a context of continuing resource constraints, quality of life issues, and environmental concerns calls for timely and practical information on how travel demand is shaped and altered by changes in our urban transportation systems and urban fabric. In response, the TCRP has undertaken a major update and expansion of the *Traveler Response Handbook*. The research effort now stretches through TCRP Projects B-12, B-12A, and B-12B.

The topic area coverage of the updated *Traveler Response to Transportation System Changes Handbook* has been shaped by project research on practitioner needs, including Handbook user surveys, ongoing outreach to the transportation planning profession, and Project Panel work sessions. The focus is on transportation system changes and alternatives or land use and site design differences that directly affect the traveler. When the updating process is complete, it is anticipated that the Third Edition will contain the following topic area chapters:

- HOV Facilities
- Park-and-Ride and Park-and-Pool
- Busways, BRT and Express Bus
- Vanpools and Buspools
- Demand Responsive/ADA
- Light Rail Transit
- Commuter Rail
- Transit Scheduling and Frequency
- Bus Routing and Coverage
- Transit Information and Promotion
- Transit Pricing and Fares
- Parking Pricing and Fees
- Road Value Pricing

- Land Use and Site Design
- Pedestrian and Bicycle Facilities
- Transit Oriented Design
- Parking Management and Supply
- Employer and Institutional Travel Demand Management (TDM) Strategies

Companion Handbooks

The *Traveler Response to Transportation System Changes Handbook* has been, from its inception, part of an overall transportation systems and travel demand research effort by the U.S. DOT and now the TCRP. Related handbooks in this effort are *Characteristics of Urban Transportation Systems*, currently in its Third Edition publication by the Federal Transit Administration (FTA)(Cambridge Systematics, 1992), and *Characteristics of Urban Travel Demand*, available in its third version as *TCRP Report 73* (Reno, Kuzmyak, and Douglas, 2002).

All three handbooks have received wide distribution and have become standard references in the transportation field. The three have now been joined by the *Transit Capacity and Quality of Service Manual* developed under TCRP Project A-15 and updated under TCRP Project A-15A (Kittelson and Associates, Inc., 1999 and 2003). The Second Edition will be available as *TCRP Report 100*. The *Transit Capacity and Quality of Service Manual* provides the public transit equivalent of the *Highway Capacity Manual* (Catalina Engineering, Inc., 2000) while also addressing transit quality of service concepts and measurement.

Publication Status of This Handbook

The magnitude of this Third Edition *Traveler Response Handbook* project has led to advance and staged publication in an effort to provide access to available findings pending completion of the full 19-chapter, 18-topic Handbook. Availability is as follows:

- Seven topic area chapters and the initial “Introduction” were electronically published in March 2000 as an *Interim Handbook—TCRP Web Document 12*—on the TCRP website and in a limited printing (Pratt et al., 2000b). Included were Chapters 1, 2, 5, 6, 9, 10, 12, and 13. Note that this current “Interim Introduction” (with Appendices A and B) replaces Chapter 1, “Introduction” and “Appendix A” of the *Interim Handbook Web Document 12* (along with available chapter/appendix update substitutions) is available at <http://www4.trb.org/trb/onlinepubs.nsf>.
- Print publication of the Third Edition *Traveler Response to Transportation System Changes Handbook* will begin in Fall 2003, chapter by chapter, as *TCRP Report 95*. Each chapter will be a separate volume. As each chapter is printed, the electronic equivalent will be posted on the same TCRP websites as indicated above.

- The first four topic area chapter/volumes being published as *TCRP Report 95* per se will be printed and posted along with this “Interim Introduction” version of Chapter 1. They are Chapters 11, 14, 15, and 18.¹ This will make a total of 11 topic area chapters available to the profession.
- Additional *TCRP Report 95* chapters will be published in print and electronically as they are ready, with posting on the same websites. See Table 1 for estimated publication dates.
- A final version of Chapter 1, “Introduction,” will be the last chapter of *TCRP Report 95* published as part of the Third Edition. It is expected to be accompanied by a searchable CD-ROM containing the complete Handbook.

Table 1 lists the 18 *TCRP Report 95* topic area chapters and “Introduction” in outline order, and summarizes development and availability status.

Scope and Development of the Handbook

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

Handbook Objective and Scope

The overarching objective of the *Traveler Response 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 different types of transportation system changes and policy actions and also alternative land use and site development design approaches. While the focus is on contemporary observations and assessments of traveler responses as expressed in travel demand changes, the presentation is seasoned with earlier

¹Chapter 18, “Parking Management and Supply,” was referred to as Chapter 17 in the *Interim Handbook, TCRP Web Document 12*. Similarly, Chapter 19, “Employer and Institutional TDM Strategies,” was referred to as Chapter 18.

Table 1 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	Estimated Publication Date
Ch. 1 – Introduction (with Appendices A, B)	1977	1981	2003 ^a	2000/03/04 ^a
Multimodal/Intermodal Facilities				
Ch. 2 – HOV Facilities	1977	1981	1999	2000/04 ^b
Ch. 3 – Park-and-Ride and Park-and-Pool	—	1981	2003 ^c	2004 ^d
Transit Facilities and Services				
Ch. 4 – Busways, BRT and Express Bus	1977 ^e	1981	2003 ^c	2004 ^d
Ch. 5 – Vanpools and Buspools	1977	1981	1999	2000/04 ^b
Ch. 6 – Demand Responsive/ADA	—	—	1999	2000/04 ^b
Ch. 7 – Light Rail Transit	—	—	2003	2004 ^d
Ch. 8 – Commuter Rail	—	—	2003	2004 ^d
Public Transit Operations				
Ch. 9 – Transit Scheduling and Frequency	1977	1981	1999	2000/04 ^b
Ch. 10 – Bus Routing and Coverage	1977	1981	1999	2000/04 ^b
Ch. 11 – Transit Information and Promotion	1977	1981	2002	2003
Transportation Pricing				
Ch. 12 – Transit Pricing and Fares	1977	1981	1999	2000/04 ^b
Ch. 13 – Parking Pricing and Fees	1977 ^e	—	1999	2000/04 ^b
Ch. 14 – Road Value Pricing	1977 ^e	—	2002-03 ^f	2003
Land Use and Non-Motorized Travel				
Ch. 15 – Land Use and Site Design	—	—	2001-02 ^f	2003
Ch. 16 – Pedestrian and Bicycle Facilities	—	—	2003	2004 ^d
Ch. 17 – Transit Oriented Design	—	—	2003 ^d	2004 ^d
Transportation Demand Management				
Ch. 18 – Parking Management and Supply	—	—	2000-02 ^f	2003
Ch. 19 – Employer and Institutional TDM Strategies	1977 ^e	1981 ^e	2003	2004 ^d

Notes:

^aPublished in *TCRP Web Document 12, Interim Handbook* (March 2000), without Appendix B. This “Interim Introduction” (2003) is a replacement. Publication of the final version of Chapter 1, “Introduction,” as part of the *TCRP Report 95* series, is anticipated for 2004.

^bPublished in *TCRP Web Document 12, Interim Handbook*, in March 2000. Available now at <http://www4.nas.edu/trb/crp.nsf/All+Projects/TCRP+B-12>. Publication as part of the *TCRP Report 95* series is anticipated for the second half of 2004.

^cThe source data cutoff date for certain components of this chapter was 1999.

^dEstimated.

^eThe edition in question addressed only certain aspects of later edition topical coverage.

^fPrimary cutoff was first year listed, but with selected information from second year listed.

experiences and findings to identify trends or stability and to fill research gaps that would otherwise exist. Comprehensive referencing of additional study materials is provided to facilitate and encourage in-depth exploration of topics of interest.

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

The findings in the *Traveler Response Handbook* are intended to aid—as a general guide—in preliminary screening activities and quick turn-around assessments. The presentation is also designed to serve as a complement to location-

specific analyses, providing a basis for comparison and helping to fill gaps in model-derived demand estimates. The Handbook is further intended to enlighten transportation systems and operations specialists concerning potential or likely travel demand implications of their individual and collective policy and design decisions. It is with improved information from a variety of sources and techniques that transportation professionals can most effectively formulate responses to transportation needs and reliably predict the efficacy of their plans.

Research Approach

The *Traveler Response Handbook* findings derive primarily from reported results and analyses of real-world

transportation system and policy applications and experiments. Quasi-experimental data have been the information source of choice, but other empirical data derivations and simple accounts of outcomes have been employed as necessary. Forecasts and other estimates derived from travel demand model applications and similar techniques have been used, but on a very selective basis, mostly for augmenting the empirical data where gaps exist and providing additional insights and context.

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

Preparatory Tasks. The assembly and review task that began the development of this Third Edition Handbook encompassed both a formal WinSPIRS-based literature search and extensive networking to locate papers, articles, reports, manuals, and syntheses with information on any aspect of traveler response to urban transportation system or policy changes. The bibliographic information obtained, mostly from the 1981 through late 1997 period, was categorized, screened, and entered into a database. This initial phase of the literature search served to ensure that important materials only available in print, as contrasted to electronic postings, were not overlooked. The Second Edition had covered materials up through 1980.

The second phase of source material gathering continued throughout the topic development process, as the research team contacted a number of organizations and individuals known to be active in research areas of concern and also performed supplementary literature and web-based searches. A number of key sources became available in the post-1997 half-decade, especially in the case of highly active areas of research and application. In addition, as noted above, the research team did undertake certain of its own original assessments to supplement available literature and reportings. Table 1 indicates how far into the 1998–2003 period these information gathering activities continued for each individual chapter.

References were selected using criteria such as the timeliness or enduring relevancy of the studies reported on, the degree to which traveler response was measured, the apparent completeness of the work, and the extent of other literature on the same topic or event. Similar criteria were used to choose between retaining and deleting individual references and information available from earlier Handbook editions. Old information found to be redundant or made suspect by the passage of time was rejected. The study team leaned toward retaining older high-quality data, however, when

they were still some of the best available. This choice was in the interests of “[not losing] the message before gain[ing] the knowledge,” to rephrase the title of a TRB Annual Meeting paper on the loss of older documentation (Rogers, 1997).

Assembly and review activities were paralleled by tasks designed to solicit advice on content and presentation; to define, detail, and outline the structure of the updated Handbook; and to develop a coordinated and comprehensive approach for moving the finished product into practice. The user outreach employed a mail-out survey as the initial vehicle for obtaining the desired information. As the project progressed, volunteer Review Groups were formed for each topic area chapter to augment the work of the Project Panel in outline review, source data identification, and chapter draft review.

Preparation of first-cut literature summaries was the final preparatory step—following the literature search and related tasks—to support topic area synthesis and provide the starting point for case studies. This process was structured to define the nature of system change reported and the degree of influence of concurrent changes, actions, and events; establish the methodology and likely reliability of the reported data sources and collection techniques; examine the nature and logic of analysis techniques used to measure or model traveler response; and assess conclusions, degree of reliability, and transferability to other situations and locations.

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

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

The earlier editions of the Handbook were organized to match the classification system used for the Transportation System Management actions published by the U.S. DOT. These actions were part of the regulations governing the

urban transportation planning process at the time. With the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, the subsequent promulgation of regulations by federal agencies, and the reauthorizations since, the previous classification system is no longer relevant.

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

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

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

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

The lessons thus derived have been synthesized in the form of generalized conclusions and guidance, including quantitative data, and estimating parameters developed in accordance with consistency and commonality guidelines. Wherever possible, the nature and sensitivity of response to

each principal variable or configuration of systems change have been indicated. A comprehensive digest has thus been prepared of the literature-based travel behavior findings for each of the transportation system change and built environment alternatives topic areas chosen for coverage in this TCRP update of the *Traveler Response Handbook*. The topic areas involved were listed earlier and in Table 1.

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

The case studies selected to complement each topic area chapter's digest of findings have been prepared according to a common approach. Each case study is designed to provide condensed case-specific traveler response and related information within the context of the system change or land use and site design option involved, and the data collection and evaluation procedures originally employed. The intent has been to preserve the descriptions, findings, and interpretations of the original sources without alteration of meaning. In some cases, the Handbook authors have added calculations or interpretations, or have even carried out the basic assessment in conjunction with contributing agencies, and these instances are so noted. The Handbook authors accept full responsibility for the end results.

USE OF THE HANDBOOK

This *Traveler Response to Transportation System Changes Handbook* consists of these Chapter 1 introductory materials, followed by the 18 topic area chapters with their digests of traveler response findings including supportive information and interpretation. Each topic area chapter also includes case studies and a bibliography consisting of the references utilized as sources.

Each topic area chapter begins with an overview and summary section that includes a description of the types of system and policy change involved. The main digest that follows is provided in three major sections:

- “Response to [the System Change],” covering traveler responses to the various specific sub-types of system change encompassed.
- “Underlying Traveler Response Factors,” addressing the travel demand mechanisms involved.
- “Related Information and Impacts,” providing both cross-cutting summaries of selected user, travel demand, and

impact characteristics and overviews of associated sub-topics.

The case studies and references follow, and they conclude each topic area chapter. Together, these components offer the following:

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

Appendix A provides additional information on the derivation and application of elasticity measures, and Appendix B gives historical cost of living statistics and conversions useful for interpreting transportation system changes involving user costs. The appendices accompany this “Interim Introduction.”

Handbook Application

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

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

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

- Select the most pertinent topic area chapter.
- Review the “Overview and Summary” section to understand context and data limitations, and to obtain a preview from the “Traveler Response Summary.”
- Upon finding relevant topics in the “Table of Contents” or potentially useful information in the “Traveler Response Summary,” proceed to the “Response to [the System Change]” section of the chapter for the full traveler response presentation for each sub-type of system change, with citations.
- Refer to any of the accompanying “Case Studies” that apply for additional case example detail. Case studies are near the end of the chapter, ahead of “References.”
- Consult the “Underlying Traveler Response Factors” section for interpretations useful in understanding the travel demand mechanisms in play.
- See subtopics of interest within the “Related Information and Impacts” section. This section includes cross-cutting compilations relevant to the chapter topic, ranging from user characteristics and trip purpose data to prior travel mode information and system usage characteristics and also includes overviews of related experience and research findings.
- Check relevant cross-referenced material in other chapters.
- Go outward from the Handbook—either from the main text, using the source material citations and the “References” entries linked to them, or from the “Sources” listing in each case study or the “Additional Resources” listing—to applicable papers, studies, and texts. Only the source literature can provide the breadth and detail of the original work.

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

Handbook Organization

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

classification structure of the full Third Edition Handbook, encompassing 18 system change topics, as described earlier. Each topic area chapter is assigned, as illustrated in Table 1, to one of six broad system change categories. These categories constitute general sections, which simply serve to order the system change topics.

Chapter and page numbering is in conformance with the planned 19-chapter, 18-topic *TCRP Report 95* Third Edition. Consequently the user of this work in progress will encounter gaps where individual chapters are not ready. Chapter availability, and where to get the latest information on status, were identified earlier under “Handbook Context and Preparation”—“Publication Status of This Handbook.” Referrals in chapter text to another chapter not yet available may be encountered. These are further explanatory cross-references and do not detract from the use of the published chapter. Referrals in *Interim Handbook* chapters to Chapter 17 and 18 should be interpreted as referrals to Chapters 18 and 19, respectively, of *TCRP Report 95*.

Topic Area Chapter Format

Table 2 illustrates the general format of each topic area chapter presentation, using the “Vanpools and Buspools” chapter as an example.

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

With that background, the last item in the overview is a “Traveler Response Summary” section, highlighting the traveler response findings for the topic. The recommended approach to using either the “Traveler Response Summary” or the material which follows, is to do so only after first reading the initial three sections of the “Overview and Summary” for background. Moreover, any consequential use of findings previewed in the “Traveler Response Summary” should be accompanied by consideration of caveats set forth only in the more detailed presentations which follow.

The “Overview and Summary” of each topic area chapter is followed by the full Handbook survey of observed traveler responses for each type of system change (or built environment option) addressed in the chapter. This “Response to [the System Change]” section of the chapter is accompanied by an “Underlying Traveler Response Factors” section that examines the role of both underlying travel behavior mechanisms and external factors in producing the traveler responses. Note that this sort of information is useful not only for a better understanding in general, but also for practical application in achieving effective transportation service, facility,

and urban design. Next is a “Related Information and Impacts” section, which touches upon other subject areas pertinent to the particular system change topic, including environmental and cost considerations. It is important to be aware, as previously noted, that this section includes various cross-cutting compilations relevant to the chapter topic.

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

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

Bibliographic Format

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

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

Certain of the citation protocols derive from the non-academic origins of this Handbook and are retained in this *TCRP Report 95* edition as a practical matter. In the text, citations are generally located at the *end* of sentences or paragraphs drawn from the cited source material, but ahead of bulleted lists drawn from a single source. Where multiple paragraphs have been extracted from the same source, citations are repeated every so often, particularly where the continuity is not fairly obvious. Citations are not provided in the condensed “Traveler Response Summary” presentations

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

Format (Outline/Major Headings)	Example (Vanpools and Buspools)
(General Section) (Transportation System Change Topic) Overview and Summary Objectives of [the System Change] Types of Programs Analytical Considerations Traveler Response Summary Response to [the System Change]	Transit Facilities and Services Vanpools and Buspools <i>A roadmap to the chapter, plus the following:</i> <i>Vanpool/Buspool program focus, objectives</i> <i>A listing and definition of:</i> Vanpools—Employer Sponsored Programs Vanpools—Third Party Programs Vanpools—Owner Operator Buspool Programs <i>Limitations, caveats, data interpretation alerts</i> <i>Overview of traveler response to programs</i> <i>A survey of the traveler responses to:</i> Employer Sponsored Vanpool Programs Third-Party Vanpool Programs Buspools (Subscription Bus)
Underlying Traveler Response Factors	<i>Exploration of traveler response mechanisms:</i> [Travel Time Components] and Trip Distance Access Considerations Work Scheduling Implications Incentives and User Costs Preferences, Privileges, and Intangibles
Related Information and Impacts	<i>A survey of related special and standard topics:</i> Extent of Vanpooling and Buspooling Demographic Characteristics of Riders Sources of New Ridership and Turnover Indicators of Market Potential Impacts on VMT, Energy, and Environment Revenue/Cost Considerations
Additional Resources Case Studies References	<i>Two references of special interest highlighted</i> <i>Four case studies provided</i> <i>60-odd references listed</i>

that conclude the “Overview and Summary” section at the front of each topic area chapter. The Handbook user must look further, into the more detailed presentations that follow, for the applicable citations.

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

Degree-of-Confidence Issues

Findings presented in this *Traveler Response Handbook* derive primarily from quasi-experimental and other field

observations, supplemented with interpretations from additional sources such as travel demand model research and other cross-sectional studies. Traveler response is expressed using such measures as elasticities, before and after market shares, and percentage changes or differences, with indicators of scale and guidance ranging from examples of volumes and passenger demand to simple feasibility indicators.

The confidence that can be placed in the generalizations drawn in each topic area digest concerning impacts of the transportation system changes varies among the types of change involved. The appropriate degree of confidence necessarily depends on the number of documented observations of a certain type of change, the design and statistical soundness of the associated analyses, confounding factors that may have affected the reported results, the extent to which impacts have been successfully modeled, and the consistency with which findings were obtained and reported. Some transportation system changes examined here have had only limited application, or have been very infrequently subjected to systematic analysis, so that it is difficult to generalize to universal experience. In other instances, confounding factors or unique situations have influenced the results. Even where

it has been possible to draw upon and compare numerous study findings, the validity of the inferences made is still dependent upon the quality of the data and analysis methods originally employed in deriving the reported conclusions.

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

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

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

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

Impact Assessment Considerations

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

The result is a virtual minefield that must be negotiated carefully by the user of available observations and studies, as well as the user of compendia such as this one that must rely on available sources. If only the best and most sound of

evaluations were to be reported, the data points would be too few. The choice has been made in developing this Handbook to use more studies and observations than just the most rigorous. It is therefore important that the Handbook user read caveats provided and also pick up on available study design clues that can help determine how much reliance to put on any given finding. Three categories of problems to be alert for are highlighted here: issues of measurement and statistical significance, effects of confounding events and environments, and additional analytical concerns.

Measurement and Statistical Significance

Field observations of traveler response to transportation system changes are typically provided by user surveys or by before-and-after counts of volume, passengers, or revenue. Problem areas to be alert to include (Pratt, 1967; Pratt et al., 2000a; Higgins and Johnson, 1999):

- Inadequate survey controls with the potential, especially in the case of self-administered surveys, to skew results.
- Data completeness and definitions that may introduce bias or misunderstandings.
- Lack of adequate determination that the outcome was statistically significant.

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

Data completeness for a before-and-after evaluation requires a comprehensive, quantitative description of the “before” conditions and circumstance, the “before” usage or travel demand, the “after” conditions and circumstance, and the “after” usage or travel demand. If any of these critical elements are missing, then the scope of legitimate study conclusions possible is severely degraded.

Data definitions may also hamper analysis. The “unlinked-trip” method of tracking transit ridership—mandated for reporting ridership to the FTA and its National Transit Database—is a case in point. An unlinked trip is a passenger trip made in a single transit vehicle, effectively the same as a passenger boarding. A one-way trip from home to work that involves one transfer, such as between two buses or a bus and train, produces two unlinked transit trips. Yet, those two unlinked transit trips serve only one person trip from the rider’s perspective, have the social and environmental benefit of only one transit trip, and often generate only one

transit fare. To fully understand whether transit route or system changes have attracted more ridership or the converse, the before-and-after number of “linked trips” must be determined. An example of a linked trip is a one-way trip from home to work with or without one or more changes of vehicle. An increase in unlinked trips may reflect nothing more than the effect of more forced transfers (Pratt et al., 2000a).

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

Confounding Events and Environments

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

- External Transportation Events—transportation system changes unrelated to the change of interest such as new or closed facilities; altered levels of enforcement; transit service changes; transportation labor actions; construction delays; altered parking charges, highway tolls, and transit fares; or employer involvement in parking/commute cost subsidies.
- Other External Events—changes in the local/national economy or unemployment rates and changes in government regulations including taxes, social unrest, natural disasters, and special events.
- Effects of Testing—impacts on travel behavior of the experimental process, as when travelers learn more about their travel options as a result of initial surveys.
- Maturation Effects—gradual changes in the circumstances of travelers, most pertinent when a given sample is surveyed at two or more points in time, or regression toward the average of subjects chosen for their above- or below-average behavior.
- Measurement Inconsistencies—changes in the measurement process, specifically including alterations in sur-

vey procedures and questions, and drop-off in survey response rates and associated reliability.

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

In the same way, unique circumstances in a particular city may influence system change results, sometimes in a markedly atypical manner, and other times by simply reinforcing or dampening impacts. The size and geography of cities serve to concentrate or disperse travel, affecting facility volumes or ridership. Cities bordering oceans or lakes have their radial travel concentrated in perhaps five major sectors or broad corridors, as in Chicago, or in fewer corridors in a mountainous urban area like San Diego’s. In extreme contrast, a flatlands pair of cities such as Minneapolis and St. Paul may have 15 separate broad corridors (8 for each city with 1 shared) over which radial travel is distributed (Deen and Pratt, 1992).

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

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

Additional Analytical Concerns

Some of the traveler response interpretations presented in this Handbook are based in part on travel demand model results as contrasted to observed results. The travel demand modeling efforts utilized are sometimes based on stated preference survey data but are more frequently based on revealed preference cross-sectional survey data from a single point in time. Use of such survey data relies on the assumption that

impacts over time of transportation system changes can be inferred from the response at a single point in time to differing system characteristics as observed in different locations in an urban area. This is an assumption that has been neither satisfactorily proved nor disproved (Mayworm, Lago and McEnroe, 1980).

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

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

Despite the benefit of structured analysis, certain of the more complex research studies are actually among the more naïve in terms of assumptions made and relationships accepted as meaningful. Concerns such as these, along with the presence of unaccounted for confounding events and local area individualities, can make validity of findings—to say nothing of comparison and transferability of findings among locales—both problematic and demanding of special care on the part of the analyst.

Finally, attention must be paid to the effect of inflation whenever traveler response has been affected by user cost changes, such as transit fare, highway toll, and parking fee modifications. This is particularly important in the case of older data from periods before or during high inflation. The effect of inflation is pertinent whether traveler responses are observed or estimated.² Absolute changes in user charges should be interpreted in constant dollars. Unless a specific base year is provided for the value of dollar costs, the best assumption is that costs (and foreign currency conversions if applicable) are for the time of the event studied, if given, or otherwise for the time period preceding publication of the source material, the date of which is available from the citation.

The Handbook user may wish to convert costs to present day dollars, in order to have a better understanding of the scale involved. Appendix B, “Inflation and CPI Conversions,” provides a table of conversions to 2002 dollars along with accompanying guidance. The more severe of the

analytical problems introduced by inflation can be largely avoided by describing user cost changes in terms of relative change. The concept of elasticity, discussed further on, is particularly useful in this regard, as it is a relative indicator.

Demographic Considerations

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

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

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

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

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

²When using travel demand models, it must be presumed unless otherwise stated that the cost expressed in the model pertains to the value of the dollar in the year of the survey upon which the model was based.

even be thought of as mobility choice, as it may affect automobile availability for other travel.

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

Concept of Elasticity

Elasticity measures provide a convenient tool for summarizing quantitative information about overall travel demand changes in response to certain types of system changes and are used extensively in this Handbook. For elasticity measures to be applicable, the transportation system change must be a relative one. In other words, it must involve a quantifiable percentage increase or decrease in the system parameter involved. There are a number of elasticities of interest with respect to demand for transportation, including elasticities for changes in the overall amount of transit service, transit frequencies, transit fares, vehicular tolls, parking charges, and gasoline costs (Kemp, 1974). Elasticity estimates are available as well for comparative degrees of presence of certain built environment characteristics (see, for example, Ewing and Cervero, 2001).

Transportation elasticities are informally adopted from the economist's measure "price elasticity." Loosely speaking, price or service elasticity may be defined as the percentage change in the quantity of a commodity or service demanded by the public in response to a 1 percent change in price or service. For example, if transit service is measured by the number of bus miles operated, the transit service elasticity indicates the percentage change in patronage observed or expected in response to a 1 percent change in the number of bus miles. If the transit service elasticity is +0.6, a $\frac{6}{10}$ of 1 percent patronage increase is indicated for each 1 percent increase in service.

There are several different methods for computing elasticity. An expanded discussion of these methods and their application, along with comparative examples and illustrations, is provided in Appendix A, "Elasticity Discussion and Formulae."

The most frequently used form of elasticity in transportation analyses is arc elasticity. There is also a more simplistic form encountered in mostly older transit fare analyses, known as a shrinkage ratio or factor.³

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

log arc elasticity:

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

mid-point (or linear) arc elasticity:

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

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

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

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

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

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

³This more simplistic computational method has recently shown up again, this time in domestic road value pricing investigations, but with different nomenclature such as "approximated point elasticities" or even simply "elasticity."

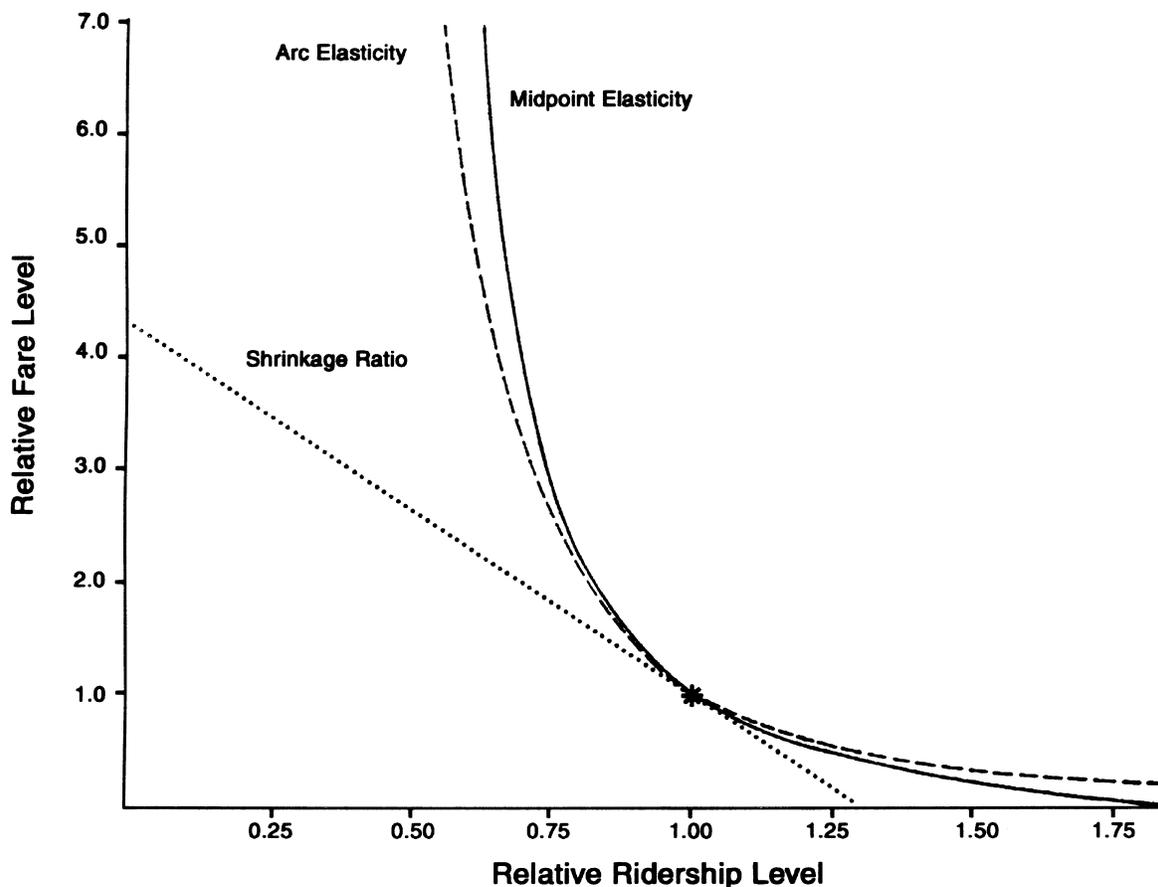


Figure 1. Elasticities of different types calculated from a demand curve with an initial point elasticity of -0.30 .
 Note: The term “point elasticity” as used in the figure title refers to the derivative of the assumed underlying demand curve—it is not used here as a synonym for shrinkage ratio or factor. See Appendix A, “Elasticity Discussion and Formulae” for further background.

Source: Mayworm, Lago and McEnroe (1980).

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Appendix A—Elasticity Discussion and Formulae

THE ELASTICITY CONCEPT

Elasticity is a convenient, quantitative measure of travel demand response to price and service changes that influence demand. Elasticity measures are found throughout the transportation literature and have been reported and used in various sections of this Handbook. When used with caution, elasticities provide a satisfactory means of quickly preparing first-cut, aggregate response estimates for a number of types of system changes and for alternative approaches to land use and site design. When considering demand for transportation, there are a number of elasticities of interest, including elasticities describing traveler response to changes in the overall amount of transit service, transit frequencies, transit fares, vehicular tolls, parking charges, and gasoline costs.

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

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

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

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

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

MEASURES OF ELASTICITY

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

- Point elasticity
- Arc elasticity
- Shrinkage ratio

Point elasticity is derived directly from the economist's definition of elasticity. Mathematically, it is described by the following formula:

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

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

In practice, lack of information on the functional relationship between P and Q (the shape of the demand curve) precludes the computation of point elasticities from empirical data. Therefore, other formulations have been developed that allow the use of observed changes in price and associated demand.

The measure that most nearly approximates point elasticity, and one frequently employed, is arc elasticity. It is defined by a logarithmic formulation and, except for very large changes in P and Q , is closely approximated by a mid-point (or linear) formulation that makes use of the average value of each independent variable (Bly, 1976; Mayworm, Lago and McEnroe, 1980).

log arc elasticity:

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

mid-point (or linear) arc elasticity:

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

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

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

A third form of elasticity, historically used in reporting response to transit fare changes, is the shrinkage ratio or shrinkage factor. In its general-use “rule of thumb” formulation, it is defined as the change in demand relative to the original demand divided by the change in price relative to the original price, or in mathematical terms:

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

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

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

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

DIFFERENCES BETWEEN ELASTICITY MEASURES

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

Table A-1 gives the same three types of elasticity values calculated for different fare changes and an assumed log arc elasticity of -0.300 .

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

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

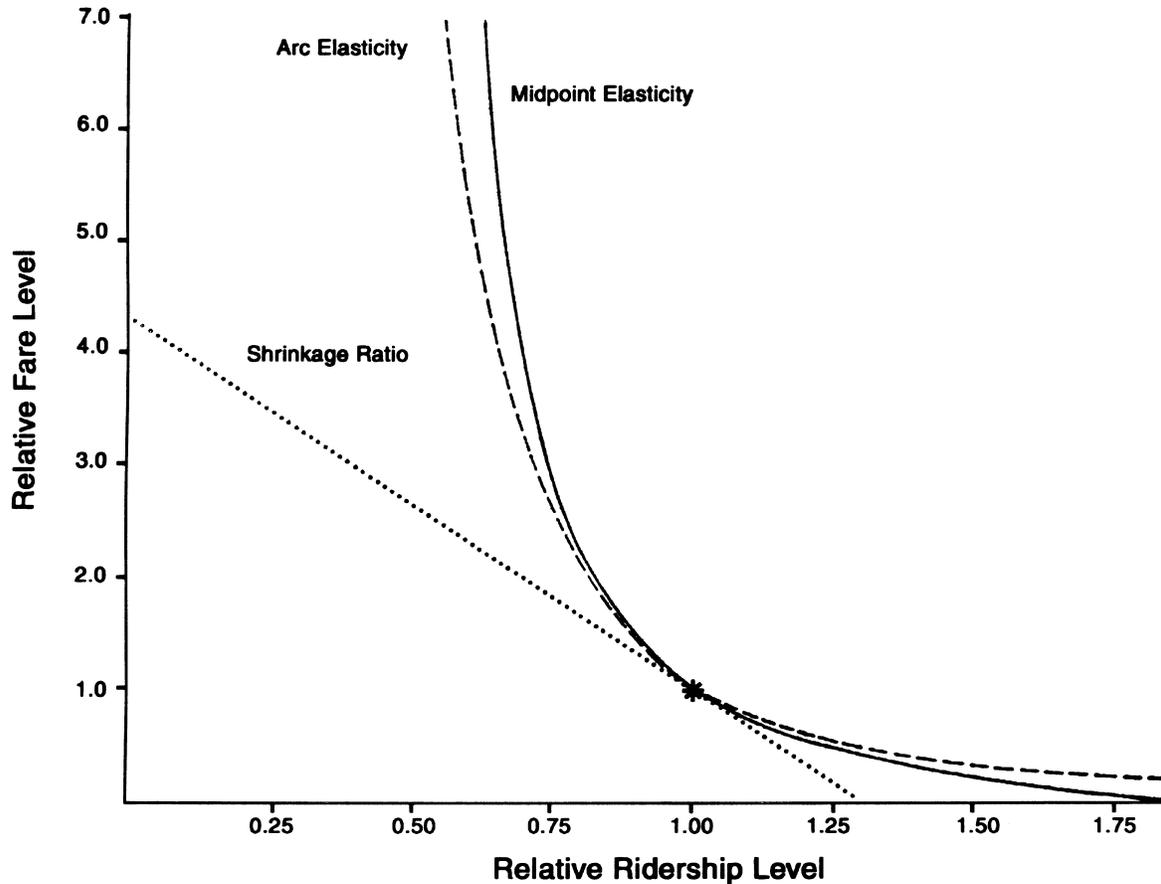


Figure A-1. Elasticities of different types calculated from a demand curve with an initial point elasticity of -0.30 .
 Note: The term “point elasticity” as used in the figure title refers to the derivative of the assumed underlying demand curve—it is not used here as a synonym for shrinkage ratio or factor.
 Source: Mayworm, Lago and McEnroe (1980).

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

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

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

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

Shrinkage ratio = -1.33
 Log arc elasticity = -0.86

USE OF ELASTICITIES IN THE HANDBOOK

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

Elasticity Application Formulae

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

log arc elasticity:

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

mid-point (or linear) arc elasticity:

$$Q_2 = \frac{(\eta - 1)P_1Q_1 - (\eta + 1)P_2Q_1}{(\eta - 1)P_2 - (\eta + 1)P_1}$$

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

Following is an example of arc elasticity application:

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

log arc elasticity:

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

mid-point (or linear) arc elasticity:

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

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

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

Elasticity Definitional Differences

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

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

When point elasticity nomenclature is applied to what is otherwise referred to as a shrinkage ratio or factor, it is simply the elasticity for the demand curve at one particular point on the curve, irrespective of whether the whole curve is known or not. The problem with this method is that the elasticity is different at different points on the curve, causing the conceptual deficiencies noted earlier for shrinkage ratios. This limitation has led to growing acceptance of log or mid-point arc

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

<i>Traveler Response Handbook</i>	Mayworm, Lago and McEnroe (1980)	Bly (1976) Webster and Bly (1980)	Dygert, Holec and Hill (1977)
Shrinkage ratio fare or service elasticity*	shrinkage factor arc elasticity* (log or mid-point)	shrinkage ratio fares elasticity* (or arc, or linear arc elasticity) service or headway elasticity	arc elasticity* “Kemp...definition of arc elasticity”
(or log or mid-point arc elasticity) point elasticity*	point elasticity*	point elasticity*	point elasticity*

Note: The forms principally used in the respective publications are indicated by an asterisk (*). Note that the discussions of “arc elasticity” properties in Dygert, et al. pertain only to what are termed shrinkage ratios/factors or growth ratios/factors elsewhere.

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

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

Sources: Sources for Tables A-2 and A-3 are as indicated in the column headings.

elasticities as the preferred approach for use with quasi-experimental data. Arc elasticities apply not to a single point, but to the entire portion of the demand curve under study.

The difficulties that may accrue from definitional and formulaic misunderstandings are not trivial. A fairly recent example, which happens to derive from confusion among a particular formula, a shrinkage ratio rule of thumb, and arc elasticity results, led to a widely disseminated conclusion that transit riders at the outset of the 1990s had been found to react more severely to fare changes than in the 1960s. Instead, the two landmark studies a quarter century apart actually found almost exactly the same average response to surface transit fare changes. (The two studies, the evolution of the earlier one into a non-equivalent rule of thumb, and the correct basis of comparison, are all detailed in Chapter 12, “Transit Pricing and Fares,” under “Response by Type of Strategy”—“Changes in General Fare Level”—“Urban Transit Overall” [Simpson & Curtin formula and traditional rule of thumb] and “Transit by Mode” [study of 52 U.S. transit systems].) This example serves as a warning that full understanding of measures such as elasticities, including their historical antecedents and variations in terminology, is absolutely essential when making use of them.

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Appendix B—Inflation and CPI Conversions

INFLATION AND THE VALUE OF THE DOLLAR

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

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

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

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

Note that it is important for time series cost data to be converted to and displayed in constant dollars for some one year, to avoid having inflation confound the interpretation of trends. Proper handling of this need is illustrated by compilations like Table 18-38, “Portland CBD Trends in Daily Equivalent Monthly Parking Costs, in 1985 Constant Dollars” (in Chapter 18, “Parking Management and Supply”).

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

The Handbook user may nevertheless wish to convert costs to present day constant dollars, if only to have a better understanding of the scale of expense and change involved. Absolute changes in user charges, along with time series data, should always be interpreted in constant dollars. To facilitate interpretation of transportation system changes involving user costs, the following section of this appendix provides a table of historical cost of living statistics along with factors for converting to 2002 dollars.

COST OF LIVING AND CONVERSIONS

Table B-1 gives the annual average “Consumer Price Index Data for All Urban Consumers (CPI-U) for the U.S. City Average for All Items, 1982–1984 = 100” for the years 1946 through 2002. The CPI-U is the broadest, most comprehensive CPI (Bureau of Labor Statistics, 2003).

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

Various regional and local indexes are published, monthly CPIs are available, and the BLS seasonally adjusts CPI data. The BLS advises that the CPIs for individual areas should not be used to compare living costs among areas (Bureau of Labor Statistics, 2003). Use of regional or local CPIs will clearly improve the accuracy of assessments made using data from different points in time from a single locale. Following the BLS recommendation concerning comparisons among areas, only national CPIs should be used in multiple city analyses, including evaluations involving transfer of findings from one area to another. In light of the various confounding factors always present in travel demand assessments, it seems hardly worthwhile

Table B-1 U.S. Consumer Price Index Data for All Urban Consumers (CPI-U) with Conversion Factors to 2002 Dollars

Year	CPI-U	Factor to 2002	Year	CPI-U	Factor to 2002
1946	19.5	9.226	1976	56.9	3.162
1947	22.3	8.067	1977	60.6	2.969
1948	24.1	7.465	1978	65.2	2.759
1949	23.8	7.559	1979	72.6	2.478
1950	24.1	7.465	1980	82.4	2.183
1951	26.0	6.919	1981	90.9	1.979
1952	26.5	6.789	1982	96.5	1.864
1953	26.7	6.738	1983	99.6	1.806
1954	26.9	6.688	1984	103.9	1.731
1955	26.8	6.713	1985	107.6	1.672
1956	27.2	6.614	1986	109.6	1.641
1957	28.1	6.402	1987	113.6	1.584
1958	28.9	6.225	1988	118.3	1.521
1959	29.1	6.182	1989	124.0	1.451
1960	29.6	6.078	1990	130.7	1.376
1961	29.9	6.017	1991	136.2	1.321
1962	30.2	5.957	1992	140.3	1.282
1963	30.6	5.879	1993	144.5	1.245
1964	31.0	5.803	1994	148.2	1.214
1965	31.5	5.711	1995	152.4	1.180
1966	32.4	5.552	1996	156.9	1.147
1967	33.4	5.386	1997	160.5	1.121
1968	34.8	5.170	1998	163.0	1.104
1969	36.7	4.902	1999	166.6	1.080
1970	38.8	4.637	2000	172.2	1.045
1971	40.5	4.442	2001	177.1	1.016
1972	41.8	4.304	2002	179.9	1.000
1973	44.4	4.052	2003		
1974	49.3	3.649	2004		
1975	53.8	3.344	2005		

Note: To convert costs and prices to year 2002 constant dollars, multiply the original dollar value by the conversion factor for the year of the original cost or price. For conversion to constant dollars of years beyond 2002, obtain the CPI-U for the year of interest, divide by 179.9, and multiply the result by the indicated conversion factor to 2002 dollars before application to the original cost or price.

Source: Bureau of Labor Statistics (2003), with conversion factors to 2002 by the Handbook authors.

to worry about fine points such as issues of seasonal adjustments to the CPI, either. In any case, seasonal adjustments are irrelevant with respect to the CPI-U data selected for Table B-1, given that the CPIs presented are limited to annual averages.

In addition to annual average CPI-U data, Table B-1 provides conversion factors for going from dollar values of any year to 2002 constant dollars. They are the result of dividing the CPI-U for each year by the 2002 CPI-U. When multiplied by dollar prices for any given year, the conversion factor for that year will translate those prices into 2002 constant dollars. For example, a 15¢ transit fare in 1950 equates to 0.15×7.465 or \$1.12 in 2002 constant dollars.

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