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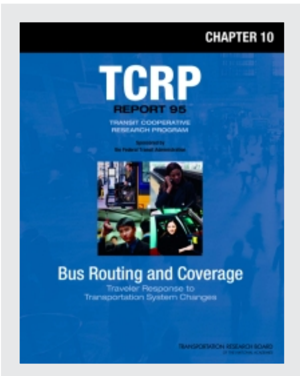

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74 pages | | null
ISBN null | DOI 10.17226/23330

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 95

Traveler Response to Transportation System Changes

Chapter 10—Bus Routing and Coverage

RICHARD H. PRATT
and
JOHN E. (JAY) EVANS, IV
Lead Chapter Authors

RICHARD H. PRATT, CONSULTANT, INC.
Garrett Park, MD

TEXAS TRANSPORTATION INSTITUTE
College Station, TX

JAY EVANS CONSULTING LLC
Washington, DC

PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC.
Baltimore, MD and San Francisco, CA

CAMBRIDGE SYSTEMATICS, INC.
Chevy Chase, MD

J. RICHARD KUZMYAK, L.L.C.
Silver Spring, MD

BMI-SG
Vienna, VA

GALLOP CORPORATION
Rockville, MD

MCCOLLOM MANAGEMENT CONSULTING, INC.
Darnestown, MD

HERBERT S. LEVINSON, TRANSPORTATION CONSULTANT
New Haven, CT

K.T. ANALYTICS, INC.
Bethesda, MD

SUBJECT AREAS
Planning and Administration • Public Transit • Highway Operations, Capacity and Traffic Control

Research Sponsored by the Federal Transit Administration in Cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2004
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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 10

Project B-12A FY'99
ISSN 1073-4872
ISBN 0-309-08763-5
Library of Congress Control Number 2003108813

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Price $20.00

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the National Research Council, the Transit Development Corporation, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

Special Notice

The Transportation Research Board, the National Research Council, the Transit Development Corporation, and the Federal Transit Administration (sponsor of the Transit Cooperative Research Program) do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the clarity and completeness of the project reporting.

Published reports of the

TRANSIT COOPERATIVE RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at
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Printed in the United States of America

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COOPERATIVE RESEARCH PROGRAMS STAFF FOR TCRP REPORT 95

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STEPHAN A. PARKER, *Senior Program Officer*
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FOREWORD

By Stephan A. Parker
Staff Officer
Transportation Research Board

This "Bus Routing and Coverage" chapter addresses traveler response to, and related impacts of, conventional bus transit routing alterations. Included are routing changes at both the individual route and system levels, new bus systems and system closures, bus system expansion and retrenchment, increases and decreases in geographic coverage, and routing and coverage changes made together with fare changes.

This chapter covers the travel demand and related aspects of most types of service changes to local conventional bus operations, except that headway changes are addressed in Chapter 9, "Transit Scheduling and Frequency." Bus routing changes focused primarily on express service are the province of Chapter 4, "Busways, BRT and Express Bus," and all aspects of dial-a-ride and ADA (Americans with Disabilities Act) services are covered in Chapter 6, "Demand Responsive/ADA."

TCRP Report 95: Chapter 10, Bus Routing and Coverage will be of interest to transit planning practitioners; educators and researchers; and professionals across a broad spectrum of transportation agencies, MPOs, and local, state, and federal government agencies.

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

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

The Second Edition of the handbook *Traveler Response to Transportation System Changes* was published by USDOT in July 1981, and it has been a valuable tool for transportation professionals, providing documentation of results from different types of transportation actions. This Third Edition of the *Handbook* covers 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, select "TCRP, All Projects, B-12" from the TCRP website: http://www4.national-academies.org/trb/crp.nsf.

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*.

Upon completion of the *Report 95* series, the final Chapter 1 publication will include a CD-ROM of all 19 chapters. The complete 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: First Edition	U.S. DOT Publication: Second Edition	TCRP Report 95: Source Data Cutoff Date	TCRP Report 95: 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	2000/05[b]
Ch. 3 – Park-and-Ride/Pool	—	1981	2003[c]	2004[d]
Transit Facilities and Services				
Ch. 4 – Busways, BRT and Express Bus	1977[e]	1981	2003[c]	2005[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	2005[d]
Ch. 8 – Commuter Rail	—	—	2003	2005[d]
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[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]	2005[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	2005[d]

NOTES: [a] Published in TCRP Web Document 12, *Interim Handbook* (March 2000), without Appendix B. The "Interim Introduction," published in Research Results Digest 61 (September 2003), is a replacement, available at http://www4.trb.org/trb/crp.nsf/All+Projects/TCRP+B-12A,+Phase+II. Publication of the final version of Chapter 1, "Introduction," as part of the TCRP Report 95 series, is anticipated for 2005.

[b] Published 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 in 2004 or 2005.

[c] The source data cutoff date for certain components of this chapter was 1999.

[d] Estimated.

[e] The edition in question addressed only certain aspects of later edition topical coverage.

[f] Primary cutoff was first year listed, but with selected information from second year listed.

CHAPTER 10 AUTHOR AND CONTRIBUTOR ACKNOWLEDGMENTS

TCRP Report 95, in essence the Third Edition of the "Traveler Response to Transportation System Changes" Handbook, is being prepared under Transit Cooperative Research Program Projects B-12, B-12A, and B-12B 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.; BMI-SG; Gallop Corporation; McCollom Management Consulting, Inc.; Herbert S. Levinson, Transportation Consultant; and K.T. Analytics, Inc.

Richard H. Pratt is the Principal Investigator. Dr. Katherine F. Turnbull of the Texas Transportation Institute assisted as co-Principal Investigator during initial Project B-12 phases, leading up to the Phase I Interim Report and the Phase II Draft Interim Handbook. With the addition of Project B-12B research, John E. (Jay) Evans, IV, of Jay Evans Consulting LLC was appointed the co-Principal Investigator. Lead Handbook chapter authors and co-authors, in addition to Mr. Pratt, are Mr. Evans (initially with Parsons Brinckerhoff); Dr. Turnbull; Frank Spielberg of BMI-SG; Brian E. McCollom of McCollom Management Consulting, Inc.; Erin Vaca of Cambridge Systematics, Inc.; J. Richard Kuzmyak, initially of Cambridge Systematics and now of J. Richard Kuzmyak, L.L.C.; and Dr. G. Bruce Douglas of Parsons Brinckerhoff Quade & Douglas, Inc. Contributing authors include Herbert S. Levinson, Transportation Consultant; Dr. Kiran U. Bhatt, K.T. Analytics, Inc.; Shawn M. Turner, Texas Transportation Institute; Dr. Rachel Weinberger, Cambridge Systematics (now of Nelson/Nygaard); and Dr. C. Y. Jeng, Gallop Corporation.

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.; Lydia Wong, Gordon Schultz, Bill Davidson, and Andrew Stryker of Parsons Brinckerhoff Quade & Douglas, Inc.; Kris Jagarapu of BMI-SG; and Laura C. (Peggy) Pratt of Richard H. Pratt, Consultant, Inc. As Principal Investigator, Mr. Pratt has participated iteratively and substantively in the development of each chapter. Dr. C. Y. Jeng of Gallop Corporation has provided pre-publication numerical quality control review. 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 Parsons Brinckerhoff, others too numerous to name but fully appreciated, and lastly the warmly remembered late Susan Spielberg of SG Associates (now BMI-SG).

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, are providing review and comments for what will total over 20 individual publication documents/chapters. They have gone the extra mile in providing support on call including leads, reports, documentation, advice, and direction over what will be the eight-year 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 is guiding the entire project to its complete fruition. Editor Natassja Linzau is providing her careful examination and fine touch, while Managing Editor Eileen Delaney and her team are handling all the numerous publication details. 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.

In the *TCRP Report 95* edition, John (Jay) Evans and Richard H. Pratt are the lead authors for this volume: Chapter 10, "Bus Routing and Coverage."

Participation by the profession at large has been absolutely essential to the development of the Handbook and this chapter. Members of volunteer Review Groups, established for each chapter, reviewed outlines, provided leads, and in many cases undertook substantive reviews. Though not listed here in the interests of brevity, their contribution is truly valued. In the case of Chapter 10, Gary Hufstedler stepped in to provide an independent outside review.

Finally, sincere thanks are due to the many 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 here, many appear in the "References" section entries of this and other chapters. Special mention should go to Diane Harper and her colleagues at King County Metro for what essentially evolved into a research project on hub-and-spoke and other bus routing changes by that agency, prepared for, and incorporated into, Chapter 10.

CHAPTER 10—BUS ROUTING AND COVERAGE

CONTENTS

10 – Bus Routing and Coverage

OVERVIEW AND SUMMARY

This "Bus Routing and Coverage" chapter addresses traveler response to, and related impacts of, conventional bus transit routing alterations. Included are routing changes at both the individual route and system level, new bus systems and system closures, bus system expansion and retrenchment, increases and decreases in geographic coverage, and routing and coverage changes made together with fare changes.

Within this "Overview and Summary" section:

- "Objectives of Bus Routing and Coverage Changes" summarizes the purposes of bus route and system modifications.
- "Types of Bus Routing and Coverage Changes" provides a brief taxonomy of the bus service changes and types of bus routes covered in this chapter.
- "Analytical Considerations" discusses the nature and state of available research on this topic and how that affects judicious use of the information provided.
- "Traveler Response Summary" encapsulates key travel demand and related findings for bus routing and coverage. The reader is urged to use the "Traveler Response Summary" only after first digesting the background provided in the three initial sections of this "Overview and Summary." The same applies to using the rest of the chapter as well.

Following the four-part "Overview and Summary" is the full exploration of effects of the various types of bus routing and coverage changes:

- "Response by Type of Service and Strategy" describes the observed traveler responses with service elasticity, ridership volume and growth, productivity, and other measures.
- "Underlying Traveler Response Factors" examines the role of changed travel parameters, demographics, transit accessibility, and underlying travel patterns in affecting response.
- "Related Information and Impacts" covers a broad range of subtopics ranging from rider characteristics to modes of access and characteristics of routes most likely to be feasible.
- "Case Studies" provides more information on two multi-property evaluations, three other service expansion and restructuring case studies, and one assessment of strike impacts.

Although this chapter covers the travel demand and related aspects of most types of service changes to local conventional bus operations, it does not address transit scheduling or frequency changes in and of themselves. They are covered in Chapter 9, "Transit Scheduling and Frequency." Bus routing changes focused primarily on express service are the province of Chapter 4, "Busways, BRT and Express Bus," and all aspects of dial-a-ride and ADA (Americans with Disabilities Act) services are covered in Chapter 6, "Demand Responsive/ADA." Bus service enhancements focused on employment areas and implemented as a Travel Demand Management (TDM) strategy receive additional attention in Chapter 19, "Employer and Institutional TDM Strategies."

Objectives of Bus Routing and Coverage Changes

Routing and coverage changes may improve transit system efficiency, effectiveness, or reach through the adjustment, extension or creation of bus routes. Such changes aim to preserve or enhance the mobility of the non-driving population, provide alternatives to auto use, and, especially in congested or sensitive areas, to minimize auto travel and related auto facility requirements. Conversely, transit route and coverage curtailment may be undertaken as a cost-cutting measure.

Improvement of accessibility to employers and merchants for the non-driving population is intended to benefit both parties and society at large. Linkage of the unemployed or underemployed to unfilled jobs is a major example. Enhanced transit accessibility for the driving population provides alternative transportation for those who wish or sometimes need to use it. Bus routing and covering improvements sufficient to make transit more competitive with the auto may be part of a package for reducing auto dependency and mitigating adverse impacts of auto traffic and parking.

Types of Bus Routing and Coverage Changes

Routing refers to the specifics of bus service alignment, both as individual routes and as a system of routes working together. Coverage is a measure of the proportion of a metropolitan area, corridor, or population served by transit. A rule-of-thumb indicator of coverage is the presence or lack of transit service within 1/4 mile. Types of bus routing and coverage changes include:

New Bus Transit Systems. The action of implementing an entire bus system where there was no transit service previously, the extreme case of expanding coverage, is typed here under the label "new bus transit systems." The converse action is the abandonment of a bus system or temporary closure due to a strike.

Comprehensive Service Expansion. An expansion strategy involving major systemwide extension and addition of bus routes with substantial enlargement of system coverage, sometimes with concurrent or follow-on frequency enhancements, is categorized here as comprehensive service expansion. The converse is major service retrenchment.

Service Changes with Fare Changes. Service changes are often implemented with other strategies, with fare reductions or increases perhaps the most common. Included are changes in fare and service that are not necessarily concurrent or preplanned as a package, as well as service changes carried out in conjunction with private/public partnerships providing "free" or discounted use of transit to target populations.

Service Restructuring. Restructuring is the strategy of reworking an existing bus network to rationalize or simplify service, accommodate new travel patterns, reduce route circuitry, ease or eliminate transfers required for bus travel, or otherwise alter the service configuration. Restructuring may include through routing of separate bus routes, realignment and recombination of routes, and the provision of trunkline, crosstown, express, and feeder services, generally in the context of a cohesive systemwide service plan.

Changed Urban Coverage. New coverage represents the strategy of extending or adding individual, conventional bus routes to provide transit service coverage for new development and other previously unserved areas. Paring back on coverage is the converse.

Changed Suburban Connections. Provision of new suburban connections involves a strategy of implementing outlying radial services, either in the conventional commute direction or reverse commute, or circumferential services, designed to enable transit travel within the typically lower density suburbs, especially to and from suburban activity centers.

Circulator/Distributor Routes. This strategy utilizes circulator shuttle services to provide enhanced connectivity within downtowns or other activity centers, or between activity nodes in relatively close proximity. Circulator routes may be multipurpose, or may be targeted to a particular function, such as tourist mobility. They are often low-fare or free to the user.

Feeder Routes. Provision of feeder routes (often called shuttles) is a local service coverage strategy designed for residential area collection and/or employment area distribution of passengers utilizing express or line-haul services. Feeder routes are used in connection with rail lines, inherently limited in their collection and distribution capability or as an integral component of hub and spoke or other trunk and feeder bus service configurations. Depending on their design and land use patterns (especially at the transfer point), feeders may also serve neighborhood circulation or intra-suburban service functions.

Disadvantaged Neighborhoods to Jobs Routes. This strategy utilizes special purpose routes to connect disadvantaged neighborhoods to jobs. Such routes provide areas of high unemployment with access to employment concentrations, typically suburban, that are not otherwise easy to reach by public transit.

Other Special Routes. This category covers the special purpose bus routes operators use to serve specific, inadequately served, existing or potential travel demands.

Analytical Considerations

The response of transit ridership to aggregate changes in amount of transit service is the one aspect of bus routing and coverage, and related service changes, that lends itself well to quantification on the basis of actual experience as expressed in the data typically collected by transit agencies. This response is expressed here in the form of elasticities. Elasticities are a convenient vehicle for numerical generalizations, but require caution in their interpretation and use, as discussed in Chapter 1, "Introduction" (see "Concept of Elasticity" under "Use of the Handbook"). Much of the available collective work on elasticities and comparisons across systems is old, and yet must be repeated here for lack of sufficient recent investigation. Fortunately, the limited recent findings that do exist suggest that basic relationships between transit service level changes and impacts on ridership are, in the aggregate, remaining stable over time, even though they may be superimposed on long term trends that have altered the usage of public transit over the years.

The ridership and travel demand effects of individual routing and coverage changes present a different situation. Individual route performance is so tied to case-specific travel patterns and demographics, which themselves are rarely reported, that generalizations are difficult at best.

The dearth of detail often leads to classification in gross terms such as whether or not ridership generated was sufficient that the operator found the service feasible, i.e., retained it. Here, the effects of aging data are critical. In the 1960s, an era of fairly well documented experiments (the "HUD Demonstrations"), feasibility was judged in the context of few subsidies and very limited operating resources. In the 1970s, an epoch of additional quasi-experimental demonstrations (the "SMD Projects"), subsidies were relatively generous and together with societal goals led to a relaxation of financial feasibility criteria. Subsequently, funding for bus operations has been more variable, again affecting "feasibility" as a measure. It is still useful to derive lessons from the past, but only with extreme caution if service retention must be the primary indicator of ridership response.

Another effect to be alert to in drawing strategy-specific lessons from older experiments is that travel patterns have changed markedly as jobs as well as people have moved to the suburbs. For example, 1960s disadvantaged-neighborhoods-to-jobs routes had to contend with suburban employment concentrations that were typically much smaller in aggregate numbers than are encountered in today's edge cities. Thus a service design that did not succeed then, might today succeed in the same urban area. Results of older experiments are presented here when lessons learned are thought to be valid over time, especially when little or no newer information has been found. Obviously particular care must be exercised by the analyst in extrapolating from such results.

Confounding analysis of any situation where transit routing changes increase or decrease the need for passengers to transfer, such as conversion to or away from a hub and spoke or timed transfer route structure, is the "unlinked-trip" method of tracking ridership. Unlinked trips are the mandated measure for reporting transit ridership to the Federal Transit Administration (FTA) and its National Transit Database. An unlinked trip is a passenger trip made in a single transit vehicle (Gray, 1989). A count of unlinked trips is effectively the same as a count of boardings. 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 routing changes have attracted more ridership or the converse, the before and after number of "linked trips" must be determined. A linked trip is the entire person trip between a rider's point of origin and destination, irrespective of how many vehicles or modes are used (Gray, 1989). The one-way trip from home to work used as an example above is a single linked trip. Since linked trips are not the official reporting measure, they are not often surveyed or estimated, and the meaningfulness of route structure change evaluations suffers accordingly. More unlinked trips may reflect nothing more than the effect of more forced transfers.

Additional guidance on using the generalizations and examples provided in this Handbook is offered in the "Use of the Handbook" section of Chapter 1. Please note that in this chapter as well as others, figures may not sum exactly to totals provided, and percentages may not add to exactly 100, because of rounding.

Traveler Response Summary

Completely new areawide bus transit systems that proved successful typically achieved first full year ridership on the order of 3 to 5 rides per capita, with 0.8 to 1.2 or so passengers per bus mile. Higher first year ridership may be achieved in special situations such as university towns or suburbs with Metro stations to feed.

The mid-range of ridership response to expansions of bus transit, either acting alone or with fare changes, is bounded by service elasticities in the +0.6 to +1.0 range.[1] Much broader variations have been reported, including instances of ridership increase in the elastic range (over +1.0). The degree of systemwide ridership response to changes in service appears to be greater in small cities, in suburbs, and in the off-peak, i.e., wherever and whenever initial transit service levels tend to be lower than average. Large scale suburban service expansions under favorable conditions have produced ridership growth proportionally in excess of service increases over substantial periods of time.

Results of bus service restructuring have been variable. Service restructuring designs that can be readily customized to individual land use and travel patterns (such as hub and spoke systems) appear to have a slight but not universal edge over more purely geometric configurations (such as grid systems) in their success rates. Local conditions govern, however. Restructurings where operating efficiencies and ridership growth have been achieved in tandem include at least a majority of the following: emphasis on high service level core routes, consistency in scheduling, enhancement of direct travel and ease of transferring, service design based on quantitative investigation of travel patterns, and favorable ambient economic conditions.

There is evidence suggestive that packages of improvements, not only better routes and schedules but also new buses and/or fare reductions, do particularly well in attracting increased ridership. Service expansion and restructuring in conjunction with fare reductions or new unlimited travel pass partnerships have led to a tripling of systemwide ridership in instances of university towns, and to substantial ridership gains in larger cities with targeted universities.

Roughly three-fifths of the radial, crosstown, and low-income area bus routes tried in the Mass Transportation Demonstration Projects of the 1960s were sufficiently attractive to be retained after the experimental period. More recent programs to expand transit accessibility with route extensions, reverse commute routes, and suburbs to suburbs routes suggest a success rate at or slightly above 50 percent. Logic, but no hard evidence, suggests a higher rate of success with ongoing service expansions in growing areas.

Irrespective of bus route category, routes serving multiple functions tend to fare best. Dispersed travel patterns make suburbs-to-suburbs routes particularly difficult to establish. Indicators of successful suburbs-to-suburbs services are: service to transit centers located at major activity centers, service to major transit travel generators such as medical centers, and service to fixed guideway transit stations as an adjunct to other functions.

Ridership on downtown circulator/distributor routes and systems deemed successful ranges from 500 to one or more thousands per day—45,000 in the case of Denver. There have been a number of circulators terminated; the more successful services are well targeted to serve an identifiable transportation need or opportunity. The service frequency threshold below which it is difficult to attract lunchtime travel may be on the order of a 10 minute headway.

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[1] A service elasticity of +0.8 indicates, for example, a 0.8 percent increase (decrease) in transit ridership in response to each 1 percent service increase (decrease), calculated in infinitesimally small increments. Service is normally measured as bus miles or bus hours operated. An elastic value is +1.0 or greater, and indicates a demand response that is more than proportionate to the change in the impetus. Elasticities reported in this chapter are thought to all be log arc or other closely equivalent computations (see "Concept of Elasticity" in Chapter 1, "Introduction," and Appendix A, "Elasticity Discussion and Formulae"). All are short-term elasticities (first- or second-year outcomes) except where noted.

New residential and multipurpose feeders to trunkline bus services and commuter rail tend to attract volumes, after two or three years, in the range of 100 to 600 daily trips. Comparable results for new single purpose employer shuttles are in the range of 25 to 600 daily trips. The prevalence of such shuttles, both conventional transit and paratransit, is indicated by the tally of over 150 non-airport, non-ADA shuttles in the San Francisco Bay Area, 70 percent of which connect with rail transit.

New bus routes have been found to take 1 to 3 years to reach their full patronage potential. Ridership development on entirely new systems may take even longer. The majority of ridership on new bus lines, other than transfer passengers, comes from homes within one to three blocks of the route. Nevertheless, a major component of patronage on individual new bus routes may be prior riders of other transit routes; percentages as high as 60 to 94 percent have been reported in center city environments. This phenomenon argues for examining routing changes in a system context.

Results of transit strikes confirm the dependency of many existing riders on transit service for mobility. A reported 15 to 20 percent of all work purpose trips and 40 to 60 percent of non-work trips normally made via transit were suppressed during strikes. Increases in vehicular traffic on the order of 6 to 16 percent have been observed on the affected approaches to the central city during transit strikes. Otherwise, reductions in auto traffic in response to bus transit routing and coverage changes have usually been too small or gradual to be measured directly. The auto is not a major player, percentagewise, in providing access to the average urban bus. In nine small to large cities, 88 to 97 percent of bus riders walk between home and the transit system, and between 93 and 96 percent walk at the non-home end of their trip.

RESPONSE BY TYPE OF SERVICE AND STRATEGY

New Bus Transit Systems

Rare opportunities for examining effects of implementing new transit systems were provided by the transit funding of the 1970s. Table 10-1 gives ridership data for the first full year of operation for three areas previously unserved by transit and for Chapel Hill, North Carolina, where the data is for the second full year (Wagner and Gilbert, 1978):

Table 10-1 Ridership Characteristics of New Systems

Location	Year	Service Area Population	Peak Buses	Annual Bus Miles	Annual Boardings	Passengers per Bus Mile
Orange Co., CA	1975	1,900,000	88	6,560,000	7,953,000	1.08 (sic)
Chapel Hill, NC	1975	32,000	21	908,000	1,902,000	2.09
Bay City, MI	1975	78,000	8	329,000	255,000	0.78
Greenville, NC	1977	24,000	3	134,000	107,000	0.80

Note: Boardings = Unlinked passenger trips.

Source: Wagner and Gilbert (1978) as presented in Pratt and Copple (1981).

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The initial passengers per bus mile rates obtained were for the most part lower than the national average of 2.06 then pertaining for urbanized areas of less than 500,000 population. A large student population combined with a student pass program may account for the relatively high utilization in Chapel Hill (Wagner and Gilbert, 1978). Table 10-2 indicates that new system usage as measured by passengers per bus mile most often continues to grow for several years after service initiation:

Table 10-2 Passengers per Bus Mile Trends for New Systems

Location	1975	1976	1977	1978	1979	1980	1996	1996 Trips
Chapel Hill, NC	2.09[a]	n/a	2.25	2.69	2.35	2.40	2.40[b]	2,619,700[c]
Bay City, MI	0.78	0.87	n/a	n/a	n/a	n/a	0.62	482,000[c]
Greenville, NC	—	—	0.80	0.99	1.23	1.41	1.50	250,000[c]

Notes: [a] Second year.
[b] Per actual revenue vehicle mile, or 2.18 per vehicle mile.
[c] Annual boardings (unlinked Trips) on fixed route services only.
n/a = not available.

Sources: Wagner and Gilbert (1978), FTA National Transit Database (1996), Harrington (1998).

Further information on the Greenville, North Carolina, experience is provided in the case study, "Transit Route and Schedule Improvements in Eight Cities and New Transit Systems in Four Previously Unserved Areas." Growth of the Orange County, California, system is examined further under "Comprehensive Service Expansion"—"Suburban Systemwide Service Expansions." In 1996, the Orange County Transit Authority carried 44,961,000 annual unlinked passenger trips on all services, more than a five-fold increase over the first year of operation. The passengers per bus mile result for 1996 was 2.49 per actual revenue vehicle mile or 2.06 per vehicle mile (FTA National Transit Database, 1996).

Cobb County, Georgia, has experienced a more recent introduction of an all-new bus transit system. Initiated in 1989 with deployment of 12 buses in local service and 19 buses in express service, use of transit for travel to work by Cobb County residents increased from 1 percent to 5 percent. Riders reported no car available for 63 percent of surveyed trips via local bus and 7 percent of trips via express bus (Cambridge Systematics, 1992). In 1996, with service roughly doubled, Cobb County Transit served 3,066,900 annual unlinked passenger trips on all services; 1.28 per actual revenue vehicle mile or 1.14 per vehicle mile (FTA National Transit Database, 1996).

Comprehensive Service Expansion

Systemwide ridership response to overall expansion of transit service varies markedly from case to case, and yet follows a somewhat predictable pattern. Service elasticities calculated for response to increases in bus miles or hours operated are typically in the +0.6 to +1.0 range, although individual results as low as +0.3 are not uncommon. Results well into the range of elastic response, over +1.0, are not uncommon either. Such positive results may reflect not only service quantity but also benefits of successful service restructuring or external factors such as a booming economy (see also the subsection "Service Restructuring").

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The service expansion elasticity average is +0.7 to +0.8. In contrast, changes in frequency alone result in elasticities averaging +0.5, while changes in service accompanying the introduction of express operation result in elasticities averaging +0.9. There is, however, considerable variability and overlap surrounding these averages, reflecting different starting conditions, expansion programs, operating environments and demographics. (See Chapter 9, "Transit Scheduling and Frequency," and Chapter 4, "Busways, BRT and Express Bus," for further information.)

In systemwide service expansion, in addition to new routes and expanded coverage, a portion of the increased bus mileage is typically attributable to increased frequency and expansion of service hours. The route expansions into previously unserved or poorly served areas have been observed to account for a proportionally higher increase in passengers than the increased frequencies (Boyle, 1980; U.S. DOT, 1976), as might be expected from the elasticity findings.

Urban Systemwide Service Expansions

Table 10-3 lists elasticities for 1970s systemwide service expansions in 11 North American cities. (Additional background on eight of these service expansions is found in the case study, "Transit Route and Schedule Improvements in Eight Cities and New Transit Systems in Four Previously Unserved Areas.") Little or no change in transit fare occurred during the analysis periods, resulting in the actual decrease of real fares due to inflation. No attempt was made to adjust the data for this or for gasoline shortage effects.

On average, the larger metropolitan areas of those listed in Table 10-3 exhibited lower service elasticities than did the smaller cities. The average value for urbanized areas over 500,000 population was +0.83 and for areas under 500,000 population was +0.98. This probably resulted in whole or in part from the better initial coverage in historically more transit-oriented large cities. Where transit service is substantial at the outset, there is typically less leeway for dramatic change from the viewpoint of the prospective user. Thus lesser additional ridership tends to be attracted proportionately as the larger systems expand (Kemp, 1974; Mayworm, Lago and McEnroe, 1980; U.S. DOT, 1976; Wagner and Gilbert, 1978).

Statistical analysis of time series data is often employed to separate out the impact of service expansion from other factors. Analysis of 17 bus systems in the United States between 1960 and 1970 resulted in bus miles per capita service elasticities ranging from +0.6 to +1.02, after accounting for fare changes and inflation. The average was +0.76 to +0.78 (Dygert, Holec and Hill, 1977; Webster and Bly, 1980). An examination of ten bus operations in New York State between 1964 and 1973 produced a range of service elasticities from +0.24 to +1.26, with an average of +0.73 (Mayworm, Lago and McEnroe, 1980). Three separate studies of transit vehicle-mile elasticities in several British cities yielded average values of +0.62, +0.71 and +0.83 (Webster and Bly, 1980). Additional values are given in Table 10-6 of the section "Service Changes with Fare Changes."[2]

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[2] Some of the newest elasticities research emphasizes difference between short-run and long-run elasticities. Short-run elasticities apply to effects within the initial 1 or 2 years following a change (typical of almost all historic elasticities), while long-run values reflect the effects of longer term decisions such as auto ownership and residence and workplace location (Litman, 2004). Few transit service elasticities have been reported in this format, but a study of fare and service changes covering 20 years between 1975 and 1995 obtained elasticity estimates of ridership with respect to vehicle kilometers of transit service of +0.54 to +0.57 short run and +0.74 to +0.77 long run in the United Kingdom, and +0.29 short run and +0.57 long run in France (Dargay et al, 2002, as presented in Litman, 2004). It was not reported what mix of frequency change (the purview of Chapter 9) versus coverage change made up the kilometers of transit service changes analyzed.

Table 10-3 Service Elasticities for Individual Comprehensive System Expansions

Location	1970 Urbanized Area Population	Years	Increase in Bus Miles	Increase in Ridership	Service Elasticity
Minneapolis, MN*	1,700,000	1971–1975	47.3%	39.6%	+0.86
Seattle, W	1,240,000	1974–1975	9.6	8.3	+0.87
Miami, FL*	1,220,000	1972–1975	12.5	10.9	+0.88
San Diego, CA	1,200,000	1974–1975	20.1	13.3	+0.68
Portland, OR*	820,000	1971–1975	42.5	36.4	+0.88
Vancouver, BC*	740,000	1971–1975	77.6	56.8	+0.78
Salt Lake City, UT*	480,000	1971–1975	117.8	118.4	+1.00
Madison, WI	210,000	1974–1975	7.6	8.9	+1.16
Bakersfield, CA	180,000	1974–1977	50.8	49.0	+0.97
Raleigh, NC	150,000	1976–1977	28.6	10.9	+0.41
Eugene, OR*	140,000	1972–1975	166.5	271.3	+1.34
Average					+0.89

Notes: Asterisk denotes period including 1973–74 gasoline shortages.

No attempt was made to adjust the data for service restructuring, changes in peak/off-peak ratios, senior citizen/student rates, fare zone redistricting, or decrease in real fares due to inflation.

Service elasticities are log arc elasticities calculated directly from the reported data by the Handbook authors.

Sources: U.S. DOT (1976), Wagner and Gilbert (1978).

Service increases in the off-peak were found to affect off-peak ridership more than peak service increases affect peak ridership in an examination of 30 British cities. Off-peak service elasticities averaged +0.76 versus +0.58 for peak period service (Mayworm, Lago and McEnroe, 1980).

Table 10-4 compares ridership change to service growth for 18 Florida transit operators. In two cases rail operators are included, and the extent of inclusion of service changes focused on frequency enhancement is unknown. Nevertheless, the tabulation serves to underscore the variability in response to service changes, the result of myriad other factors such as other attributes of the transit service, changes in auto travel conditions, changes in demographics and economic conditions, and perhaps personal lifestyle considerations. Regression analysis on this data gives a coefficient on service of +0.32, but the regression statistics confirm that service changes alone do not explain the differences in performance among the Florida operators (Center for Urban Transportation Research, 1998). Caution should thus be applied in using the coefficient as a service elasticity.

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Table 10-4 Ridership Change Compared to Service Growth in Florida

Operation	FY 1991–96 Percent Revenue Miles Growth	FY 1991–96 Percent Ridership Growth
Pinellas Suncoast Transit Authority	8.68%	-27.06%
Gainesville Regional Transit System	4.59	-17.88
Jacksonville Transportation Authority	4.72	-10.76
Lee County Transit	15.33	-1.24
Manatee County Area Transit	2.87	-0.19
Palm Beach County Transportation Agency	94.94	1.23
Hillsborough Area Regional Transit	2.77	2.24
Tallahassee Transit	8.45	6.65
Metro-Dade Transit Division	9.37	8.63
Key West Department of Transportation	17.00	13.48
Volusia County d.b.a. VOLTRAN	60.75	22.09
Tri-County Commuter Rail Authority	62.22	23.24
Broward County Mass Transit Division	7.80	23.97
Escambia County Area Transit	14.92	38.51
Lakeland Area Mass Transit District	10.33	48.86
Lynx Transit (Orlando)	88.11	55.48
Sarasota County Area Transit	38.69	56.05
Space Coast Area Transit	30.69	57.67

Source: Center for Urban Transportation Research (1998).

Suburban Systemwide Service Expansions

Analogous to the small city/large city dichotomy, suburbs and suburban "edge cities"—with their traditionally poorer transit service—tend to achieve greater ridership response to service increases than central cities and commuting corridors with their typically better service. Calculation of service elasticities by route type in San Diego gave the following results, with the least sensitivity exhibited by routes oriented to the central business district (CBD) (Mayworm, Lago and McEnroe, 1980):

Radial routes to CBD	+0.65
Central city routes	+0.72
Suburban routes	+1.01

Large scale suburban bus service expansions undertaken under favorable conditions have, over substantial periods of time, produced ridership growth in excess of the increases in service provided. Table 10-5 summarizes results for systems in Montgomery County, Maryland, and Santa Clara County, California. The Montgomery County Ride-On operation has benefited from expansion of Washington's Metrorail, which it feeds, while the Santa Clara Valley Transit Authority's routes cover "Silicon Valley" and include a network of express buses on high occupancy vehicle (HOV) lanes.

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Table 10-5 Growth of Montgomery County Ride-On and Santa Clara VTA

Operator —>	Montgomery County Ride-On (excludes Metrobus/Metrorail)			Santa Clara Valley Transportation Authority (bus operations only)		
(Operational Situation) —>	(Established 1975 as a complement and feeder to Metrobus/Metrorail)			(Took over San Jose bus system in 1973; expanded county wide)		
Parameter	**1977**	**1997**	**Change or Elasticity**	**1977**	**1997**	**Change or Elasticity**
Service Measure	606,000 Bus Miles	8,974,000 Bus Miles	+1,381%	657,000 Bus Hours	1,408,000 Bus Hours	+114%
Unlinked Bus Passenger Trips	966,000	17,433,000	+1,705%	15,600,000	45,890,000	+194%
Two-Decade Simple Log Arc Elasticity			+1.07			+1.42
Population	581,000	828,000	+42%	1,224,000	1,653,000	+35%
Employment	268,000	477,000	+78%	544,000	933,000	+72%
Passengers Per Capita Log Arc Elasticity			+0.94			+1.02

Sources: Bone (1998a and b); Lightbody (1998); Santa Clara Valley Transportation Authority (1998); assembly of Montgomery County demographics and calculations of changes and elasticities by Handbook authors.

Ride-On exhibited a service elasticity of +1.14 during its peak growth and +1.07 over a 20-year period. Santa Clara VTA achieved a service elasticity of +1.17 during its peak service growth and +1.42 over a 20-year period. These elasticities ascribe ridership growth entirely to service expansion, irrespective of interplay with parallel and intersecting transit services, fare changes, demographic and economic growth, or other influences. Normalizing for population growth deflates the 20-year elasticities to +0.94 for Ride-On and +1.02 for VTA. Normalizing on employment growth would deflate the elasticities further (see Table 10-5 for sources). For additional information and data for the Ride-On and Santa Clara VTA experiences (and also Orange County), see the case study, "Long Term Large Scale Bus Service Expansions in Three Growing Areas."

The Orange County Transit District in California quintupled service between 1974 and 1989 (see the subsection "New Bus Transit Systems" for first year statistics). Econometric modeling using quarterly statistics and designed to isolate out effects of employment growth produced alternative elasticity values of +1.04 and +0.68. The analysts selected the lower value (Ferguson, 1991). The simple unadjusted log arc service elasticity across the full period is approximately +1.33, in between the comparable values for Montgomery County Ride-On and Santa Clara VTA. All three counties are characterized by population and employment growth on the order of 2 percent to 6 percent per year and attendant highway congestion.

Service Changes with Fare Changes

Service Versus Fare Sensitivities

Table 10-6 provides comparisons between service and fare elasticities reported on the basis of either quasi-experimental data or time series analyses. The service changes covered are not exclusively bus routing and coverage changes. Correction is known to have been made for inflation where so indicated (de Rus, 1990; Dygert, Holec and Hill, 1977; Goodman, Green and Beesley, 1977; Kemp, 1974; Mullen, 1975; Webster and Bly, 1980).

Table 10-6 Fare Elasticities Compared with Service Elasticities

Location	Fare Elasticity	Service Elasticity	Service Measure Used
Atlanta (1970–72)	-0.15 to -0.20	+0.30	bus miles
San Diego—all routes (1972–1975)	-0.51	+0.85	bus miles
17 U.S. Transit Operators (1960–1970)	(deflated) -0.48	+0.76	bus miles/capita
12 British Bus Operators (1960–1973)	-0.31	+0.62	bus miles
30 British Towns (pre–1977)			
work trips	-0.19	+0.58	bus miles/capita
non-work trips	-0.49	+0.76	bus miles/capita
11 Spanish Towns/Cities (1980–1988)	(deflated)		
range (short term)	-0.16 to -0.44	+0.34 to +1.26	bus kilometers
average (short term)	-0.30	+0.71	bus kilometers

Sources: de Rus (1990); Dygert, Holec and Hill (1977); Goodman, Green and Beesley (1977); Kemp (1974); Mullen (1975); Webster and Bly (1980).

The data suggest that ridership tends to be one-third to two-thirds as responsive to a fare change as it is to an equivalent percentage change in service, although in isolated cases this differential has been exceeded. The size of the differential, and the consistency with which ridership is shown to be more sensitive to routing and coverage service changes than fare changes, contrasts with the smaller and sometimes reversed differentials in sensitivity for frequency changes versus fare changes (see "Response by Type of Strategy"—"Frequency Changes with Fare Changes"—"Frequency Versus Fare Sensitivities" in Chapter 9, "Transit Scheduling and Frequency").

The service elasticities presented in Table 10-6 are about 20 percent lower on average (+0.65) than those reported earlier for systemwide service expansions not tied to fare changes (+0.8). This difference may reflect a more complete treatment of confounding factors in the statistical analyses employed in the studies covering fare and service changes taken together, or may simply be a reflection of the different times and places involved.

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Service and Fare Changes in Combination

Service improvements in combination with fare decreases obviously provide greater impetus for ridership increase than would result from applying either change alone. There is also a synergistic effect important to energy conservation and emissions reduction efforts, which is that reduced fares help fill expanded seat-miles of service, increasing service effectiveness (see also "Related Information and Impacts"—"VMT, Energy and Environment" in Chapter 9, "Transit Scheduling and Frequency").

Los Angeles, Atlanta, Dallas and Iowa City provide a range of examples of service enhancement in combination with fare reductions. Three months after a 32 percent fare reduction and a 6 to 9 percent service increase in Los Angeles, patronage was up 17 percent (Weary, Kenan and Eoff, 1974). Eight months after fare reductions and service improvements in Atlanta, bus ridership was 30 percent above what it would otherwise have been given the previous downward patronage trend. Atlanta improvements included extensions to 13 lines, revisions to 14 lines, and initiation of 5 lines (Bates, 1974). Ridership increased almost 50 percent in not quite 3 years in Dallas during a period initiated with a 29 percent 1984 base fare reduction. The fare reduction was followed by service expansions in city and suburbs that by late 1986 doubled peak bus requirements (Allen, 1991). There was no rail transit in these cities at the times involved.

Fifty-two percent of new riders in Atlanta said they shifted to bus because of the low fare (Bates, 1974). Application of mathematical models to quantify causality indicated that roughly two thirds of the increase was attributable to the fare reduction. However, these findings did not show fare reductions to be more effective than equivalent service improvements in increasing ridership. On the contrary, as shown in Table 10-6, the patronage gain obtained in Atlanta for each 1 percent of fare reduction (fare elasticity) was estimated to be only one-half to two-thirds the patronage gain achieved with each 1 percent of increase in service as measured by bus miles operated (service elasticity) (Kemp, 1974).

In Iowa City, Iowa, a bus system of three radial routes with 20 minute headways and four radial routes with 30 minute headways was completely redesigned in 1971. The new system provided five through-routed radial route pairs with moderately expanded coverage, new buses, a 15¢ instead of 25¢ fare, and a universal 30 minute headway. In the fifth month, the systemwide headway was changed to 20 minutes in peak periods to alleviate crowding. Based on prior experience in Iowa City, the fare decrease alone should have produced a 57 percent ridership increase. By the sixth month following the service and fare changes, weekday ridership was 6,000 compared to 2,000 before service improvements. The increase that accompanied the peak period headway improvement was 10 percent, small by comparison to the overall ridership response (Dueker and Stoner, 1972; Dueker and Stoner, 1971; Horton and Louviere, 1974). The Iowa City experience is more fully described in the case study, "A Combined Program of Improvements with Fare Changes in Iowa City."

Service Changes with Unlimited Travel Pass Partnerships

An innovation benefiting both parties is the development of partnerships between transit operators and major traffic generators to have the cost of transit passes or service picked up by or through the traffic generating institution. The institution then arranges for its employees (and students, for schools) to have passes providing unlimited transit travel at no out-of-pocket trip cost. The traffic generating institution thereby seeks to reduce local area congestion and parking requirements, while the transit operator gains an additional revenue source. Further details, with several examples, are provided in Chapter 12, "Transit Pricing and Fares," under "Response by Type of Strategy"—"Changes in Fare Categories"—"Unlimited Travel Pass Partnerships."

Some key examples for which ridership results are available were associated in a major way with bus service changes and are thus described here. Introduction of the University of Washington U-Pass in 1992 was accompanied by both routing changes associated with opening of the Seattle Bus Tunnel and bus frequency improvements. New routes were added and frequency on existing routes was increased from 30 to 15 minute headways. U-Pass introduction was also linked with significant University parking cost increases. Ridership per bus trip stayed constant, suggesting that route ridership doubled. The University is the next largest ridership generator after downtown Seattle (Rosenbloom, 1998). The U-Pass experience and other commute partnerships and TDM actions involving bus service improvements are further explored in Chapter 19, "Employer and Institutional TDM Strategies."

The Champaign-Urbana Mass Transit District began enhancing and expanding bus services focused on the University of Illinois in 1990. Four campus routes were introduced, one a parking shuttle. Daytime headways range from 5 minutes on two routes to 15 and 20 minutes on the other two. Community routes operate in a modified timed-transfer configuration, with major transfer points in the Champaign and Urbana downtowns and at the University. The service concept is one of bringing people to the campus on the community routes, where they can transfer to the campus routes. Students pay a mandatory fee ($18 per semester in 1995) which permits free rides throughout the system. Faculty and staff receive an 80 percent subsidy on passes. Total transit ridership throughout Champaign and Urbana on all routes grew from 2.8 million unlinked trips annually in FY 1989, typical of performance in the preceding 5 years, to 5.4 million in FY 1990 and 8.5 million in FY 1995 (Moriarty, Patton and Volk, 1991; Rosenbloom, 1998).

Boise Urban Stages undertook substantial service increases during the same general time span that several private/public partnerships were implemented to provide unlimited transit use to target employee and student populations. The Boise State University program was implemented in the fall of 1993. The three bus routes serving the campus were augmented with an on-campus shuttle and parking connector. This partnership was followed by others at two regional medical centers and 10 additional employers. From 1992 to 1995 citywide annual bus miles and hours operated were increased by 46 percent to 912,100 and 67,400, respectively. Ridership increased 70 percent to 1,320,000 annual unlinked trips in 1995. Boise population grew by 10 percent during the same 3-year period (Michael Baker et al, 1997; Boise Urban Stages, 1996; May, 1998). Additional information is provided in the case study, "Service Changes with Unlimited Travel Pass Partnerships in Boise."

Service Restructuring

Service restructuring facilitates transit agency response to changing regional travel patterns and allows removal of redundant or ineffective services and introduction of new or better-targeted services, with the aim of improving overall system effectiveness and productivity. Basic system structures include radial systems with or without circumferential routes, grid systems, and hub and spoke systems featuring trunk lines between hubs that are the focuses of local services. Timed transfer systems, a special case variation of hub and spoke systems, are covered within Chapter 9, "Transit Scheduling and Frequency," under "Response by Type of Strategy"—"Regularized Schedule" (see both "Minimizing Transfer Times" and "Timed-Transfer Findings").

A concern in service restructuring is whether alterations that force existing transit riders to change their familiar patterns run the risk of driving away patronage. Obviously, if the change is for the worse from the passenger perspective, ridership loss will result. An early demonstration project provides an extreme example—an ill-conceived outright substitution of express for local service in a smallish city. Most existing riders were, in fact, local riders. They were left stranded, and had no choice other than alternative transportation. To make matters worse, the express operation had little market of its own (Dupree and Pratt, 1973).

Service restructuring is deserving of analysis designed to identify winners and losers among existing riders, as insurance that the alterations will be beneficial overall. Tools for such analysis are ridership surveys and, in the case of complex large system restructurings, urban transportation planning network models, or equivalent GIS procedures. Two outstandingly successful major restructurings in Orange County, California, and Seattle are both known to have utilized such techniques in parallel with citizen involvement.

On the whole, little conclusive evidence has been reported of ridership defection in response to the disruption of service restructuring. It has, however, been cited as a possible contributing factor to post-restructuring ridership loss in Boise, Idaho (see "Variations on Hub and Spoke Configurations"). Ridership held fairly steady, although it never increased much, in a New Castle, Pennsylvania, demonstration project that rerouted transit lines at programmed intervals throughout a 27 month experimental period (New Castle Area Transit Authority, 1968).

Demand elasticities describing ridership response to overall transit service expansion (with some service restructuring) were presented in the section on "Comprehensive Service Expansion." It is difficult to isolate the effects of service restructuring from other effects, because service expansion is often part of the mix of changes. When service expansion is not involved, there is no basis for calculation of elasticities. The service restructuring examples that follow are loosely grouped by type.

Radial Downtown Penetration

Boston restructured routes in a late 1970s experiment to provide more direct service to the Downtown Crossing area, then being transformed into an auto-restricted zone. Previously, the transit authority relied almost completely on the subway for service in the central business district. Local and express bus lines terminated near subway stops on the fringe, requiring passengers to either walk or take the subway (at an additional fare) to their final destination. Six local routes and four express routes from the suburbs were extended into the area, first on a transit street (Washington Street) and later on parallel streets.

The initial bus route extensions increased bus ridership by 26 to 30 percent: between 2,200 and 2,400 daily riders. About 40 percent of these trips were new transit trips, and the rest shifted from other bus and subway lines. For the 1,300 or so shifting from other transit, the route extensions provided increased convenience, savings in total travel time, and user cost savings, eliminating either a long walk or an additional fare transfer to subway. Much of the bus ridership gain was lost in the month after shift of buses off of Washington Street, although pedestrian mall construction activities may have been a factor. Revenue versus cost analyses led to elimination of the route extensions at the end of 1980, but they were restored 16 months later (Weisbrod et al, 1982).

Variations on Grid Configurations

A major realignment of the radial routes serving Southeast Portland, Oregon, was undertaken in 1977. More continuous east-west and north-south service patterns were established, combined with introduction of new crosstown service. Ridership increased. The service change involved additional bus miles and hours of service, allowing a later analysis to estimate a modest service elasticity of +0.29 for the combined changes (Kyte, Stoner and Cryer, 1988). C-TRAN in nearby Vancouver, Washington, converted from a skeletal timed-transfer system to a grid system during the 1994–96 period. The 30 and 60 minute headway timed-transfer system's reliability had begun to break down. The change allowed and was accompanied by improved headways and provided more cross-area routes. A 48 percent ridership increase during the period was attributed to a combination of factors, including economic and population growth, anti-sprawl growth management, high parking rates in Portland, and the service changes (Stanley, 1998).

Suntran in Albuquerque, New Mexico, revised their entire route system in 1995 to a more gridlike service. Ridership increased 4 percent, and farebox revenue increased 7.3 percent, with the same number of bus service hours and miles (Volinski, 1997). When the Phoenix Transit System departed from its grid system to better serve large employment centers, the new routes were popular, but did not provide a net gain in riders (for more, see "Changed Suburban Connections"—"Suburbs to Suburbs Routes") (Rosenbloom, 1998). Overall, there is insufficient information about grid system effects to draw strong conclusions, other than that the impacts, as best they can be isolated from other factors, appear to be somewhat variable but muted (see also Boise under "Variations on Hub and Spoke Configurations"). This result—higher peak than off-peak elasticities—is not typical. It may reflect the circumstance that the "off-peak" service reduction involved evening service only. Midday service was unchanged and omitted from the elasticity calculations of crucial importance.

Variations on Hub and Spoke Configurations

Boise, Idaho's traditional "spoke and wheel" route structure was revamped into a hybrid hub-spoke and grid system in January 1996, immediately following the period of system expansion and ridership growth described under "Service Changes with Fare Changes"—"Service Changes with Unlimited Travel Pass Partnerships." Public involvement was a major influence in the system design. Included were two minor transfer hubs introduced in addition to the traditional downtown hub, and two new crosstown routes added to improve east/west and north/south travel and transfer options. Overall revenue vehicle miles were held essentially constant in the changes. An accompanying marketing campaign, including a schoolhouse-red bus offering a "Bus Riding 101" course, focused on retraining existing riders.

Boise Urban Stages ridership was down 10 percent in 1996 and did not recover in 1997. Possible reasons that have been advanced include lack of rider acclimation to the service changes and temporary construction-related disruption of the Boise State University shuttle. Introduction of a competing bus service from a municipality encircled by Boise to downtown, and downsizing by a major employer, may have been minor contributing factors (Michael Baker et al, 1997; Boise Urban Stages, 1996; May, 1998). See the case study, "Service Changes with Unlimited Travel Pass Partnerships in Boise" for additional statistics.

The Sacramento Regional Transit District in California substantially restructured seven routes in 1994 to improve service to its growing population in the South Sector and to better link residents with downtown employment concentrations and the adjacent emerging health services complex. A major shopping mall was used as a transit center. Non-productive service was replaced with through routes connecting the most productive route segments and linking together major attractors along arterial streets with heavy commercial activity. Low productivity routes were abandoned or received reduced service frequency. In 1 year, ridership increased 12 percent on the restructured routes. Controlling for level of service, ridership per service hour increased 1.3 percent on the restructured routes (Rosenbloom, 1998).

In Southern California, the Orange County Transportation Authority (OCTA) commissioned a comprehensive operational analysis and worked with the public to restructure services for improved efficiency and effectiveness, attraction of more riders, and provision of more bus options for discretionary users, but without a cost increase. Analysis included combining census and survey data with GIS methodologies to identify candidate routes and locations for restructuring. In a 1995 partial implementation, total service hours were cut back while increased service was provided on high-demand routes. System headways were made more consistent. Unproductive routes were eliminated. More direct service was offered on major arterials, and 8 more community routes were provided, featuring small buses circulating in neighborhoods. Three feeder lines to a new commuter rail service were included, and trips were extended on some existing routes to serve the new stations.

An all-time systemwide high for OCTA of 38.2 boardings per vehicle hour was achieved, surpassing the previous high of 36.5 in FY 1991. A 10 to 15 percent increase in ridership was obtained, along with a 5 percent reduction in net operating costs, amounting to a $5 million annual savings for OCTA. The ridership growth is attributed to a combination of economic resurgence in the county, response to the service changes and accompanying marketing efforts, and the feeder routes to commuter rail (Rosenbloom, 1998; Stanley, 1998; Volinski, 1997).

King County Metro has undertaken extensive service restructuring with hub and spoke emphasis and core route enhancement under their Six-Year Plan for greater Seattle. A major 1996 restructuring of bus service to and around suburban Renton took the form of consolidating six routes between the Renton area and Seattle into three redesigned Renton-Seattle routes serving a Renton Transit Center hub, and several community service routes focused primarily on the same transit center. Headways were enhanced, especially but not only in the off-peak, even as peak period bus hours were reduced. Screenline counts north of Renton (toward Seattle) showed a two year ridership growth of 23 percent.

Boardings, examining only routes connecting Renton with Seattle proper in the interests of not inflating the count with transfers, increased during the 3-1/3 years between 1994 and 1998 by 24 to 36 percent (16 to 26 percent in the peak and 28 to 45 percent in the midday). Ridership grew during peak periods at a rate similar to, or perhaps slightly less than, a "control group" of express routes. Gains in off-peak ridership were more dramatic. Midday linked trips on all routes to and within the broader Renton service area increased about 45 to 50 percent over the 3-1/3 years. Simultaneously, major efficiencies were achieved in utilization of through buses to downtown Seattle. Articulated bus average seat utilization increased from 42 percent on 21 buses to 55 percent on 27 buses, and 23 forty-foot buses were released from the service.

King County Metro undertook a number of other service consolidations intended to strengthen their growing hub and spoke system orientation. The three most extensive of these resulted in unlinked trip ridership growth, counting feeder as well as trunkline routes, ranging from 28 to 54 percent over 3-1/3 years. Measured in similar fashion, the Renton Corridor unlinked trip ridership growth was 52 percent. Each instance was sufficiently above ambient growth for the regional sectors involved to give reasonable certainty that the difference was not simply an artifact of increased transferring. In one case, the Bellevue—University District consolidation, passengers per bus hour productivity growth was three times the sector average. Three "control" routes similar to the consolidated Bellevue—University District routes, not altered significantly, had about the same riders and productivity in 1998 as in 1984 (King County DOT, 1998a and b; Harper, Rynerson and Wold, 1998–99).

All four of King County Metro's most extensive hub and spoke oriented corridor and core route consolidations as well as two suburb to suburb core route enhancements produced total weekday ridership gains in excess of the ambient unlinked passenger trip growth, and four out of six did so while either maintaining or exceeding ambient growth in productivity. This was achieved even though some of the consolidations were in place only half a year prior to evaluation. In Sacramento, Orange County, and several Seattle reconfigurations, an elastic response to the service changes, or the equivalent, was obtained. (Situations where ridership increases and bus hour reductions are obtained in concert lie beyond the range where meaningful elasticities can be quantified but are obviously also highly beneficial outcomes.)

As with grid systems, information on hub and spoke systems is insufficient for strong conclusions. Reported results are variable but strikingly positive in the cases of Orange County and King County.[3] As previously noted, hub and spoke systems operated as timed transfer systems are covered within Chapter 9, "Transit Scheduling and Frequency." Additional hub and spoke and other route recombination "before and after" service, ridership, and operating data are tabulated and assessed in the case study, "Service Restructuring and New Services in Metropolitan Seattle."

Other System Recombinations and Rationalizations

In New Castle, Pennsylvania, public reaction was favorable to various demonstration project routing changes, specifically including the creation of combination radial/crosstown routes or two-way loop routes formed by joining two or more preexisting radial lines at their outer ends or downtown terminal. Revenues (as a surrogate for ridership) did not significantly increase, however, even with other amenities such as new buses (New Castle Area Transit Authority, 1968). Improved bus routing by Putnam Area Regional Transit, a small system with eight buses, enabled maintenance of ridership levels while reducing expenses by approximately 5 percent. Putnam reviewed route performance, consolidated routes, and reduced hours of service (Volinski, 1997). College town system restructurings accomplished in combination with fare reductions or unlimited rides for university students and staff have achieved as much as a tripling of systemwide ridership (see Iowa City and Champaign-Urbana in the section "Service Changes with Fare Changes").

In Snohomish County north of Seattle, Community Transit's route restructuring program adjusted individual routes and also changed the fundamental orientation of the network. North County net-

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[3] San Juan, Puerto Rico, now offers another major example. The preexisting service configuration's long routes allowed many no-transfer rides but at the expense of indirect routing with infrequent and unreliable service. The hub-and-spoke system implemented in December 1997 provides high frequency trunk lines connecting centers and shorter local routes feeding them. The service plan was designed to ensure that 25 to 30 percent at most of prior users would be forced to transfer. Given these parameters, it is felt that transfers are not a major factor in the 41 percent 1995–1999 growth in unlinked trips, attributed primarily to the new service plan. Contributing factors were 100 new buses in a fleet of 273, and markedly increased reliability attributed to the route revisions and new buses. Fares remained constant at a low 25¢ with no free transfers (Taylor et al., 2002).

work adjustments in 1993 included elimination of two routes, addition of two routes, and expanded service on other lines. Ridership increased 5 percent overall, with sharp changes on individual lines. Impacts of earlier South County network revisions were not reported (Rosenbloom, 1998). Eight different network changes of unspecified type carried out in Portland, Oregon, from 1971 through 1982, including two major suburban service restructurings, were determined to have insignificant ridership impact. One network improvement, however, produced a service change elasticity greater than +1.0 (Kyte, Stoner and Cryer, 1988).

Ridership on HARTline buses in greater Tampa, Florida, rose by 31.7 percent in 1993 following a complete reorganization of the system in August 1992 for increased responsiveness to travel patterns (Stanley, 1995). Service and schedule restructuring by Omnitrans in Riverside, California, was accomplished in the fall of 1995 following comprehensive operational analysis. Route restructuring focused on enhancing direct travel, and schedule restructuring emphasized consistency and ease of transfer (see also "Response by Type of Strategy"—"Regularized Schedule"—"Minimizing Passenger Wait Times" within Chapter 9, "Transit Scheduling and Frequency"). The increase in total bus service hours was limited to 4 percent, yet ridership increased by 20.4 percent over the prior year (Stanley, 1998). This response is in the highly elastic range of service elasticity.

Changed Urban Coverage

The ability of an individual new or modified bus route to attract patronage is so strongly a function of how the route in question relates to the local development, transportation system, and travel patterns that impacts typically can be generalized only in qualitative terms. Formal estimation of likely ridership requires recourse to either full-scale or shortcut travel demand estimation techniques.

Radial Routes

The most elemental approach to providing coverage in areas previously unserved is by means of new or extended local radial bus routes oriented toward downtown. To the extent that a new or extended radial route employs the same equipment, operating procedures, fare structure, transfer rules, and service frequency as other radial routes in the same city, the ridership per capita served should ultimately build up to about the same level as that obtained in previously served neighborhoods of similar socioeconomic background and downtown orientation (Heggie, 1975). The service area of a conventional bus route is narrow; in studies of new radial routes in Nashville and St. Louis, more than half the ridership was found to come from homes within one and three blocks, respectively (Rechel and Rogers, 1967).

Eleven out of 13 all-new, CBD-oriented 1960s demonstration project routes penetrating previously unserved suburban areas in greater Boston, St. Louis, Memphis, Nashville, and Providence (excluding routes primarily serving park/ride facilities) were successful enough to be retained, some with service reductions, after the experimental period (Rechel and Rogers, 1967; Rhode Island Public Transit Authority, 1968). Average weekday ridership at the end of the demonstrations, on the routes retained, ranged from 160 to 560 rides (Mass Transportation Commission et al, 1964; W. C. Gilman and Co., 1966). Of five new radial routes in the smaller cities of greater Fitchburg, Newburyport, and Pittsfield, Massachusetts, and New Castle, Pennsylvania, none were retained, although certain route extensions in New Castle proved viable (Mass Transportation Commission et al, 1964; New Castle Area Transit Authority, 1968).

An examination of 10 late 1970's route extensions in Albany and Rochester found that although household density and service area population were rough indicators of patronage attraction, specific local conditions appeared to be more important. One route experienced significant ridership loss despite no change in operations aside from extension, indicating that exogenous factors can overshadow impacts associated with increased coverage. Of the five route extensions that were able to cover increased operating costs with revenue generated by new riders, two were extensions to suburban employment sites on the reverse leg of park/ride routes (see also the sections on "Changed Suburban Connections" and "Disadvantaged Neighborhoods to Jobs Routes"). The three other extensions able to cover costs served residential areas, including one with a large public housing complex and another with a hospital. On one route, headways were widened at the same time coverage was extended, resulting in an overall decrease in vehicle miles operated. Ridership increased, indicating patronage was more sensitive to coverage than frequency, at least in that particular instance (Boyle, 1980).

Tri-Met in Portland, Oregon, implemented 12 route extensions between 1971 and 1982. Of the 11 that could be evaluated, 6 extensions (55 percent) resulted in no significant change in ridership. Three extensions (27 percent) exhibited service elasticities of +0.1 to +0.9, and two (18 percent) resulted in service elasticities of +1.0 or greater (Kyte, Stoner and Cryer, 1988).

An occurrence in Chatham, England provides a reminder of the importance of considering the market served by a route before attempting revisions. A service previously through-routed from one side of the city to the other was divided into two radial routes to improve schedule reliability. Crosstown travelers as well as riders going to and from the far side of the central area were faced with the need to transfer and make an added transfer payment. The result was a drop in patronage on the affected service, particularly at stops near the central terminus. Whether riders changed routes, modes, or suppressed travel was not examined (Parry and Coe, 1979).

Crosstown Routes

Crosstown routes are implemented to enhance service to non-radial travel, and sometimes to increase coverage as well. City crosstown routes are covered here, along with some almost suburban in character. For cross-suburbs services, see "Suburbs to Suburbs Routes" within the following "Changed Suburban Connections" section.

The Massachusetts Bay Transportation Authority and its predecessors have tried close-in crosstown routes on at least two occasions. Two 1960's demonstration project crosstown routes attracted substantial numbers of riders; however, all but a fraction were diverted from other transit routes. The services were not retained (Mass Transportation Commission et al, 1964). More recently, three new limited-stop crosstown bus routes were implemented in the same general area as before. This time the routes were deliberately targeted at existing riders. The objective was improvement of connections for employees and patients at several hospitals and medical centers and for faculty, staff, and students at several universities. The limited-stop routes perform essentially as a rapid transit system for the institutions, eliminating need to travel in and out of the downtown area. Despite targeting of existing riders, it is thought that a third of the estimated 7,500 daily boardings actually represent new transit trips (Rosenbloom, 1998).

In Seattle, a close-in crosstown route in the shape of an inverted "L" was introduced in 1995–1996 to serve attractions and transfer points just north of downtown and through the east side. Headway is 30 minutes throughout the day, with evening and weekend service limited to the north leg. The north leg is anchored by the Seattle Center development and Group Health Hospital. The service investment is about 19,700 bus hours annually. Weekday 1998 ridership averaged about 1,900 trips daily with 2,200 total on weekends. Route productivity in 1998 was already 30.9 boardings per bus hour, above average for King County Metro and 88 percent of the average for Seattle proper and its north suburbs (King County DOT, 1998a and b; Harper, Rynerson and Wold, 1998–99).

A 1960s in-town crosstown route demonstration in Nashville attracted new riders to the system and was recovering about one-fourth of operating costs by the end of the third quarter (Rechel and Rogers, 1967). The Century Boulevard crosstown line on the south side of Los Angeles, implemented in the 1960s as a disadvantaged neighborhoods to jobs route, became very heavily used. This line through Watts was carrying 3,000 riders per weekday, 1,700 per Saturday, and 700 per Sunday after only 22 months (Pignataro, Falcocchio and Roess, 1970). More recently, in Charlotte, North Carolina, the transit agency CTS began a crosstown service to reduce transit travel times and transfers between outlying areas including a university. The route was considered a success because ridership after one year was nearly meeting the goal of 13 passengers per bus hour (Rosenbloom, 1998).

Changed Suburban Connections

"Edge cities" and other relatively high-density suburban activity centers, as contrasted to low-density suburban sprawl development, present opportunities for transit service addressing changing mobility needs. Suburban nodes are being used as secondary focal points for transit service as these centers increase their share of commercial activity relative to downtowns. Both extensions of traditional radial routes and introduction of circumferential routes are among the possible configurations. Addition of reverse-commute service to traditional morning-inbound and evening-outbound radial routes from the suburbs is another, introduced here with selected examples, but also covered further under "Disadvantaged Neighborhoods to Jobs Routes" and within Chapter 4, "Busways, BRT and Express Bus." Despite these possibilities, service to suburban destinations remains a difficult transit market justifying consideration of all options including paratransit (see "Costs and Feasibility," footnote 4, in the "Related Information and Impacts" section).

Radial Extensions and Reverse Commute Service

Radial route extensions can provide through connections to suburban centers, allowing low-income center city household members to reach a wider selection of public services. An example is provided by Hartford, Connecticut. In Hartford, where traditional express buses to downtown have experienced a decade-long 3 percent-per-year ridership decline, the proportion of system riders headed for non-CBD destinations has exceeded 40 percent. CTTransit responded by redirecting existing radial routes to reach outlying shopping malls and large retirement communities (Rosenbloom, 1998). Loss of ridership has been held to less than might be expected given major fare increases and declining population and jobs.

New Jersey Transit (NJT) implemented several suburban services in the 1980s upon request of employers. First was service to the new Harmon Meadow shopping mall and office complex, provided by rerouting reverse peak trips associated with a nearby park-and-ride facility. It continues today without the private subsidy initially provided. NJT started 13 other reverse-commute or suburbs-to-suburbs services following that initial success. Varying results were obtained: about half the routes continue to operate. NJT has found provision of reverse commute services to be more successful, on the whole, than suburbs to suburbs services.

Two examples illustrate. In 1987, the River Terminal Development Corporation requested a stop and offered $9,000 a year for operating costs to realign Route 1 between Newark and Jersey City. Within a few months, daily ridership reached 46, slightly more than required to cover operating costs. The deviation of selected trips continues without subsidy. In the same year NJT extended its Route 29, a radial intersecting virtually all Newark area routes, to serve UPS. UPS anticipated direct service would attract 45 to 75 people and ease a shortage of semi-skilled workers for an afternoon shift. They agreed to pay an annual subsidy of $38,000. The service averaged three riders per trip, and was discontinued after three months (Rosenbloom, 1998).

Suburbs to Suburbs Routes

Of crosstown routes tested in 1960s/1970s demonstrations, two in particular were suburbs to suburbs. A suburban route in Nashville was a total failure, while an outlying route in St. Louis that connected older, matured suburbs and shopping attracted enough patronage (560 on the average weekday) to be retained by the operator (Rechel and Rogers, 1967; W. C. Gilman and Co., 1966). More recently, the Santa Monica Municipal Bus Line in California introduced commuter service, funded by the air quality district, from Santa Monica to El Segundo's aerospace employment area. Buses outfitted with reclining seats and TVs attracted 10 riders per trip, 40 percent of capacity: a total of 40 to 50 passengers per day. Fare was $2.00 each way for the 20-mile trip (Rosenbloom, 1998). This service did not meet criteria for retention and has been discontinued (Catoe, 1998).

In 1994, the Regional Public Transportation Authority in Phoenix implemented a Color Line Service to serve large employment centers such as the airport and Arizona State University. The most productive segments of the existing grid system of routes were selected, realigned along major transportation corridors, and linked together, with significantly improved headways. Riders could reach formerly inaccessible destinations and most no longer needed transfers. Ridership has been high on the Color Lines. However, it has been matched by a roughly equal decline in use of the older routes in the grid system (Rosenbloom, 1998).

Although not detailed in research literature, transit operators such as the Santa Clara Valley Transit Authority and Orange County Transit Authority in California, and Washington Metrobus operations in Maryland, have substantial suburbs to suburbs routes, both radial and circumferential. They operate in areas of extensive suburban employment and in some cases double as feeders to rail lines.

Dallas offers two recent examples of modifying existing crosstown and circumferential routes to connect with additional traffic generators and new light rail stations. Route 428, a DART crosstown service connecting two bus Transit Centers, first had its headway improved from 30 to 20 minutes in the peak and 60 to 30 minutes in the base, with addition of Sunday service. Ridership increased roughly half as much as the increase in service, as shown by the data for 1994 and 1995 in Table 10-7, exhibiting a log arc service elasticity of +0.49, average for frequency increases.

Two-and-a-half years later, Route 428 was modified to serve a new light rail station, peak headway was further improved to 15 minutes, and the west end was split to add service to a major medical center. The 30/60 minute peak/base headway of the split service meshed with the bus pulses at the westerly Transit Center, in North Irving. The route modifications produced a short-term (5 months) ridership increase of 41 percent over the prior year, and a longer term (17 months) increase of 50 percent, restoring productivity to better than prior to the 1994 frequency increase. Service elasticity calculations give a highly elastic value of +5.8 (short term) or +5.4 (longer term). These extremely high elasticities serve simply as indicators that the ridership gain is primarily attributable not to the modest increase in scheduled bus miles of service per se, but rather to the achievement of important new and improved connections and market penetration.

Table 10-7 Dallas Crosstown and Circumferential Route Modifications Results

	1994	1995	1996	1997	1998
Route 428 Service Change (route modified to serve...)	Frequency Increased			LRT, Medical Center	
Months After Change	(before)	11	23	5	17
June Weekday Boardings	1,837	2,277	2,434	3,419	3,612
June Boardings Annualized	517,495	668,250	706,085	998,070	1,056,525
Percent Change from 1994		+29%	+36%	+93%	+104%
June Bus Miles Annualized	314,511	530,750	541,305	574,292	583,179
Percent Change from 1994		+69%	+72%	+83%	+85%
Boardings/Mile Productivity	1.65	1.26	1.30	1.74	1.81
Percent Change from 1994		-24%	-21%	+6%	+10%
Route 466 Service Change (route modified to serve...)				Light Rail Transit Sta.	Transit Center
Months After Change				3	6
Sept. Weekday Boardings	4,478	4,634	5,112	5,239	6,221
Sept. Boardings Annualized	1,392,030	1,454,910	1,563,215	1,601,540	1,894,410
Percent Change from 1994		+4%	+12%	+15%	+36%
Sept. Bus Miles Annualized	853,770	853,770	918,393	928,567	962,231
Percent Change from 1994		0%	+8%	+9%	+13%
Boardings/Mile Productivity	1.63	1.70	1.70	1.72	1.97
Percent Change from 1994		+4%	+4%	+6%	+21%

Source: Hufstedler (1998).

DART Route 466, also examined in Table 10-7, follows a circumferential highway loop (Loop 12) on the south and east of Dallas. This bus route was modified in June 1997 to serve a light rail station at its midpoint. The result in this case, a 2.5 percent ridership increase over the prior year, was indistinguishable from secular growth since 1994. However, in March 1998, it was modified again, with an extension to the South Garland Transit Center. Concurrently, peak headway was improved from 20 to 15 minutes (base headway remained at 30 minutes). The 1997 to 1998 ridership growth was 18.3 percent, with a service elasticity of +4.7. Taking secular service and ridership trends into account does not lower this highly elastic value, which again serves mainly as an indicator that the ridership increase was primarily a response to new connections and markets (Hufstedler, 1998; elasticity calculations by Handbook authors).

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Circulator/Distributor Routes

Downtown transit shuttles vary significantly in terms of ridership and cost per passenger: the success experience is very mixed. Downtown shuttle systems are much more successful when there exists an identifiable transportation need or opportunity, the service is well targeted to serve the travel market or markets involved, high service frequencies can be supported, and travel distances are long enough to discourage walking.

Transit Terminal and Parking Distributors

The 16th Street pedestrian and transit mall in Denver, and the mile-long shuttle that serves it exclusively, were designed concurrently in the late 1970s. The shuttle was explicitly planned to distribute passengers from two new bus stations, one at each end of the route, and also to provide general downtown circulation. Regional, express, and some local bus routes were cut back to the two stations. Today the shuttle also distributes passengers from Denver's Light Rail line, which crosses midway along the shuttle route. It also provides workplace to retail and restaurants connections, with major office concentrations at the Civic Center end and an entertainment and retail district at the Market Street end.

The Denver shuttle operates with low floor, no and low emissions buses, at intervals ranging from 70 seconds during commuter hours to 2 to 5 minutes at other times during the approximately 18-hour operating day. No fare is charged. Each weekday it carries 45,000 passengers on average at an annual 1996–97 operating cost of $3,186,238, equating to 22¢ per passenger. The shuttle has adapted to, and probably influenced, evolving land uses in the downtown area (Jewell, 1992; Kurth, 1998; Urban Transportation Monitor, March 28, 1997).

In Santa Barbara, California, park-and-ride is the motive for another low cost per passenger shuttle. It connects the downtown with the waterfront, where there is limited parking. This shuttle charges a 25¢ fare and carries 2,000 passengers per weekday at an annual 1996–1997 operating cost of $450,000, 64¢ per passenger (Urban Transportation Monitor, March 28, 1997). Shuttle operation in connection with peripheral parking is addressed more extensively in Chapter 18, "Parking Management and Supply" under "Response by Type of Strategy"—"Peripheral Parking Around Central Business Districts."

Workplace to Retail and Restaurants Circulators

In Memphis, the 1976 development of a 10-block downtown pedestrian mall led to the creation of a 10¢ demonstration project shuttle called the Hustle Bus. The shuttle did not traverse the mall, but instead connected it with the Medical Center a good mile away. Heavily marketed via multiple media, the shuttle averaged 2,700 passengers a day in initial phases and was reported to have increased the use of bus for discretionary travel. Ridership in the first month was 55,845, and later in the two-year demonstration had grown to 72,210 per month. Service was retained post-demonstration. Data for 1988 indicate a weekday ridership of 860 passengers, fare unspecified. In January 1990, with rubber tired "trolley" equipment and a new name of "Trolley 2," service intervals were approximately 20 minutes and operation was from 6:30 AM to 5:30 PM (Public Technologies, 1980a and b; Jewell, 1992).

Attracting enough ridership to keep cost per passenger down is a particular problem with shuttles focused exclusively on non-home-based discretionary trips within and around a downtown area. On the shuttle that connects Houston's downtown to the courthouse area and restaurant district, the fare is 25¢ and the daily ridership is 1,200. The annual 1996–97 operating cost was $1,827,100, or $5.06 per passenger (Urban Transportation Monitor, March 28, 1997). There is evidence of a service frequency threshold, below which it is difficult to attract lunchtime travel. Examples from Phoenix and Richmond suggest the break point may be on the order of a 10-minute headway, although any threshold will certainly vary according to local circumstances.

The Phoenix, Arizona, transit system started free downtown circulator service in November 1990 with sponsorship of downtown merchants and an Air Quality Management grant. Initially, it operated on a 10-minute headway, looping through downtown with service to the state capital. While free, growth was high and ridership peaked at 650,000 passengers a year. When funding ended in July 1992, a 25¢ fare was instituted. Ridership declined with imposition of the fare, and service was cut back. In response, ridership fell again. After March 1995, service to the capital was provided only during lunch hours. Use ultimately dropped to roughly 1/3 of the high, down to under 600 a day, with over 70 percent riding during lunchtime (Rosenbloom, 1998).

The Greater Richmond Transit Company in Virginia operated a fare-free downtown rubber tired "trolley" for 18 months, ending in July of 1995. The service ran from 11:30 AM to 2:30 PM at a 6 minute headway. The service carried 250,000 passengers in the first year. With the imposition of a 25¢ fare, ridership dropped in half, exhibiting a mid-point arc fare elasticity of approximately –0.33. Service was then halved, widening headways from 6 minutes to 12. This caused the lunchtime crowd to abandon the system (Rosenbloom, 1998; elasticity computation by Handbook authors).

The Charlotte, North Carolina, City Council persuaded the Charlotte DOT to create a City Loop service at the cost of $400,000 a year. The inner-city transportation consisted of two loops traveling in opposite directions on an hourly headway. Ridership averaged 8 passengers per vehicle hour. Evaluation indicated that the passengers did not represent new ridership. The service was stopped after an 18-month test period (Rosenbloom, 1998).

Good frequency is not always enough to secure adequate ridership. A downtown circulator was tested in the Seattle suburb of Bellevue, running weekdays between 11:00 AM and 3:10 PM, with a 7.5 minute headway (5 minutes during the Christmas season). Three 22–25 passenger vans were utilized. The objective was enhancing the attractiveness of transit and ridesharing commute options for CBD employees by providing an alternative to the automobile for midday shopping and restaurant trips. Operating within the relatively compact Bellevue CBD, the circulator connected the major office center, the transit center, and the regional retail center. It was modeled after a demonstration service during the two prior Christmas shopping seasons that attracted 200 to 300 riders per day. Year-round service started in September of 1989 and operated for a year, during which time the expected ridership did not materialize. Evaluation indicated that travelers preferred to walk when possible to reach downtown activities, especially in response to the 25¢ fare (Comsis, 1991).

Recreational and Tourist Circulators

San Antonio, Texas, operates several downtown circulator bus routes focused on the tourist market. Each rubber tired "trolley" route operates a one-way 30-minute circuit. Together, they serve all major hotel and tourist attractions, including the Alamo. In the initial phase, the services were free and carried 12,000 riders per day. A series of fare increases to 10¢, 25¢, and then 50¢ reduced total ridership to 8,000 daily passengers. Seventy percent of 1997 passengers were tourists (Rosenbloom, 1998). The response to the fare increases on these tourist oriented routes exhibited a mid-point arc fare elasticity of –0.20.

In Santa Monica, California, two fare-free summertime shuttles are operated. One is a shopping shuttle sponsored by downtown hotels. It provides service with 22 passenger buses between two major shopping areas, the Promenade and Main Street. Between 500 and 600 riders a day are carried. The other is a lunch-time shuttle between a business park and downtown, promoted by the downtown business district. Both tourists and workers make use of it (Rosenbloom, 1998). Sacramento, California, has a fare-free shuttle that connects the convention center, the downtown transit/pedestrian mall, and historic old Sacramento. It carries 600 passengers per weekday at an annual 1996–97 operating cost of $409,000; $1.94 per passenger (Urban Transportation Monitor, March 28, 1997).

A privately operated tourist "trolley" in Kansas City, undertaken by the non-profit "Kansas City Trolley Corporation," affords a look at rider characteristics, thanks to a rider survey. Supported by the business community to enhance the attractiveness of downtown, the rubber tired "trolley" operation in 1983 linked the two downtown areas of Kansas City. Service frequency was 10 minutes, and the fare, 25¢. Ridership was 500 daily during the 9:00 AM to 6:00 PM hours. There were also 400 riders per evening on a 7:00 PM to 11:00 PM Wednesday through Saturday service funded by local hotels. In 1984, the "trolley" was operated 11:00 AM to 11:00 PM on approximately a 20 minute headway, along a route expanded outward to include Country Club Plaza, an historic 1920s shopping complex, thus linking three shopping/employment areas in the city. Ridership was 1,263 on the 1984 survey day.

As detailed in Table 10-8, hotels were the predominant starting point for passengers of the Kansas City Trolley. Sightseeing and shopping were the dominant trip purposes, followed by entertainment and dining. The survey asked about the money trip makers had spent or planned to spend in connection with their trip on the "trolley." Averages by purpose of expenditure are given in Table 10-8. It was estimated that trip related expenditures by passengers on the survey day were $19,150 in total, or $5,000 counting only those passengers who said they would not have made the trip without the Kansas City Trolley. (Stores stayed open late, until 9:00 PM, on the survey day.) Trolley operating expenses were not reported for 1984, but the previous year had been $80,000 for the full five-month operating season (Metropolitan Washington COG, 1984a and 1984b).

Feeder Routes

The traditional function of bus feeder routes has been to connect residential neighborhoods with trunk-line transit services, predominantly rail transit, which is limited in its ability to provide its own neighborhood coverage. As employment has moved outward from central areas, this traditional function has been joined by the use of feeders to distribute riders to off-line employment, also largely from rail stations. Feeders to and from trunk-line bus routes are also used, however, particularly in hub and spoke service configurations.

Table 10-8 Characteristics of Surveyed Trips Taken on the Kansas City Trolley

Trip Start Location	Percentage	Purposes of Trip	Percentage	Purpose of Expenditure	Actual/Planned Spending — Average
Hotel	48%	Shopping	32%	Shopping	$8.60
Home	5	Dining	12	Restaurant	$8.60
Work	7	Entertainment	23	Entertainment	$2.80
Shopping	27	Sightseeing	43	Other	$2.60
Restaurant	5	Work	6	No Spending	$0.00 (15%)
Other	8	Other	9		

Notes: Stores stayed open late, until 9:00 PM, on the survey day.
Multiple answers were allowed to the "Purposes of Trip" survey question.

Source: Metropolitan Washington COG (1984b).

Multipurpose Rail Feeders

Surface transit feeders to rail stations are a long-established component of many big city transit operations. Many have multipurpose characteristics, connecting not only residential but also mixed-use neighborhoods to Metro stations in particular. Boston is a classic case, where starting a century ago, streetcar lines were extensively aligned to feed high platform heavy rail transit (HRT). Such surface transit feeder routes to HRT/Metro, now almost exclusively operated with buses in the United States, have spread into the newer suburbs.

In Montgomery County, Maryland, for example, virtually every route of the county's "Ride-On" bus service by design connects with one or more Washington Metrorail stations, or a commuter rail station in a few instances, performing a feeder function in conjunction with local suburban transportation service. Ride-On ridership grew from 966,000 unlinked bus passenger trips in 1977, the year before Metrorail reached Montgomery County, to 17,433,000 in 1997 (Bone, 1998b), with 11 of 12 planned county Metrorail stations open. (Further detail on Ride-On growth was provided under "Comprehensive Service Expansion"—"Suburban Systemwide Service Expansions," and is found in the case study, "Long Term Large Scale Bus Service Expansions in Three Growing Areas.")

SamTrans, in San Mateo County immediately south of San Francisco, restructured its service during the 1994–96 period in conjunction with BART rail rapid transit penetration into the county. Bus operations were reduced and reoriented to emphasize shuttle service to the new Colma station. With the new rail station, bus ridership declines were predicted, and indeed SamTrans ridership went down 9.6 percent from 1994 to 1996. Overall SamTrans service area transit use increased, however. Moreover, ridership on SamTrans itself recovered by almost 9 percent in the following year alone (Stanley, 1998).

In the St. Louis area, opening of MetroLink Light Rail in 1993 was accompanied by bus network reconfiguration. Radial routes to downtown were terminated at MetroLink stations, requiring downtown-destined riders to transfer. Operational savings from this "bus-rail integration system" were applied to new bus routes and restoration of some that had been previously discontinued. Although many bus riders had been upset by planned route changes, they

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reportedly liked the arrangement in the end. The resulting transfer rate within the Bi-State bus/rail system is 43 percent, high relative to other systems. Bus use, expected to decline with diversion to Light Rail, instead increased by 3 percent from the FY 1993 pre-MetroLink low of 37,700,000 as measured in terms of annual unlinked trips (boardings including transfers). Light Rail annual unlinked trips were 14,500,000 and bus unlinked trips were 38,500,000 in FY 1997 (Michael Baker et al, 1997).

Ridership patterns on Metropolitan Suburban Bus Authority (MSBA) feeder buses originally designed to bring suburban Nassau County residents of Long Island to the subway system in Queens, for access to New York City jobs and activities, illustrate the expansion of feeder route functions in response to suburban employment growth. The reverse direction began filling up during the 1980s as light industrial and service jobs developed on Long Island. By 1988, conventional commute passengers became the minority; in 1993, reverse-commute passengers constituted 60 percent of all MSBA ridership (Rosenbloom, 1998).

A new multipurpose commuter rail feeder was established in 1994–95 by New Jersey Transit to serve the Princeton Junction rail station. It feeds the station from Lawrence and West Windsor residential areas, while providing a shuttle between the station and West Windsor employment sites. Ridership, in response to 14 daily commute hours trips, was 24,600 trips annually in 1996–97. Farebox recovery was 60%, three times the applicable NJT route retention threshold (Michael Baker et al, 1997). Single-purpose commuter rail feeders are covered in the next two subsections.

Residential Commuter Rail Feeders

Ridership at individual commuter rail stations, other than downtown terminals, is typically much less than at HRT/Metro stations. Feeder service potential is thus correspondingly less. Where commuter rail feeders have been provided, they are often operated with small buses or vans. In suburban New York, the Metro North Railroad introduced five "Hudson Rail Link" feeder shuttles connecting nearby communities with two stations. Two modified routes provide off-peak service. Operation is from 5:45 AM to 11:45 PM, with 15 minute headways during the peak and hourly off-peak. Fares range from $1.25 in the peak to 25¢ off-peak. Hudson Rail Link started in 1991. The 1993 feeder ridership was roughly 85 percent of 1995 levels, when it reached about 1,000 daily trips. Rail ridership at the two stations served by the shuttles increased by a third (300 riders) from 1991 to 1993. The two stations not only have limited parking, but also are at a significantly lower elevation than the communities served (Charles River Associates, 1997; Rosenbloom, 1998).

For some years, starting in December 1994, Virginia Railway Express (VRE) rail commuters from Prince William County to Washington, DC, and adjacent Northern Virginia employment areas were served by five OmniLink feeder routes. These bus routes connected to three separate VRE stops. The Potomac and Rappahannock Transportation Commission provided this service in an auto dominant area, about 25 miles out from Washington, that for the most part has a residential density of under three persons per acre. Routes were fixed in the morning, but riders could flag their bus anywhere along the route. In the evening the buses only served route segments that riders wished to go to. Buses were timed with the peak period train schedule, which at the time offered approximately half-hourly service, and a VRE ticket allowed a free bus ride. The initial OmniLink feeder bus ridership of 100 trips per day grew in eight months to 350 daily trips (Rosenbloom, 1998). These fixed route VRE feeder services were ultimately eliminated, however, as a result of insufficient ridership and productivity.

Approximately 32 percent of the OmniLink feeder bus riders were new to VRE. Some 52 percent reported having started or continued to use VRE in part because of the OmniLink service and free transfer. Of the new VRE riders using OmniLink, 77 percent reported being strongly influenced in their choice of VRE by OmniLink service availability (Michael Baker et al, 1997; Rosenbloom, 1998). Off-peak, OmniLink was operated as a point-deviation service for local travel, carrying about 1,000 riders daily. This aspect is covered in Chapter 6, "Demand Responsive/ADA," under "Response to General Public, Urban Demand Responsive Services"—"Introduction of Demand Responsive Service into Previously Unserved Areas." The point-deviation operation was retained upon termination of the fixed-route feeder service, and its operating hours were expanded into the commuter time periods.

Employer Shuttle Rail Feeders

Employer shuttles typically link stations of a regional rail network to suburban employment sites, providing a distributor function for the rail system and making practical the use of transit for access to off-line employment. Employer shuttles are often privately contracted and administered by the employer's in-house staff to keep costs low and enhance flexibility. They frequently use small vehicles to more cost-effectively match service with demand.

In the San Francisco Bay Area, there were 154 non-airport/non-ADA shuttle services in 1993, approximately 60 percent of them sponsored fully or partially by employers. About 70 percent of the shuttles provide connections to rail stations, 40 percent provide multiple connections, and 10 percent serve remote parking exclusively. Rail stations served include BART rapid transit, CalTrain commuter rail, and the Santa Clara Valley Transit Authority's light rail. Most are focused on peak hour service, although large employers such as high-technology firms, hospitals, and universities have shuttles connecting campuses during the midday.

Eight of the largest San Francisco Bay Area shuttles, located in Santa Clara County, were connecting major employers and related activities with VTA's light rail as of late 1994. They operate primarily as fixed-route services in the peak, at headways from 5 to 30 minutes, with either no or mostly demand responsive service in the off-peak. The shuttles are free, and the patrons tend to be well-salaried professional workers. Two were initiated in 1988, and the remainder in 1993–94. In 1994, they carried from 30 to 345 passengers each per weekday, about 930 total for all eight, and accounted for 5 percent of all access trips to and from the VTA light rail stations. Of the two first implemented, the Metro/Airport shuttle grew in the first three of six years of operation to about half its 235-passenger 1994 weekday ridership. The Great American shuttle grew to 76 percent of its 345-passenger ridership in the same timespan (Cervero et al, 1995).

The potential market for employer shuttle rail feeders consists of the employees who on the one hand live in rail accessible communities and on the other hand work at employment sites beyond walking distance but preferably no more than 20 minutes by shuttle from a rail station. Data collected in Connecticut and presented in Table 10-9 suggest employer shuttle mode shares within that narrowly defined market of 4 to 10 percent, depending on distance from the train station, directness of the service, the fare structure, employment area parking costs, and other factors (Minerva, Sampson and Levinson, 1996).

Table 10-9 Mode Shares in Connecticut Commuter Connection Shuttle System Markets

Town or City	Total Employment	Shuttle Accessible Employment (non-walk)	Percent from Rail Accessible Communities	Potential Market	Daily Shuttle Riders[a]	Mode Share[b]
Stamford	76,484	7,255	24%	1,741	70	4%
Greenwich	33,093	2,500	23	625	48	8%
New Haven[c]	85,000	21,197	12	2,500	250	10%

Notes: [a] Not daily trips, which can be expected to be roughly twice the number of daily shuttle riders.

[b] Based on shuttle service to downtown areas within the town/city indicated.

[c] Shore Line East commuter rail service from beyond New Haven; other locations served by New York's Metro North.

Source: Minerva, Sampson and Levinson (1996).

The employment sites covered in Table 10-9 are all in suburban and even urban downtowns, and thus the market shares may not be representative of what is achievable in highly auto-oriented office and industrial parks. Indeed, based on a similar compilation of shuttle/rail market shares for suburban employer application, using experience from Chicago and unspecified comparable metropolitan areas, mode shares of 3.4 percent transit for inter-suburbs commute trips and 5.0 for reverse commute trips from the central city have been derived. These shares are for commute trips from zip codes convenient to rail service to full time jobs with reporting hours from 6:00 to 9:00 AM (Fish, Dock and Baltutis, 1995).

All three of the Commuter Connection shuttles listed in Table 10-9 are operated by Connecticut DOT or local transit agencies, during peak periods only. The afternoon peak period is rather broad, however, covering 6 hours in the case of the Shore Line East shuttle in New Haven. Reported fares range from a $2.00 to $4.00 surcharge on a monthly commuter rail ticket to $1.00 one-way.

The Norwalk Transit District, which operates the Greenwich Commuter Connection shuttle, has also tried employer shuttles to a South Norwalk suburban employment corridor with over 13,000 employees. Free rides were provided for the first 6 months to encourage ridership. In 1994–95, the two routes together served an average of 63 passenger trips/day. One route was dropped for insufficient patronage, attributed to indirect routing with too long a travel time from the station.

Table 10-10 provides 1994–95 operating statistics for the Connecticut employer shuttle programs and January 1995 statistics for three comparable shuttles implemented in 1994 by New Jersey Transit. NJT's farebox recovery ratio goal of 15 percent was not yet met in January 1995 (Minerva, Sampson and Levinson, 1996).

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Table 10-10 Connecticut and New Jersey Shuttle Operating Statistics

Town or City	Service	Passengers per Day	Passenger Trip Productivity	Cost Effectiveness Measure	Cost Effectiveness
Stamford, CT	1 route	139	10.7/veh. hour	Cost per	$2.19
Greenwich, CT	1 route	88–106	7.3/veh. hour	Passenger	$8.54
New Haven, CT	1 route	600	28.8/veh. hour	Trip	$2.05
Norwalk, CT	2 routes	63	5.1/veh. hour		$7.82
Morristown, NJ	Route 1	35	3.5/veh. trip	Farebox	10.4%
Morristown, NJ	Route 2	27	2.7/veh. trip	Recovery	7.2%
New Brunswick, NJ	1 route	44	5.5/veh. trip	Ratio	11.0%

Source: Minerva, Sampson and Levinson (1996).

Similar operations run by SEPTA in the Philadelphia suburbs, timed to meet reverse commute trains operating on 30-minute headways, carry from 10 to 20 passengers per bus trip. SEPTA was operating five such "200-series" routes in early 1995; one of the original routes had been canceled and another converted to Saturday only service (Rosenbloom, 1998). A sample of Pace rail feeder reverse commute routes in suburban Chicago exhibited an average of just under 18 passenger trips per vehicle hour (Fish, Dock, and Baltutis, 1995).

Chapter 19 provides additional information on employer shuttles. The perspective in Chapter 19 is that of examining the role and effectiveness of employer shuttles as a component of overall workplace TDM programs.

Feeders to Trunk-Line Bus Routes

King County Metro, in starting to implement its Six-Year Transit Development Plan, has implemented or restructured a number of feeders and circulators connecting with "core" and other trunk-line bus routes, and also ferries. Table 10-11 provides ridership and productivity information for fixed route local services initiated or redesigned during 1996 or early 1997 that stay within one community. All are in Seattle suburbs or exurbs, except First Hill, which is actually a circulator connecting a hospital center to downtown Seattle.

Ridership on the new or mostly new routes ranges from 540 down to 100 weekday rides for multipurpose services, and from 510 down to 30 for single purpose employer shuttles. Ridership on redesigned feeders and circulators, including both feeders developed from former trunk-line route tails and routes already attempted in other formats without much success, ranges from 980 down to 20 weekday rides (King County DOT, 1998b; Harper, Rynerson and Wold, 1998–99). For an example of employer shuttles to trunk-line bus in Detroit, see the first entry under "Disadvantaged Neighborhoods to Jobs Routes"—"Experiences of the 1990s."

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Table 10-11 Fixed Route Local Services Ridership and Productivity

Location	Origin	Type	Weekday/ Sat./Sun. Headway	Route	Fall 1997 Weekday Rides	Fall 1997 Rides/ Bus Hour	Spring 1998 Weekday Rides	Spring 1998 Rides/ Bus Hour
Renton	106/107[a]	Community	30/60/60	105	552	16.6	620	18.8
Auburn	150[a]/new	Community	30/60/—	186	137	14.6	172	17.5
Auburn	150[a]	Community	30/30/30	151	767	13.3	829	14.4
Northgate	New	Community	30/—/—	318	216	7.9	320	11.8
Renton	New	Employee	15/—/—	110	397	9.1	509	11.7
Bellevue	221/235[a]	Community	30/30/60	222	851	11.0	979	11.6
Jackson Park	Most new	Community	30/30/60	315	547	11.7	540	11.6
Auburn	New	Community	30/60/—	185	81	8.8	102	11.5
Beacon Hill	New	Community	All 20-30	38	84	5.3	164	10.4
Kirkland	New	Community	60/—/—	231	284	11.6	221	9.0
Lk. Forest Pk.	932[b]	Community	30/—/—	314	210	8.2	204	7.9
Mercer Island	Other	Community	30/30/30	204	161	7.8	144	7.0
Issaquah	New	Community	30/—/—	200	223	5.7	286	7.0
Mercer Island	Other	Community	30/—/—	202SH	13	3.1	24	6.2
First Hill	New	Employee	30/—/—	944	13	2.7	29	5.0
Clyde Hill	924[b]	Community	84 peak	924	23	3.4	22	3.2
Bothell	307[a]	Community	30/30/—	334	40	3.0	38	2.8
Redmond	New	Employee	15–60/-/-	291	48	3.1	55	2.5
Bothell	New	Employee	—[c]	310	28	1.5	44	2.3

Notes: [a] Composed primarily of former tail or other segment of route(s) indicated.
[b] Composed of former demand responsive or shuttle route indicated.
[c] Discontinued and resources put into vanpool promotion, etc.

Sources: King County DOT (1998a and b); Harper, Rynerson, and Wold (1998–99).

Disadvantaged Neighborhoods to Jobs Routes

The 1960s saw a major federally supported effort to provide transit service between mostly-inner-city areas of high unemployment and suburban job sites. More recently, with welfare reform, attention again has been focused upon reverse commute and other routes that afford transit access from disadvantaged neighborhoods to jobs. The thrust in both instances has been to provide missing transit service links where they are needed by unemployed or underemployed persons without an auto available in order to access employment opportunities. Such bus routes can be difficult to develop because the destinations are so dispersed. Since the 1960s, however, the potential travel market for such routes has grown along with the tremendous expansion in suburban employment, especially in large cities. The experiences from the 1960s still offer lessons, though, for smaller cities and today's outer suburbs.

Experiences of the 1960s

Predecessor agencies to the Federal Transit Administration initiated in 1966, and continued through 1969, a program of exploratory and service development grants to foster provision of missing but needed transit services in the high-unemployment-area-to-suburban jobs category. A study of projects in 14 cities found about three-fifths of the grant expenditures to be resulting in permanent bus route development. Multi-user routes that served not only poverty area to employment travel but also other travel as well were the most successful: the Century Blvd. line through Watts in Los Angeles, which provided general cross-town service; those Long Island routes that also served shoppers and other user groups; the Maryland suburban lines in Washington, DC, which attracted suburbs-to-CBD commuting on the reverse trips; a similar arrangement in the Twin Cities; the Sunflower Arsenal line in Kansas City, which also provided Sunflower to Kansas City interurban service; and the O'Hare Express in Chicago, which provided general airport access (Crain, 1970).

When no purposes other than access to jobs were served, service was provided only at shift changes, and ridership was typified by the 26 to 166 daily one-way rides recorded on Long Island demonstration project routes after 18 months. Some purely reverse commuter routes did succeed when the suburban job site served was large and work shifts were such that a single bus round trip could accommodate all arrivals and departures. When the route was designed to serve multiple user groups, more riders were attracted. On Long Island, a multipurpose route carried 256 riders per weekday. In Los Angeles, one multipurpose route had only 160 weekday riders, but the previously noted Century Boulevard line through Watts was carrying 3,000 riders each weekday plus 2,400 weekend riders after 22 months (Crain, 1970; Pignataro, Falcocchio, and Roess, 1970).

Experiences of the 1990s

The Suburban Mobility Authority for Regional Transportation in suburban Detroit developed a "Job Express Shuttle" service in 1994 to transport passengers from the outer terminals of city of Detroit DOT bus lines and other central suburban Detroit DOT transfer hubs to suburban job centers not previously served by transit. Low-income inner city commuters were targeted. The three shuttles were as of 1995 operating from 5:00 AM to 7:00 PM on 15-minute headways. The shuttles accepted transfers and passes from the Detroit DOT services; otherwise, the fare was 50¢. Ridership in the year following implementation had grown steadily and was about 400 to 500 per route daily, 1,200 to 1,500 daily overall. Studies showed 80 percent to be women and 98 percent to be racial or ethnic minorities, with most of the riders between 16 and 44 years of age (Rosenbloom, 1998).

Detroit DOT subsequently designed its own labor mobility project, Translink, to provide access for Detroit residents to job opportunities in the suburbs and outlying areas of the city. Translink service is a combination of new routes to formerly unserved areas and services restructured to reach new employment centers. The services represent approximately 2 percent of DDOT's routes. The fare is $1.50, 25¢ higher than DDOT's base fare. With the majority of routes initiated in February 1997, DDOT estimated later the same year that it was carrying 7,784 trips per month to mostly suburban employment centers, of which 4,904 represented trips originating in empowerment zones. Translink routes recover a higher percentage of costs from farebox revenues (33 percent) than DDOT's regular routes (22 percent). DDOT offers a program that facilitates employer provision of $65 per month tax-free transit benefits to employees (Laube, Lyons, and vander Wilden, 1997).

The Federal Transit Administration funded ten 1995–1996 JOBLINKS demonstration projects that attempted to demonstrate various means of providing transportation to employment-related destinations for unemployed and underemployed people. Three of the ten projects involved fixed route bus service. One, in Glendale/Azalea, Oregon, included a small but successful program element that allowed job trainees to ride public school buses on their regular runs. Another, in Portland, Oregon, reported ridership that in most months was on the order of 100 per month. The viability of that project was in doubt.

Among the more successful of the JOBLINKS demonstrations was a project in Louisville, Kentucky, involving a reverse commute express bus service and a local circulator shuttle, discussed further in Chapter 4, "Busways, BRT and Express Bus." Monthly ridership ranged from 3,000 to 3,500, and the express service continues to be provided by the regional transit agency. Key findings of the JOBLINKS program overall were that proven transportation service delivery strategies worked best and that projects that used the same vehicles for multiple populations and trip purposes were the more viable (Goldenberg, Zhang and Dickson, 1998).

Some of the examples cited above have, or may have, express bus elements or operating characteristics. Additional examples that are clearly and exclusively express bus in nature are covered in Chapter 4, "Busways, BRT and Express Bus."

Other Special Routes

Recreation

The Southern California Rapid Transit District studied response to weekend service to parks as part of a Service and Methods Demonstration project from 1979 to 1980. Five buses were deployed, each making one trip a day from transit-dependent areas of Los Angeles to two parks in the Santa Monica Mountains, about 35 miles from downtown. The weekend service operated for a 10-week period during summer. The round trip fare was $1.00 the first year. Riders were allowed to book in advance, and a waiting list was maintained for days when all buses were full. The project was aggressively marketed and received media attention including newspaper and television coverage. Some 2,400 riders, including 55 groups, used the service; an average of 240 riders per weekend. Nearly half the patrons were from heavily transit dependent areas. Service revenue covered 19 percent of operating costs (Public Technologies, August, 1981).

Shopping

Two shopping centers in Knoxville, Tennessee, worked with the transit authority (K-TRANS) to restore Sunday service to their facilities for twelve weeks during the holiday shopping season. Citywide Sunday service, which had averaged 750 unlinked trips, had been eliminated by the transit agency to reduce costs. The new mall-funded service charged a flat fare of 50¢, instead of the previous 75¢ for adults, 35¢ for elderly and disabled, and 20¢ for transfers. Each shopping center had one route with a 30 minute headway, designed to maximize coverage, integrate as many sources of potential riders as possible, and also serve downtown. About 36 percent of the previous citywide coverage was provided. Service hours were 11:00 AM to 5:00 PM as compared to the original 8:00 AM to 4:30 PM. On the former citywide Sunday service, 33 percent of the ridership had occurred before 11:00 AM.

November and December ridership on the West Towne Mall route averaged 44 passengers per Sunday, and on the East Towne Mall route, 29 passengers. Productivity per vehicle mile was less than half that of the previous citywide operation. Given its orientation, the service attracted mostly shoppers (68 percent of riders surveyed). Of all riders, 96 percent could be classified as transit dependent, but 82 percent said they could have made the trip at another time. Reasons cited for the low ridership included unfamiliar route structure and fare schedule, incomplete coverage of the city, little marketing including lack of promotion by the malls, and lack of commitment to extend service beyond January (Chatterjee and Wegmann, 1989).

UNDERLYING TRAVELER RESPONSE FACTORS

Running, Walk, and Wait Time

Improved bus routing may serve to reduce time spent on the bus, shorten the walk necessary to reach bus service, or reduce the number of transfers (and transfer time) necessary to make a trip. Any of these outcomes will help make transit a more attractive modal alternative if there are not outweighing disadvantages such as lower frequencies with corresponding longer waits. Obviously, a service retrenchment or poorly designed routing change may lengthen ride, walk, or initial or transfer wait times and detract from transit usage.

The value of time, and the degree to which initial wait time, transfer time, and other out-of-vehicle travel time components may be more onerous than in-vehicle travel time (running time), are addressed in Chapter 9, "Transit Scheduling and Frequency," for both work and non-work purpose travel (see "Underlying Traveler Response Factors"—"Wait and Transfer Time Savings"). Additional information especially relevant to routing design is presented here. Modeled estimates of the value of simply being able to walk to transit service thanks to effective coverage, as compared to having to utilize an auto for access, are presented and discussed in the "Underlying Traveler Response Factors" section of Chapter 3, "Park-and-Ride/Pool," under "Overall Effects on Transit Mode Share"—"The Park-and-Ride Mode Change Penalty."

Table 10-12 gives relative importance of different types of travel time as determined from eight different mode choice modeling efforts covering work-purpose travel and believed to be primarily "originally estimated" (in contrast to being largely based on another city's model). Where the relative importance of two or more travel time components is shown to be identical, it may be assumed that the values were originally estimated as a single model variable, indicating that the particular model does not speak to the possibility of differences between them. Of particular interest in this tabulation are the differences, within each model, in the relative impact on choice of mode of time spent walking to and from transit service, time waiting for the initial transit vehicle, and the need and time required to make transfers.

As already alluded to, choice of mode is typically found, in mode choice model estimation, to be more sensitive to out-of-vehicle times overall (walking and waiting combined) than in-vehicle (running) time. A majority of models show a sensitivity to out-of-vehicle time overall that is in the range of 1.5 to 2.3 times the sensitivity to in-vehicle time (Schultz, 1991). Some but not all of newer models utilizing new techniques and approaches to fine-grained measurement of out-of-vehicle time components exhibit even higher out-of-vehicle time sensitivities (see the previously noted discussion in Chapter 9).

Table 10-12 Relative Importance of Travel Time Components for Work-Purpose Travel

City	Survey Year	Running Time	Walk Time	Initial Wait Time	Transfer Wait Time
New Orleans[a]	1960	1.0	2.20	5.13	2.13
Minn./St. Paul	1970	1.0	1.42	0.97	1.42
Chicago[a]	1970	1.0	4.13	0.84	4.13
Seattle	1977	1.0	1.10	0.75	1.10
Dallas	1984	1.0	1.86	1.85[b]	1.99
Minn./St. Paul	1990	1.0	4.36	4.36[c]	4.36[d]
Boston[a]	1991	1.0	0.79	1.31	2.38[e]
Portland, OR[a]	1994/95	1.0	1.87	1.25	2.46

Notes: [a] Transit modes included rail (in addition to extensive bus systems) during the survey year.

[b] First 7 minutes; sensitivity about half for any additional initial wait time.

[c] First 7.5 minutes; sensitivity about one-fifth for any additional initial wait time.

[d] Additional transfer penalty tested but not used for work purpose (see discussion in text).

[e] Plus a penalty equivalent to 12.98 minutes of running time for making one or more transfers (see discussion in text).

Sources: Minneapolis-St. Paul 1990 — Parsons Brinckerhoff (1993); Boston — Central Transportation Planning (1997); Portland, OR — Kim (1998); Others — Schultz (1991).

When out-of-vehicle time is broken out into its walk and wait time components, as in Table 10-12, consistency among modeled sensitivities becomes less apparent. Nevertheless, as in the recent Portland model (Kim, 1998), the median pattern is for initial wait time to be slightly more important per minute than running time, for walk time to be more important than initial wait time, and for transfer wait time to be the most important per minute of all. Walk time and transfer time are heavily influenced by bus routing and coverage, which is to say that routing and coverage design directly affects major determinants of the choice to use transit or not.

Research has been undertaken using Boston-area work-purpose travel data to determine if there is a penalty for need to make a transfer that is above and beyond the effect of the transfer wait time involved. In the Boston area, 39 percent of linked trips involve one transfer and another 7 percent require two or more. The transfers involve various rail and bus services. Most transfers take place in sheltered locations and most require an extra fare (separately accounted for in the analysis). The research did identify a penalty, and it was estimated to have a value in the range to 12 to 15 minutes of in-vehicle time per trip involving a transfer, irrespective of the number of transfers involved. This transfer penalty is additive to the effect of the transfer wait time, as noted in Table 10-12 (Central Transportation Planning, 1997).

A very limited number of other modeling efforts have quantified a transfer penalty. One is the 1990s development of a new mode choice model for Minneapolis-St. Paul, then an all-bus environment emphasizing through-routing and achievement of coverage with branching. A transfer penalty for work-purpose travel was investigated but found to be not significant. For home-based travel to and from non-work activities, a penalty equivalent to 17 minutes of in-vehicle time *per transfer* was estimated, additive to the effect of transfer wait time. For trips with

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neither end at home, the estimated transfer penalty ranged from the equivalent of 27 minutes per transfer for work-related trips to 2 hours for non-work, non-home-based travel (Parsons Brinckerhoff, 1993). One interpretation is that the penalty for having to transfer gets progressively worse the less repetitive and more discretionary the trip purpose becomes, until the need to transfer becomes essentially a "fatal flaw" for transit travel between two non-work activities, as in non-work, non-home-based travel.

Increased out-of-vehicle time or incidence of transfers is not necessarily a fatal flaw for a service design. It is all a matter of trade-offs. If there are sufficient counterbalancing advantages to the rider gained, for instance, by introducing an additional transfer, the results may be positive. Such was the case with several King County Metro service consolidations, discussed under "Response by Type of Service and Strategy"—"Service Restructuring"—"Variations on Hub and Spoke Configurations" and also in the case study "Service Restructuring and New Services in Metropolitan Seattle."

Demographics

Bus usage is most prevalent among households with no car, and next most prevalent among one-car households. Riders with no auto available for the trip are termed transit "captives," a concept introduced in Chapter 1. Because low auto ownership and transit captivity are predominantly, although not exclusively, associated with lower incomes, lower incomes and greater use of bus service also tend to go together (Pratt, Pedersen and Mather, 1977). A profile of transit users is provided in the "Related Information and Impacts" section under "Characteristics of Existing Ridership."

Transit captives have limited options other than to use transit, obtain rides or forgo desired travel. These factors suggest that attention should always be given, in the planning of new service, to the location of low auto ownership or low income population groups (Holland, 1974).

Transit Accessibility

Expansion of bus service coverage and introduction of new bus routes is directed at either shortening the walk time required to reach transit service, or at bringing service to more people. The shorter the walk is to transit service, the higher the probability that transit will be used. A survey of the Buffalo metropolitan area in 1968 showed that among workers residing 1/10 of a mile from a bus, 20 percent used transit, while among those 1/8 of a mile from a bus, 10 percent used transit (Holland, 1974). Similarly, in St. Louis, the patronage of new radial routes (express routes in this case) came 35 percent from the adjacent blocks, 17 percent from the next tier, 12 percent from the third, and 7 percent from the fourth (W. C. Gilman and Co., 1966).

More recent and comprehensive information from the Boston region suggests similar walk distances to bus and rail transit. When making work-purpose trips, 67 percent of transit riders walk less than 1/4 mile, similar to the 64 to 71 percent that walked 3 to 4 blocks in St. Louis. Table 10-13 gives additional detail (Central Transportation Planning, 1997). The St. Louis and Boston data may possibly be skewed in the direction of longer walks by the presence of express services. All of these data pertain to the walk at the home end of the transit trip.

Table 10-13 Percentage Distribution of Walking Distances to Bus and Rail Transit

Metropolitan Boston 1991	0 to 1/4 Mile Walk	1/4 to 1/2 Mile Walk	1/2 to 3/4 Mile Walk	3/4 to 1 Mile Walk	Greater than 1 Mile Walk
Transit Trips	56.7%	31.7%	7.7%	2.7%	1.2%
Auto-Owner Transit Trips	53.4	33.4	8.8	2.9	1.5

Source: Central Transportation Planning (1997).

Comprehensive service expansion and restructuring is directed at providing attractive transit service to an increased proportion of total travel requirements. The degree to which urban activities in general can be reached within a reasonable time via public transit has in some studies been found to influence transit usage in somewhat the some way as income does (Metropolitan Washington COG, 1981; Texas Transportation Institute and Barton-Aschman, 1979). This finding suggests that overall service presence may have an influence on auto ownership decisions and the proclivity to use transit.

Travel Patterns

For patronage to be attracted to a bus route or system, the operation must first and foremost connect points between which there is a significant demand for travel. Travel to and from the central business district has been the traditional mainstay for transit patronage. Significant factors in the previously cited strong response to restructured and enhanced bus service in Iowa City were undoubtedly the fact that the downtown of that small city attracted over 25 percent of all urbanized area trips, together with the adjacent university campus and hospital complex, and the fact that the central area could be served by all of the redesigned bus routes (Dueker and Stoner, 1972).

The increasing dispersion of urban activity and related travel brings with it the need to critically examine existing systems and investigate not only crosstown and reverse commute bus routes along with extension of existing routes, but also alternative forms of overall system design. Bus system designs that can be readily customized to individual land use and travel patterns (such as hub and spoke systems) appear to have a slight edge over more purely geometric configurations (such as grid systems) in their success rates. Finding non-downtown oriented travel corridors of sufficient trip density to support conventional bus service can be difficult. Insufficient concentration of travel demand presumably contributed to the failure of individual crosstown, suburbs-to-suburbs, reverse commute and industrial service bus routes cited at various points throughout this chapter.

It follows that enhanced success rates in bus route and system design and redesign should be achievable if quantitative investigation of travel patterns and their relationship to proposed bus service configuration is built in to the process. It is probably no coincidence that two of the most successful large scale system redesign efforts encountered used such procedures (in conjunction with citizen involvement). OCTA in Orange County, California, reports undertaking comprehensive operational analysis utilizing examination of census and survey data with GIS methodologies to identify candidate routes and locations for restructuring (Stanley, 1998). King County Metro service redesign for greater Seattle utilized census work trip origin-destination

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data, boarding and alighting data, special counts, non-user surveys, and estimation of winners and losers among existing riders (Harper, Rynerson and Wold, 1998–99). Results of these successful redesign efforts were covered under "Response by Type of Service and Strategy" in the subsections on "Service Restructuring"—"Variations on Hub and Spoke Configurations" and "Changed Urban Coverage"—"Crosstown Routes."

Tools for such analysis are ridership surveys and, in the case of complex large system restructurings, urban transportation planning network models or equivalent GIS procedures.

RELATED INFORMATION AND IMPACTS

Characteristics of Existing Ridership

Demographic and Socioeconomic Characteristics

The demographic characteristics of bus ridership in the aggregate differ to a degree, in the United States, from those of total transit ridership. Total ridership is significantly influenced by substantial numbers of rail system riders in New York City, in particular, and in other large cities. The mode share of journey to work travel via subway and elevated rail systems does not vary markedly by income, while the mode share via commuter rail increases with higher incomes. In contrast, the average mode share of bus, trolley and streetcar ridership tends to decrease with rising income, such that above average usage for work trips was found primarily among persons making less than $20,000 per year in 1990 (Rosenbloom, 1998).

Table 10-14 is constructed from 1990 journey to work Census data for cities of under 1,000,000 population, in order to exclude most influences of rail transit modes and thus focus on bus ridership. The source tabulations (Tables 4 and 5, Rosenbloom, 1998) utilized a calculation of average transit shares for three density categories within each city size category, and with those as norms, developed a transit use index for each market niche. An index of 1.00 indicates average transit usage, higher indicates above average (for example, 2.00 is twice average), and lower indicates less than average. The source tables have been collapsed into Table 10-14 by combining density-stratified results and adjacent market niches into ranges of indices.

Income is clearly a major determinant of who rides bus transit, with decreasing usage as one goes up the income scale, except perhaps above household incomes of $70,000. Nevertheless, some groups are genuinely more likely to use transit to commute to work, irrespective of income, including women, minorities, immigrants (especially recent immigrants), persons without a car, the mobility impaired, workers under 30 and also age 65 to 70, those with less than a full high school education, and interestingly, college graduates and those with graduate school education (Rosenbloom, 1998). Some of these findings may be the effect of geography. Minorities and immigrants may tend to live in center cities, and the well educated and very highest income groups may tend to work more in CBDs, both locales where transit service is generally better and more competitive with auto travel.

Table 10-14 Transit Use Indices by Market Niche for Metropolitan Areas under 1,000,000 Population

Population Range (Average Transit Share)	**50,000–200,000** (0.80% to 3.32%)	**200,000–500,000** (1.55% to 4.40%)	**500,000–1,000,000** (2.35% to 28.81%)
Market Niches			
Sex			
Men	0.62 – 0.95	0.79 – 0.96	0.76 – 0.85
Women	1.06 – 1.42	1.05 – 1.25	1.18 – 1.30
Race and Ethnicity			
White	0.81 – 0.93	0.83 – 0.92	0.67 – 0.93
Black	3.03 – 4.99	2.11 – 3.23	1.25 – 3.31
Hispanic (all races)	0.84 – 3.03	2.28 – 3.34	0.53 – 2.74
Asian	0.96 – 3.15	1.04 – 1.83	1.27 – 1.55
Immigration Status			
Non-immigrant	0.64 – 0.95	0.81 – 0.95	0.82 – 1.00
Immigrant	1.13 – 2.15	1.47 – 3.29	1.01 – 1.90
Vehicle Ownership			
No Car	7.06 – 13.45	4.93 – 10.88	1.78 – 10.17
One or More Cars	0.48 – 0.69	0.68 – 0.83	0.68 – 0.86
Personal Limitations			
Work Limitation	2.29 – 5.20	1.61 – 2.76	0.89 – 2.20
Mobility Limitation	0.47 – 14.68	2.60 – 7.61	0.78 – 4.53
Age of Worker			
17 – 29	1.15 – 1.30	1.05 – 1.26	0.98 – 1.21
30 – 39	0.80 – 1.02	0.76 – 1.01	0.86 – 1.05
40 – 49	0.69 – 0.87	0.83 – 0.94	0.84 – 0.95
50 – 59	0.82 – 1.08	0.69 – 0.99	0.80 – 1.16
60 – 69*	0.50 – 2.16	0.97 – 1.88	0.76 – 1.46
Education			
No/Elementary School*	1.31 – 7.46	1.18 – 12.80	0.80 – 2.96
Jr./Some High School*	1.36 – 2.46	0.20 – 2.44	0.77 – 2.54
High Sch./Some College*	0.58 – 1.07	0.05 – 1.02	0.81 – 1.04
College/Grad. School*	0.51 – 1.18	0.43 – 1.58	0.68 – 1.44
Annual Household Income			
Less than $10,000*	0.91 – 1.90	1.09 – 1.99	1.05 – 1.79
$10 – $20,000*	0.74 – 1.54	0.80 – 1.40	0.87 – 1.29
$20 – $30,000*	0.20 – 1.28	0.32 – 0.75	0.50 – 1.02
$30 – $50,000*	0.48 – 0.80	0.28 – 0.94	0.46 – 0.90
$50 – $70,000*	0.31 – 0.83	0.33 – 1.82	0.57 – 1.15
Greater than $70,000	0.20 – 0.91	0.53 – 2.32	0.67 – 1.26

Notes: An asterisk indicates that the high and low transit use indices were picked from among consolidated niche ranges as well as from among the three density stratifications per metropolitan area. See text for transit use index explanation.

Source: Extracted from Tables 4 and 5, Rosenbloom (1998).

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Transit riders traveling for non-work purposes in 1990 presented a similar cross-section, but without the higher usage effect at the highest income and educational levels. Higher than average transit usage for non-work trips was found among persons with household incomes below $30,000. Controlling for income, higher usage was again found among women, minorities, persons with no car, young people between 12 and 30, and those with less than full high school education (Rosenbloom, 1998).

Purpose of Travel

Rider surveys were conducted in nine cities during the 1996 through 1998 period as part of a Federal Transit Administration (FTA) and American Public Transit Association (APTA) project to develop a transit performance monitoring system. One of the items of information obtained in these surveys was the purpose of travel of the transit riders. Table 10-15 gives the results for bus riders over 12 years of age. Also provided in Table 10-15 is the transit service area population and the number of riders determined, by observation, to be 12 years old or younger. For the five cities with rail transit lines (the five largest cities), equivalent information for rail transit riders is found in Chapter 7, "Light Rail Transit," along with bus rider versus rail transit rider comparisons.

Table 10-15 Bus Transit Trip Purpose Percentages for Riders over Age 12

	Kenosha	Lincoln	Grand Rapids	Austin	Sacra-mento	Port-land	Buffalo	Pitts-burgh	Chicago
Population (000)	84	192	399	605	931	988	1,182	1,523	3,709
Riders 12 yrs. and under (%)	15.5%	1.6%	2.7%	2.8%	10.3%	7.1%	6.5%	6.0%	8.9%
Over 12 yrs. (%)	84.5%	98.4%	97.3%	97.2%	89.7%	92.9%	93.5%	94.0%	91.1%
Trip Purpose (riders over 12)									
Work	26.2%	46.5%	42.5%	49.5%	37.7%	44.3%	56.0%	58.0%	53.3%
Shopping	11.9	10.9	12.2	9.7	12.6	15.2	10.6	11.6	12.7
College	3.1	19.4	3.5	8.3	11.2	4.2	5.2	6.6	2.9
Other School	39.8	8.6	16.0	6.2	10.3	4.3	6.8	4.1	4.9
Medical	5.0	1.8	4.2	3.7	5.9	2.5	5.0	3.5	3.5
Personal	8.1	6.0	6.9	8.6	9.8	10.8	7.1	7.5	11.5
Other	5.8	6.9	14.7	13.9	12.5	18.6	9.3	8.7	11.2

Notes: Regular bus service riders only (excludes rail riders, and University of Texas routes in Austin). For rail riders in Sacramento; Portland, Oregon; Buffalo; Pittsburgh; and Chicago (with bus/rail comparison) see Chapter 7, "Light Rail Transit."

Population is Service Area Population as reported for 1997 National Transit Database.

Personal trip purpose includes Social, Church or Personal Business.

Source: McCollom Management Consulting, Inc. (1999).

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The travel purposes in Table 10-15 are determined according to standard travel demand analysis protocol, except that non-home-based travel (trips with neither end at home) is not separately identified. Passengers were asked where they were going to and where they were coming from. If the place they were going to was not home, then their trip destination established the trip purpose. If it was home, the trip origin determined the purpose. Since young children were excluded, the percentage of total bus riders making work purpose trips is to some degree overstated (McCollom Management Consulting, Inc., 1999). Also, these data include travel characteristics of express bus as well as local bus riders, another influence which may make the work travel percentages slightly higher than they otherwise would be. Note that Pittsburgh, with its busway system, has the highest proportion of work trips.

The data in Table 10-15 exhibit a modest increase in the percentage of travel to and from work as city size increases. The other travel purpose percentages, as well as the proportion of riders 12 years of age or less, appears to vary according to local conditions. Perhaps the local condition with the most influence on non-work travel purposes is local school transportation policy. The reason for Portland, Oregon's high percentage of bus riders going to and from shopping is presumably the strength of its downtown and near-downtown retail.

Sources of New and Lost Ridership

New Ridership

Ridership attracted to new or revised bus routes comes as the result of changes in trip frequency, destination choice, mode choice, and route choice. New or revised routes have even greater potential for inducing shifts in transit route choice than do service frequency changes. Thus a major patronage component may be riders diverted away from other routes, as shown by the 1960s examples in Table 10-16.

Table 10-16 Available Examples of New Ridership Sources for New Bus Lines

Source of New Riders	Radial Routes to Suburbs St. Louis	Circumferential Route @ 3 Miles Boston	Circumferential Route @ 5 Miles Boston
Other Transit Routes	60%	94%[a]	87%[b]
Auto	28[c]	4	13
Walk and Other Means	12	2	—[d]
New Trips	—[d]	less than 1%	—[d]

Notes: [a] 81% of this diversion was from other routes on the same streets.
[b] 44% other bus routes and 43% rail rapid transit.
[c] 16% single auto driver and 12% carpool.
[d] Not reported.

Sources: W. C. Gilman and Co. (1966) ; Mass Transportation Commission et al (1964).

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In the case of the experimental Boston crosstown lines in particular, many former riders of other transit lines made the switch to the new routes in order to minimize travel time and transfers (Mass Transportation Commission et al, 1964). It is thought that two-thirds of the ridership on a more recently implemented express crosstown in the same general location represents trips not new to transit (Rosenbloom, 1998). These examples may exhibit atypically high diversion from other transit due to the particular circumstances involved, but the implication is valid: the impact of new routes should be examined in a system context in order to ascertain the net impact.

Systemwide patronage increases resulting from broad-scale service enhancements do not have other transit routes as a source of new riders, although there may be shifting among routes within the system. Table 10-17 gives the sources of new ridership attracted by combined 1970s service enhancements and fare decreases in Atlanta and Los Angeles. In such situations, changes in trip frequency and destination choice show up as "trips not made previously" in rider surveys after the change. Changes in mode choice appear in "after" surveys as trips made previously via non-transit modes (Bates, 1974; Weary, Kenan and Eoff, 1974).

Table 10-17 Prior Trip Mode of Ridership Attracted by Service Enhancements Together with Fare Decreases

City	Auto Driver	Auto Passenger	Walk	Other	New Trip
Atlanta	42%	22%	4%	10%	22%[a]
Los Angeles	59	21	—	10	10

Notes: [a] Weekday trips not made previously, not including additional trips by previous riders, which made up 9 percent of the ridership increase.

Sources: Bates (1974); Weary, Kenan and Eoff (1974).

The new bus transit system introduced in Cobb County, Georgia, in 1989 attracted 43 percent of its local bus riders from the auto mode for the journey to work. By comparison, 81 percent of its express bus riders previously drove or rode in an auto (Cambridge Systematics, 1992).

Lost Ridership

No surveys have been encountered to illustrate what modes former transit riders elect or are forced to use when bus systems contract or are abandoned, although surveys are available on what riders do during system strikes (see "Impacts of Strikes" below). The previously described 1996–98 FTA/APTA survey did, however, ask riders what mode they would use if transit service were not available. The results provide roughly equivalent information, except that they reflect what transit users think they would do as compared to what they actually do. The 9-city findings are given in Table 10-18.

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Table 10-18 Alternative Travel Mode Percentages for Riders over Age 12

Alternative Travel Mode	Kenosha	Lincoln	Grand Rapids	Austin	Sacra-mento	Port-land	Buffalo	Pitts-burgh	Chicago
Car	8.1%	29.7%	9.4%	17.9%	20.1%	28.5%	13.1%	32.4%	14.0%
Walk	22.5	24.2	20.7	22.8	15.4	15.0	20.8	12.8	15.2
Ride w/Someone	24.2	16.4	19.8	21.5	27.8	18.6	22.2	21.6	23.7
Taxi	11.7	6.1	13.1	8.7	3.7	4.5	10.5	7.1	16.1
Bicycle	3.9	7.3	1.8	6.5	7.3	6.0	4.0	1.6	2.9
Not Make Trip	16.6	13.6	24.0	22.6	19.2	21.0	24.2	24.6	23.8
Multiple Answers	13.1	2.8	11.2	—	6.4	6.4	5.1	—	4.2

Notes: Regular bus service riders only (excludes rail riders, and University of Texas routes in Austin). For rail riders in Sacramento; Portland, Oregon; Buffalo; Pittsburgh; and Chicago (with bus/rail comparison) see Chapter 7, "Light Rail Transit."

See Table 10-15 for population and percentage of riders 12 years of age and under.

Source: McCollom Management Consulting, Inc. (1999).

Roughly one out of five transit users surveyed stated that they would not make their trip if transit service were not available. This finding serves to illustrate the role of transit service in providing mobility to transit "captives"—persons with no automobile available for their trip (McCollom Management Consulting, Inc., 1999). This degree of anticipated trip suppression is in line with or perhaps even slightly lower than the actual trip suppression reported during systemwide transit strikes (see "Impacts of Strikes").

Table 10-18 also suggests that of those bus riders who would still be making their trip, about half would go by automobile. This level of drive or carpool substitution matches fairly closely with the actual choice of substitute mode during transit strikes. It is perhaps lower than, and the auto driver component is definitely lower than, the corresponding previous auto mode proportions of riders *attracted* by systemwide bus improvements. This supports the impression that riders attracted by service improvements tend to have higher auto availability than the pool of existing bus riders. Pittsburgh is an outlier in Table 10-18 with by far the highest percentage of riders indicating they would become auto drivers if bus service were not available. It is reasonably safe to assume that this is because of the attraction, by Pittsburgh's two major busways as of 1997, of more "choice" bus riders with autos available.

Mode of Access and Egress to Bus Service

Tables 10-19 and 10-20 present findings of the 1996–98 FTA/APTA survey with regard to the mode used by bus riders to gain access between their home and the bus and between the bus and the non-home end of their trip. Chapter 3, "Park-and-Ride/Pool," is in essence devoted to one of these modes of access, "drove car." Tables 10-19 and 10-20 are concerned with all such modes, and walking is seen to be by far the most predominant for urban bus services (McCollom Management Consulting, Inc., 1999). Note that survey respondents were asked how they were accessing or egressing the particular bus they were on, so that transfer passengers reported "bus" or "rail" for the leg (or legs) of the trip they transferred from or to (or both). If Tables 10-19 and 10-20 gave system access information instead of route access information, the

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home-to-bus walk access/egress percentages would range from 88 to 97 percent, and the non-home walk percentages would be in an even tighter range between 93 and 96 percent.

Table 10-19 Bus Transit Home Access/Egress Percentages for Riders over Age 12

Access/Egress Mode	Kenosha	Lincoln	Grand Rapids	Austin	Sacra-mento	Port-land	Buffalo	Pitts-burgh	Chicago
Walked	84.2%	91.7%	82.6%	76.3%	72.0%	75.4%	77.7%	75.4%	73.4%
Drove Car	0.6	*	*	4.9	2.7	6.1	2.5	7.7	1.3
Dropped Off	1.6	*	*	2.9	3.6	2.2	2.1	2.9	1.1
Rode Bicycle	0.1	*	*	*	*	0.4	0.2	*	*
Rode Bus/Rail	13.3	5.6	14.4	14.0	21.2	15.5	17.4	13.8	23.7
Rode w/Parker	0.2	*	*	*	*	0.4	0.1	0.2	*
Other	—	2.7	3.0	1.9	0.5	—	—	0.0	0.5

Notes and Source: See Table 10-20 for notes and source applicable to this table.

Table 10-20 Bus Transit Non-Home Access/Egress Percentages for Riders over Age 12

Access/Egress Mode	Kenosha	Lincoln	Grand Rapids	Austin	Sacra-mento	Port-land	Buffalo	Pitts-burgh	Chicago
Walked	73.4%	84.7%	73.5%	75.9%	68.5%	75.8%	68.3%	79.3%	66.6%
Drove Car	0.9	*	*	1.4	2.2	2.3	1.3	1.6	*
Dropped Off	2.8	*	*	3.1	2.1	2.6	2.5	1.6	3.0
Rode Bicycle	0.4	*	*	*	*	*	*	*	*
Rode Bus/Rail	22.0	11.6	21.1	17.7	26.5	18.2	27.6	17.0	28.6
Rode w/Parker	0.6	*	*	*	*	*	*	*	*
Other	—	3.8	5.4	1.9	0.7	1.1	0.3	0.5	1.8

Notes: Regular bus service riders only (excludes rail riders, and University of Texas routes in Austin). For rail riders in Sacramento; Portland, Oregon; Buffalo; Pittsburgh; and Chicago (with bus/rail comparison) see Chapter 7, "Light Rail Transit."

See Table 10-15 for population and percentage of riders 12 years of age and under.

Asterisk (*) indicates that the percentage for the city and mode in question is included within Other for that city.

Source: McCollom Management Consulting, Inc. (1999).

As previously noted, the FTA/APTA survey responses include express bus riders along with local bus riders. This is of no consequence in the smaller cities, but has some unknown degree of effect in the larger cities. Pittsburgh again stands somewhat apart, but only in terms of "drove car" home access/egress (Table 10-19). The Pittsburgh busways, whose passengers are mixed in with other bus riders in the survey, may be presumed to be the cause of the higher auto driver mode of access. Rail system modes of access can and have been fully separated out from the survey, and in Chapter 7, "Light Rail Transit," it can be seen that the rail modes have higher "drove car" home

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access/egress percentages. Data specific to the Pittsburgh busways is found in Chapter 4, "Busways, BRT and Express Bus."

Traveler Response Time Lag

Transit service additions and modifications do not instantaneously result in fully developed transit ridership changes. It takes time for either potential or current riders to learn about or perceive a change in service and then carry out decisions affecting their pattern of usage. For example, a time-series analysis of ridership impacts in response to service changes in Portland, Oregon, from 1971 to 1982 indicated that ridership changes occurred over a period of 1 to 10 months (Kyte, Stoner and Cryer, 1988). (See the "Traveler Response Time Lag" subsection of Chapter 9, "Transit Scheduling and Frequency," for more information on Portland.) New routes may require longer time periods to develop ridership. Table 10-21 gives the fourth-quarter ridership as a percentage increase over first-quarter ridership for several experimental bus routes (Pignataro, Falcocchio and Roess, 1970; Rechel and Rogers, 1967; W. C. Gilman and Co., 1966):

Table 10-21 New Bus Route Growth in Fourth Quarter Ridership over First Quarter

Location and Route Type	Percentage	Location and Route Type	Percentage
Long Island		Memphis	
Multipurpose Route	12%	Industrial/residential radial	11%
Industrial Route B	144	Low-income suburbs radial	26
Industrial Route C[a]	82	High-income suburbs radial	61
Industrial Route E[a]	144	St. Louis	
Industrial Route F	65	7 radial routes to CBD	37%
		Suburban crosstown	36

Notes: [a] First month excluded.

Sources: Pignataro, Falcocchio and Roess (1970); Rechel and Rogers (1967); W. C. Gilman and Co. (1966).

The limited information available on the progress of new route development beyond the first 12 months indicates that ridership growth tends to level out after 1 to 3 years. Expressed in deficit per passenger, Figure 10-1 illustrates the progress of four 1960s low income area routes for which at least 16 months of data were reported (Crain, 1970). The trend of passengers per bus mile ratios for two new transit systems over periods exceeding three years (see Table 10-2) suggests that the traveler response time lag for all-new systems may be even greater than it is for new routes of an established system.

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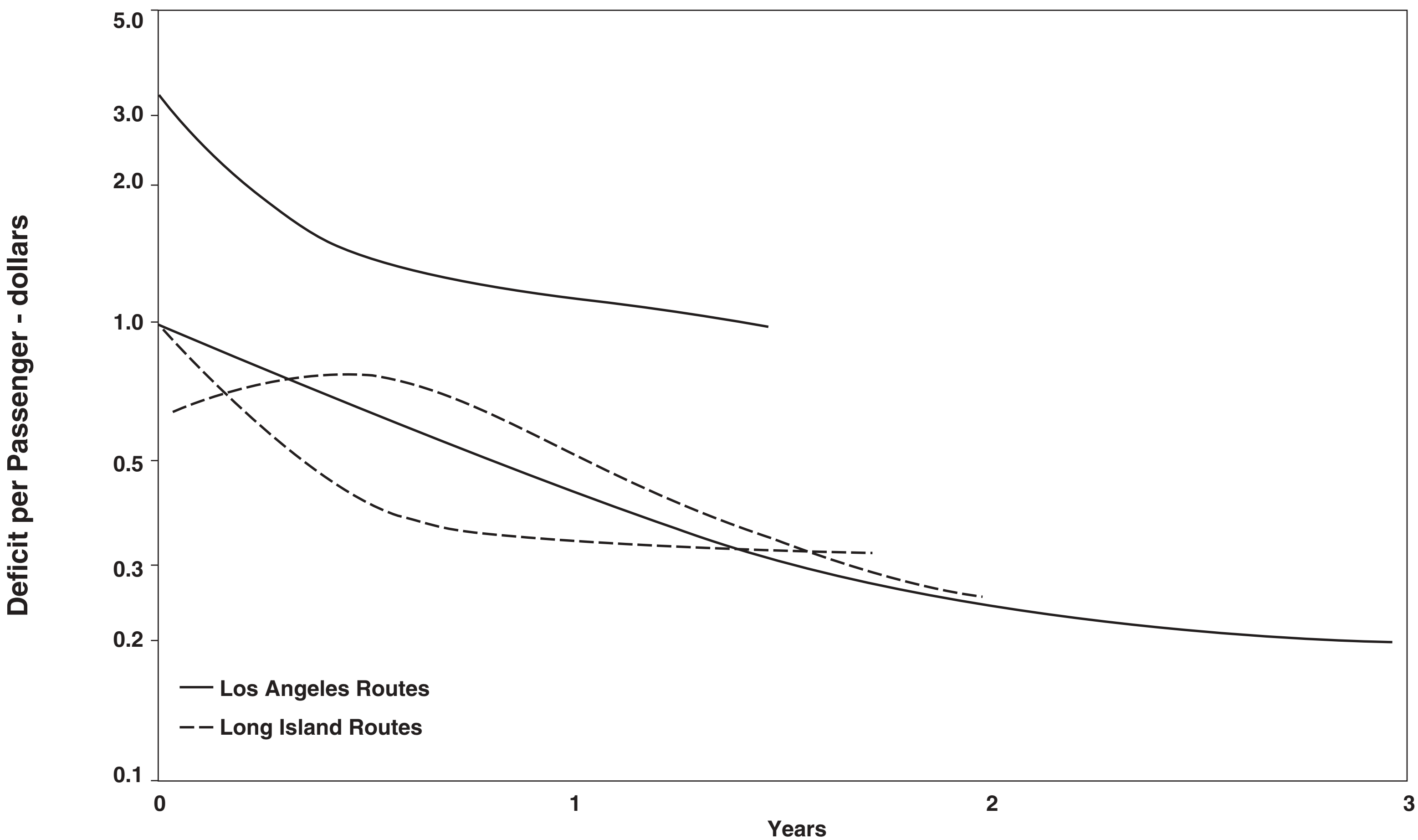
Figure 10-1 Deficit per passenger route development trends for 1960s job access routes in Los Angeles and Long Island



Note: Vertical axis is logarithmic scale.

Source: Crain (1970).

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Impacts of Strikes

Results of transit strikes serve as an indicator, albeit imperfect because of their temporary nature, of the transportation functions provided by urban transit. The majority of all trips normally made by transit shift to other travel modes, but a very significant proportion are suppressed for the duration of a strike. Such reduction in trip generation undoubtedly reflects the lack of alternative travel modes among transit "captives." Table 10-22 shows the proportion of transit trips suppressed, and the alternative modes used by those who did travel, for both a 1966 New York City transit strike and a 1974 A.C. Transit strike in the Oakland/East Bay suburbs of San Francisco (Peat, Marwick, Mitchell, 1975).

Table 10-22 Transit Strike Impacts on Transit Riders

Background Information and Impacts	New York City	A.C. Transit
Population served by suspended service	8,000,000	1,000,000
Daily patronage	5,000,000	200,000
Number of working days during strike	9	45
Percentage of work trips suppressed	15–20%	9–21%
Percentage of non-work trips suppressed	41%	49–59%
Alternate modes used for trips not suppressed		
Auto (driver or passenger)	51%	68%
Chartered bus	11	0
Taxi	12	4
Commuter train/BART train	7	15
Walk	10	8
Hitchhike, bike, etc.	2	5
Stayed all night near work	7	—

Source: Peat, Marwick, Mitchell (1975).

Trip suppression was specifically identified in the 1974 A.C. Transit strike as being most prevalent among the young and elderly. Normally these groups comprised 65 percent of all nonwork trips on A.C. Transit buses. During the strike, elderly transit riders, a bare 21 percent of whom either had a car or a drivers license, suppressed 55 to 60 percent of all trips. Approximately half of all trips by the young were suppressed (Peat, Marwick, Mitchell, 1975).

The percentage of transit riders turning to driving an auto during a transit strike is apparently significantly less than the percentage of new riders attracted by systemwide transit enhancements who are prior auto drivers (see "Sources of New Ridership" within applicable chapters). This is reasonable, in that newly-attracted transit patrons would tend to be discretionary riders with access to an auto, while the body of captive riders would be among those already using transit. Among bus transit trips normally made to downtown Oakland, only 7 percent were made as auto driver trips during the A.C. Transit strike. Of bus trips normally made across the bay to San Francisco (this was prior to opening of BART transbay rail service), 26 percent shifted to single occupant automobiles and 60 percent shifted to carpools (Peat, Marwick, Mitchell, 1975).

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The impact on vehicular volumes of major transit strikes is nevertheless readily evident. During the A.C. Transit strike, daily vehicular traffic on the three principal bridges across the San Francisco Bay rose 6 to 16 percent and AM peak congestion on the San Francisco-Oakland Bay Bridge stretched from the normal 30 minutes duration to 120 minutes, despite an increase in the average peak period Bay Bridge auto occupancy from 1.44 to 1.75 persons (Peat, Marwick, Mitchell, 1975). During a 1969 bus transit strike affecting the easterly half of the Northern Virginia suburbs of Washington, DC, the 6:00 to 11:00 AM vehicle count across the impacted Potomac River bridges was up 13 percent while average auto occupancy rose from 1.56 to 1.68. Four miles south into Virginia, however, the vehicle count was up only 2 percent with occupancy up from 1.38 to 1.50 (Pratt, Pedersen and Mather, 1977).

Impacts on Traffic Volumes and VMT

Discernible traffic volume changes thought to be associated with modification of local bus transit routing and associated improvements have almost never been observed in the field and quantified, system closures due to strikes excepted. Normally the proportion of urban travel using transit service and the impact of service changes are small enough at any one location and point in time that auto traffic impacts cannot be seen and isolated from other events. Exceptions have occurred involving college campuses and small city downtowns, where effects are not so easily lost among overall traffic shifts and growth.

In the first 6 months of the previously noted Iowa City bus service enhancements, downtown parking revenues were observed to drop by 11 percent over the prior year (Dueker and Stoner, 1972). This impact presumably reflects the increase from 3 to 11 percent in the proportion of all downtown-oriented trips using transit in response not only to routing changes, but also to the fare reduction, schedule regularization, and equipment improvements implemented concurrently. Similarly, a 1,000-space reduction in University of Illinois parking demand was reported in response to the first year (1990) of Champaign-Urbana Mass Transit District service improvements combined with a mandatory student transportation fee providing unlimited rides. Concurrently introduced carpool parking subsidies, low cost remote parking, and modest parking fee increases were also factors (Moriarty, Patton and Volk, 1991).

Table 10-23, derived from a landmark impact evaluation of new and expanded bus services, provides estimates of the effect on vehicle miles of travel in ten cities. The analysis assumed that from a congestion standpoint a bus mile is equivalent to two passenger car miles. The reduction in equivalent vehicle miles of travel (VMT) as a result of the improved transit service was minimal, averaging 0.13 percent in large cities and 0.03 percent in smaller cities. The average transit service (bus mile) increases in these same cities were 21 percent and 63 percent, respectively, exclusive of new systems. Three of the smaller cities, including two with new systems, showed small increases in equivalent VMT (Wagner and Gilbert, 1978).

New Jersey Transit analyzed the VMT reduction afforded by 29 different bus and rail service demonstrations implemented in 1994–95. Eight of these demonstrations involved new local service coverage, all in the suburbs. In total, the eight local service expansions are estimated to have reduced daily VMT by 8,673 (Michael Baker et al, 1997). Converted to an annual figure, this amount lies roughly between the larger city and smaller city reductions reported in Table 10-23.

Table 10-23 Impacts of Transit Service Expansion on Equivalent Vehicle Miles of Travel

Location	Annual VMT (millions)[a]	Annual New Bus Miles	Annual New Bus Passengers	Average Trip Length (miles)	Annual New Bus Passenger Miles	Annual Vehicle Miles if by Auto[b]	Annual Equivalent Vehicle Miles Reduced[c]	Equivalent Percent Reduction in VMT
Seattle, WA[d]	7,153	2,028,000	2,913,000	3.5	10,196,000	8,496,000	4,440,000	0.06%
Miami, FL[d]	5,917	1,850,000	6,064,000	3.5	21,224,000	17,867,000	13,987,000[e]	0.24
Portland, OR[d]	4,299	4,878,000	7,393,000	2.5	18,483,000	15,402,000	5,646,000	0.13
San Diego, CA[d]	6,929	2,158,000	3,933,000	3.0	11,799,000	9,833,000	5,517,000	0.08
Average for Larger Cities	6,075	2,729,000	5,076,000		15,425,000	12,899,000	7,397,000	0.13%
Madison, WI[d]	1,224	246,000	978,000	2.5	2,445,000	2,038,000	1,546,000	0.13%
Eugene, OR[d]	628	1,802,000	2,979,000	2.0	5,958,000	4,965,000	1,361,000	0.22
Raleigh, NC[d]	1,156	279,000	214,000	2.0	428,000	357,000	-201,000	-0.02
Bakersfield, CA[d]	709	329,000	529,000	2.5	1,323,000	1,102,000	444,000	0.06
Bay City, MI[f]	367	329,000	255,000	1.5	383,000	319,000	-339,000	-0.09
Greenville, NC[f]	96	134,000	107,000	1.5	161,000	134,000	-134,000	-0.14
Average for Smaller Cities	697	520,000	844,000		1,783,000	1,486,000	446,000	0.03%

Notes: [a] Based on 1972 DOT National Transportation Study.

[b] Assuming average auto occupancy is 1.2 persons per auto.

[c] Assuming one bus mile is equal to two equivalent passenger-car miles.

[d] Percentage increases in bus miles of service and ridership for these service expansions are provided in Table 10-3.

[e] (sic).

[f] New transit system.

Source: Wagner and Gilbert (1978) as presented in Pratt and Copple (1981).

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Energy and Environmental Relationships

In considering the energy and environmental impact of changes in transit service, it is necessary to assess not only the automotive energy and emissions savings of those trips new to transit that are former auto driver trips, but also the effect of the service change on transit energy consumption and emissions. This is particularly true with regard to bus service coverage and frequency changes.

A majority of comprehensive studies that have taken these tradeoffs into full account are now dated and made suspect to the extent that automotive fuel efficiency and emissions rates have changed substantially over time. Certain older studies are still helpful, however, in illustrating basic tradeoffs involved. A case in point is the energy assessment made of the ten areawide transit service expansion programs for which VMT reduction data were presented in Table 10-23. The estimated energy impact of these ten programs is outlined in Table 10-24, in terms of averages for the four larger cities (Seattle; Miami; Portland, Oregon; and San Diego) and the six smaller cities (Madison, Eugene, Raleigh, Bakersfield, Bay City, and Greenville, North Carolina). These programs involved some fare reductions, at least in constant dollar terms, but nothing dramatic (Wagner, 1980). There was no rail transit in any of these cities at the time.

Table 10-24 Impacts of Transit Service Expansion on 1970s Energy Consumption

Parameter	Average - 4 Largest Cities	Average - 6 Smaller Cities
Average Population	1,212,000	136,000
Fuel Savings (Gals. Annually)[a]		
Auto @ 15 mpg	857,000	99,000
Bus @ 5 mpg	-545,800	-104,000
Net Savings	311,200	-5,000
% Urban Transportation Fuel Savings	0.08%	Marginally Negative

Note: [a] Negative sign indicates additional consumption.

Source: Wagner (1980).

The data in Table 10-24 suggest that in small cities energy savings may be impossible to attain. For the larger cities examined, a savings of somewhat less than one tenth of one percent of regional auto fuel consumption was indicated after taking transit energy consumption into account.

A 1976 study of a more hypothetical nature obtained a similar result for San Diego, one of the "larger" cities of Table 10-24, but also investigated Chicago as an example of a high-density city with more intensive transit service. The study estimated a net energy loss for attempting to shift auto travel to transit through bus service expansion in the Chicago central city. It was concluded that net energy savings appear most difficult to achieve through coverage and frequency improvements alone where transit service is very dense, and least difficult with suburban service (Pratt and Shapiro, 1976). On the other hand, suburban bus service productivity and service density may be low to start with, such that the contribution to energy savings is not great.

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Fuel savings estimates have also been computed for early cases of major bus coverage and frequency improvement in San Diego and Atlanta. Strong synergistic benefits were obtained in these particular cases from implementation in conjunction with fare reductions (Pratt and Copple, 1981). Another illustration of this type of synergistic effect is provided by service improvements with a fare reduction in Los Angeles, described in Chapter 12, "Transit Pricing and Fares" under "Related Information and Impacts"—"Impacts on VMT, Energy and Environment." (See also "Related Information and Impacts"—"VMT, Energy and Environment" in Chapter 9, "Transit Scheduling and Frequency.")

Studies of 1970s bus service enhancements in Washington, DC, and Orange County, California, indicated that while net energy savings were marginal or negative under the circumstances that then pertained, the air quality benefits were more positive, relatively speaking (Pratt and Copple, 1981). Table 10-25 gives recent evaluations of vehicle trip reduction, VMT reduction and pollutant emissions reduction from a study of California Transportation Control Measures (TCMs) that utilized the latest available California Air Resources Board emissions factors (EMFAC7G) and explicitly took bus as well as auto emissions into account (Pansing, Schreffler and Sillings, 1998; Schreffler, Costa and Moyer, 1996).

Table 10-25 Effectiveness Ranges of California Fixed Route Transit and Shuttle TCMs

Effectiveness Measure and Project Category	Travel Mode Impacts[a]: Vehicle Trip Reduction	Travel Mode Impacts[a]: VMT Reduction	Emissions Reduction Impacts[a]: HC/ROGS	NOx	CO	PM-10
Reduction Impacts						
Line Haul	1,344 - 594,080	21,360 - 4,752,641	137 - 12,806	(55) - 9,269	975 - 121,067	5 - 26,649
Shuttle	1,984 - 35,713	9,950 - 835,380	187 - 1,019	6 - 1,100	2,376 - 10,056	14 - 286
Cost Effectiveness	**Cost/Trip Eliminated**	**Cost/VMT Eliminated**	**Cost per Pound Eliminated (all emissions)**			
Line Haul	$0.22 - $35.00	$0.03 - $2.20	$3.06 - $1,117.00			
Shuttle	$3.68 - $75.60	$0.05 - $27.70	$6.52 - $610.00			

Notes: [a] Impacts per project per year. An emissions increase is indicated by parentheses.

Source: Pansing, Schreffler and Sillings (1998).

The California results parallel those of earlier studies in that air quality benefits are shown but not universally for all projects in all emissions categories. The low end of the emissions savings range for NOx is negative for line haul bus projects. A total of 22 fixed route transit and shuttle projects were examined. Individual results were wide ranging. On the whole, the public transit projects were less effective and less efficient than either demand management or vanpooling TCMs. Within transit projects, line haul transit and shuttles connecting transit stations to home or work tended to provide the better results. Such projects had a peak period emphasis. Judged least effective were shuttles connecting homes to jobs a short distance away, which attracted short trips, few in number, and shuttles focused on midday travel. The evaluation did not attempt to examine sec-

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ond order effects (Pansing, Schreffler and Sillings, 1998; Schreffler, Costa and Moyer, 1996). For this reason, any impact on work trip mode choice by the availability of midday circulation would not have been considered.

Although bus routing and coverage enhancements acting alone have not generally proven to be significant contributors to energy savings and emissions reductions, they may be key contributors to overall strategy packages. The added accessibility and flexibility provided by the presence of transit service may be essential elements in making other strategy elements work, or in making them palatable politically and to program participants. In other words, any management of demand that relies heavily on making auto use less attractive needs to be counterbalanced by an array of actions that make available and enhance alternative means of travel. It is thus often important to include bus routing and coverage enhancements for this reason alone.

Costs and Feasibility

The long-term total capital and operating cost of increasing transit ridership with bus routing and coverage enhancements, such as typical peak period bus services, route restructuring, feeder services, and reverse commuter services, has been judged to be low, comparatively speaking. This is in a context where low cost approaches also include vanpool incentives, where services to employers are judged low to moderate in cost, where moderate cost approaches include express buses and park-and-ride, and where rail solutions are deemed moderate to high-cost approaches (Rosenbloom, 1998).[4]

Full development of a new transit route normally takes 1 to 3 years (see "Traveler Response Time Lag") so that a major cost element in extending service is sustaining operation while ridership builds up. Development costs and the causative gradual growth of ridership on new routes suggest an implementation approach that targets the expected development pace, such that if the gap between actual progress and the plan widens beyond an acceptable amount, the project can be aborted (Crain, 1970). Virtually no North American mass transit systems today meet costs with farebox revenues, so that an acceptable financial outcome for new route development will normally be some continuing deficit that government is willing to support.

New Jersey Transit, recognizing these factors, developed a set of farebox recovery ratio criteria to address route development subsidy needs in a context of long-term sustainability. These were applied to experimental routes initiated in 1994–95 using Congestion Mitigation and Air Quality (CMAQ) funds. The criteria required that, in order to remain in service, a new route had to achieve a 15 percent monthly farebox recovery by the end of the first year, 20 percent in the second year, and 25 percent in the third. Extensions or enhancements to existing service had to meet a slightly higher standard: 20, 25, and 30 percent farebox recovery for the first, second, and

[4] Conventional transit service may not always be the least-cost appropriate solution, however, especially in lower density suburbs and small cities—and when Americans with Disabilities Act (ADA) requirements are factored in. Recently reported examples: The Fort Worth and Houston transit systems have found express/radial bus service to many non-downtown destinations to be unaffordable, and promote the cost-saving alternative of employer partnerships featuring vanpool service. The Fort Worth per rider subsidy for serving this market went from $9.00 on bus to $1.25 in vanpool per passenger trip. The Denver Regional Transit District replaced an hourly full-sized fixed route bus circulator in the Brighton suburban neighborhood with a "Call-n-Ride" service passengers can contact directly via the driver's cell phone, increasing productivity from less than one passenger per bus hour to four per small-bus hour (Volinski, 2003). For primary "Vanpools and Buspools" coverage, see Chapter 5; and for "Demand Responsive/ADA" transit, see Chapter 6. For additional employer partnership applications, see Chapter 19, "Employer and Institutional TDM Strategies."

third years, respectively (Michael Baker et al, 1997). Certain types of routes may deserve more financial leeway than others. For example, the feeder character of many crosstown lines suggests that their costs need to be examined in relation to the system and not as independent entities (Rechel and Rogers, 1967).

Whatever the measure of feasibility and general type of route, there are strong indications that conventional bus routes that serve multiple markets fare better and are more likely to be retained on a permanent basis than most conventional single function routes. This being the case, market segmentation should arguably be used more as a service design tool than as an operating strategy—the strategy should be to serve multiple markets well or meet single function needs with exceptionally low cost approaches such as paratransit. Representative examples of multipurpose bus route successes are listed in Table 10-26.

Table 10-26 Multipurpose Bus Route Successes

Circumstance	Result	Sources
Seattle Route 8: Conventional crosstown service plus direct route to Seattle Center development and Group Health Hospital.	Above average passengers per bus mile productivity for King County Metro routes, after three years of operation.	King County DOT (1998b), Harper, Rynerson and Wold (1998-99).
Dallas Routes 428 and 466: Cross-suburbs routes modified to serve Light Rail stations and additional employment/activity centers.	Increases in passengers per bus mile productivity of 10 to 20%; ridership increase in highly elastic range.	Hufstedler (1998).
Denver downtown shuttle: Distribution for bus termini at each end, and LRT midway, plus provides workplace, retail, restaurant, entertainment connections.	Daily ridership of 54,000 on one mile route at cost per passenger of 22¢ per ride (free fare).	Jewell (1992), Kurth (1998), Urban Transportation Monitor (March 28, 1997).
"Ride-On" bus system: Virtually every route feeds Washington Metrorail or commuter rail and provides local suburban service, many with activity center focus.	Increase in ridership of 1,705% in response to increase in bus miles of 1,381% over 20 years; 1997 bus unlinked trip ridership of 17,433,000.	Bone (1998a and b).
New Jersey Transit Route 976: Commuter rail feeder from residential communities plus shuttle to employment sites.	Farebox recovery of 60% after two years, compared to 23% for Route 977, a residential-only feeder serving the same communities and rail station[a].	Michael Baker et al (1997).
Experimental routes of the 1960s connecting high unemployment areas to suburban jobs.	Multi-user routes that served not only poverty area to employment travel but also other travel as well were the most successful.	Crain (1970)

Notes: [a] Route 977 is operated as a demand responsive service — see Chapter 6, "Demand Responsive/ADA."

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Planning additional service requires choices to be made among the various types of bus routing and coverage options, frequency increases, and express service and determination of whether the changes are to be peak, midday, evening, and/or weekend oriented. Providing a comprehensive package of improvements is apparently beneficial (Holland, 1974); certainly one of the largest reported percentage gains of new bus riders was in response to the reorganized routes, lower fares, new buses, and new schedule introduced simultaneously in Iowa City. Success may bring added costs, however, as in Iowa City where the subsidy requirement increased when crowding required service expansion (Dueker and Stoner, 1972).

ADDITIONAL RESOURCES

An extensive compilation of transit service elasticities in developed countries, along with related evaluations and interpretations, is found in a report of the International Collaborative Study of the Factors Affecting Public Transport Patronage, *The Demand for Public Transport,* published by the Transport and Road Research Laboratory (Webster and Bly, 1980). As of final publication of this chapter, a periodically updated source that includes service elasticities along with references and leads to more information is the "Transportation Elasticities" compendium maintained on the www.vtpi.org website (Victoria Transport Policy Institute, 2003).

Several recent reports contain brief summaries of 1990s transit service change actions and outcomes. These include the National Center for Transit Research (NCTR) report, *Lessons Learned in Transit Efficiencies, Revenue Generation, and Cost Reductions—Second Edition* (including early 2000s reportings) (Volinski, 2003); TCRP Report 28, "Transit Markets of the Future: The Challenge of Change" (Rosenbloom, 1998); TCRP Research Results Digests Numbers 4 and 29, "Transit Ridership Initiative" and "Continuing Examination of Successful Transit Ridership Initiatives" (Stanley, 1995 and 1998); and TCRP Report 27, "Building Transit Ridership—An Exploration of Transit's Market Share and the Public Policies That Influence It" (Charles River Associates, 1997). TCRP Report 27 also provides quantitative analysis of factors influencing urban mode choice, among other assessments of interest to transit planners and travel demand analysts.

Finally, in the Second Edition of the textbook *Public Transportation* edited by Gray and Hoel, Chapter 13, "System and Service Planning," provides a comprehensive treatise on the planning of urban transit systems and services, including principles that underlie system planning and service planning methods for bus transit (Levinson, 1992).

CASE STUDIES

Transit Route and Schedule Improvements in Eight Cities and New Transit Systems in Four Previously Unserved Areas

Situation/Analysis. The study *Transportation System Management: An Assessment of Impacts* included an oft-quoted chapter, "Impact of Transit Route and Scheduling Improvements," providing comparative analysis of twelve 1970s transit service demonstrations. The analysis examined the short-term results of comprehensive transit route and schedule improvements in 8 cities and the effects of the introduction of transit service into 4 areas previously unserved.

Measures of transit system effectiveness in terms of service, ridership and productivity, VMT reduction, and revenue and expense were presented for each system. The effects of inflation (declining fares in constant dollars), along with fare zone redistricting, multi-ride passes, special student or seniors fares, and other exogenous factors were not segregated out in the analysis.

Actions/Results. In all 8 comprehensive improvement cases, the systems were mature with stable operation and made minor, if any, fare changes during the analysis period. Significant comprehensive service increases, in terms of bus miles, occurred over 1 to 3 years and included the extension and addition of routes, route restructuring, and increases in frequency and hours of service. Table 10-27 gives base year characteristics on an annual basis along with the subsequent changes in service parameters and ridership for the 8 systems that underwent comprehensive improvements.

Table 10-27 Service and Ridership Changes in Cities with Comprehensive Route and Schedule Improvements

Location	Peak Buses	Bus Miles (000)	Riders (000)	Passengers /Bus-Mile (before/after)	Percent Change in Peak Buses	Percent Change in Bus Miles	Percent Change in Riders
Seattle	496	21,121	35,096	1.66/1.63	0.0%	+9.6%	+8.3%
Miami	298	14,794	55,631	3.76/3.71	+41.9	+12.5	+10.9
Portland	249	11,478	20,310	1.77/1.67	+54.2	+42.5	+36.4
San Diego	185	10,736	29,575	2.75/2.64	+35.7	+20.1	+13.3
Madison	104	3,234	10,992	3.40/3.44	+13.5	+7.6	+8.9
Eugene	35	1,082	1,098	1.01/1.41	+31.4	+166.5	+271.3
Raleigh	21	976	1,964	2.01/1.45	+66.7	+28.6	+10.9
Bakersfield	14	648	1,079	1.66/1.51	+50.0	+50.8	+49.0

The 4 new systems ranged from one with 3 peak buses and 134,000 annual bus miles serving a 24,000 population to one with 88 peak buses and 6,561,000 bus miles serving a 1,864,000 population. See characteristics of the 4 new systems in Tables 10-1 and 10-2. Three of the systems exhibited passengers/mile ratios of 0.8 to 1.1 after 1 year of operation, while the fourth recorded a ratio of 2.1 after 2 years. The authors concluded that unless new systems serving local travel achieve passengers/mile ratios of at least 0.6 to 0.8, pressure to revise routing or convert to a demand responsive mode will result. (See Table 10-23 for VMT reduction estimates for the 12 comprehensive service improvements and the 4 new systems.)

More . . . Bakersfield, California, was highlighted as a case example of a comprehensive service improvement. Fourteen new buses were placed in service. Seven were used to expand service and seven replaced existing old but well-maintained and attractive buses. Service frequency was not increased, but greater route choice in some areas effectively increased frequency. Major route restructuring took place with new routes providing two-way service in areas previously served by one-way loops. Outlying shopping areas were made a focus of several routes, improving service to these points. Some routes were extended to areas previously unserved. New system maps and schedules were prepared and multiride fares instituted. Over the course of the first 6 months, the service elasticity was +0.78. By the end of the third year, it was +0.97.

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Greenville, North Carolina, was highlighted as a case example of a new transit system. Three routes, two of which were large loops, were initiated. One bus was assigned to each route, making one round trip each hour. All routes served the downtown, the principal outlying shopping center, and the social service facility. Little transferring was required, although the loop routing required some trips to be indirect. Fares were 25¢, transfers were free, and a reduced seniors fare was available. Schedules and maps were prepared and limited marketing was undertaken. In addition to weekday service, Saturday service was added in the fourth month. Aside from the first month when some promotional free trips were given, passengers/mile averaged 0.7 over the first 7 months. Over the next 4 months, passengers/mile averaged 0.9.

Twenty years later Greenville's "Great Bus System" has 4 routes in an east-west and north-south configuration, all passing through downtown, but potentially requiring a transfer to reach other activity centers. Headway is hourly and Saturday service is provided. Base fares are 60¢, transfers are 10¢, and the elderly and handicapped travel for half fare. ADA requirements are met through a coordinated human services provider contract. In 1997, with population up from 24,000 to an estimated 58,000, total ridership was 220,300, slightly over twice first year ridership, and passengers/mile averaged 1.3.

Sources: Wagner, F. A., and Gilbert, K., *Transportation System Management: An Assessment of Impacts. Interim Report.* Alan M. Voorhees & Associates, Inc., McLean, VA (November, 1978). • Harrington, N., Great Bus System, City of Greenville, NC. Telephone interviews (August 25— December 7, 1998).

Long-Term Large Scale Bus Service Expansions in Three Growing Areas

Situation. Montgomery County, Maryland, and Santa Clara County, California, fast-growing counties of the Washington, DC, suburbs and the San Francisco Bay Area, were in the early 1970s only partially served by bus operations following mostly historical routings. In each county, new public operating agencies embarked on large scale service expansion programs. Ride-On bus service, in Montgomery County, was initiated prior to the opening of Washington's Metrorail, and continued growing, with feeder and local service emphasis, as Metrorail penetrated well into the county. The prior bus operator, Metrobus, was maintained as a complementary operation, with some net absorption of Metrobus service occurring only after 1991. The Santa Clara County Transit District, now Santa Clara Valley Transportation Authority (VTA), took over the preexisting bus service, but not the commuter rail line into San Francisco, and developed a grid of bus routes throughout greater San Jose and "Silicon Valley." The network included a coarser grid of express bus lines, many operating on expressway HOV lanes. A Light Rail line was opened in 1988. Similar conditions and bus service expansion pertained in Orange County, California, but without introduction of rail service within the study period.

Actions. Ride-On started in 1975, while VTA's predecessor agency and the Orange County Transit District (OCTD), now the Orange County Transportation Authority, took over from private operators in 1973. Bus mile and/or bus hour service growth statistics for Ride-On and VTA are provided in Tables 10-28 and 10-29. Ride-On service went up by a factor of 15 from 1977 to 1997. VTA bus service more than doubled during the same period, mostly in the initial years. OCTD quintupled service between 1974 and 1989.

Analysis. This evaluation documents ridership growth in presumed response to increases in bus service coupled with demographic and economic growth and calculates log arc service elasticities. Interplay with parallel and intersecting transit services was not analyzed, nor was data collected on fare changes or other influences. Standard service and ridership measures are used along with, where possible, ridership normalized for population growth (bus rides per capita). The five year periods chosen for Montgomery and Santa Clara counties were selected to straddle missing data and avoid a mid-1970s period of dial-a-ride experimentation in Santa Clara County. Elasticities for time period breakouts where service shrank or grew little, and was erratic are omitted and marked with an asterisk in the tabulations of results. These instances include periods where ridership went up even though service went down or vice-versa. Statistical modeling to investigate these anomalies and quantify the role of exogenous factors, such as the post-1995 economic resurgence in Santa Clara County, was not undertaken. Summary elasticities given for the full multi-period time spans are based on the initial and final data points only.

Results. Tables 10-28 and 10-29 present data and elasticities for Montgomery County Ride-On and Santa Clara VTA, covering only bus services and excluding other operators.

Table 10-28 Montgomery County Ride-On Demographic and Service Parameters and Changes

Year	County Population	County Employment	Annual Bus Miles	Annual Bus Rides	Service Elasticity	Annual Bus Rides/Capita	Normalized Elasticity
1977	581,000	268,000	606,000	966,000	—	1.66	—
1982	593,000	319,000	2,890,000	5,725,000	+1.14	9.65	+1.13
1987	680,000	419,000	6,389,000	12,266,000	+0.96	18.04	+0.79
1992	773,000	446,000	7,689,000	15,218,000	+1.16	19.69	+0.47
1997	828,000	477,000	8,974,000	17,433,000	+0.88	21.05	+0.43
1977–97	+42%	+78%	+1,381%	+1,705%	+1.07	+1,168%	+0.94

Table 10-29 Santa Clara VTA Demographic and Service Parameters and Changes

Year	County Population	County Employment	Annual Bus Hrs.	Annual Bus Rides	Service Elasticity	Annual Bus Rides/Capita	Normalized Elasticity
1977	1,224,000	544,000	657,000	15,600,000	—	12.74	—
1982	1,329,000	702,000	1,289,000	34,310,000	+1.17	25.82	+1.05
1987	1,408,000	788,000	1,524,000	37,020,000	*	26.29	*
1992	1,538,000	788,000	1,563,000	38,940,000	*	25.32	*
1997	1,653,000	933,000	1,408,000	45,890,000	*	27.76	*
1977–97	+35%	+72%	+114%	+194%	+1.42	+118%	+1.02

Note: Asterisks indicate time periods where modest service changes gave erratic elasticities.

More . . . Bus ridership increased percentagewise as much or more than service in all three areas. Ride-On in Montgomery County matured into a system boarding 1.94 passengers per bus mile (26.5 per bus hour) in 1997. Santa Clara VTA is achieving 32.6 passengers per bus hour. The

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service elasticities derived by attributing to the service increases the entire change in ridership over the full case study time spans range from +1.07 for Ride-On to +1.42 in Santa Clara County, and approximately +1.33 for OCTD in Orange County. These values pertain only in the context of population and employment growth on the order of 2 to 6 percent average per year. Normalizing out the effect of population growth by computing elasticities on the basis of rides per capita, the service elasticities drop to a range from +0.94 for Ride-On to +1.02 in Santa Clara County. Normalizing on the basis of employment, the service elasticity for OCTD becomes approximately +0.92. (The authors of the cited paper on Orange County use a double-log econometric model taking service and employment into account to obtain a +1.04 service elasticity but reject this as exhibiting bias and being "too high by industry standards," and proffer instead a +0.68 value obtained with an alternative formulation.)

Sources: Bone, D. F., Division of Transit Services, Montgomery County DOT, Rockville, MD. Telephone interviews (March, 1998a). • Bone, D. F., Facsimile to the authors, (April 2, 1998b). • Lightbody, J. R., Santa Clara Valley Transportation Authority, San Jose, CA. Personal interview (March 4, 1998). • Santa Clara Valley Transportation Authority, San Jose, CA. *Service and Demographic History.* Tabulation [1998]. • Ferguson, E., "Temporal Effects of Incidents on Transit Ridership in Orange County, California." *Transportation Research Record 1297* (1991). • Assembly of Montgomery County population and employment data, calculations of elasticities, and interpretations are by the Handbook authors, except as noted.

A Combined Program of Improvements with Fare Changes in Iowa City

Situation. On September 1, 1971, the municipal government of Iowa City assumed the ownership and operation of the city's bus transit system. The former operator had maintained a relatively constant service level throughout a period of metropolitan and automobile usage growth while raising fares, and transit use had declined from 4 percent of all urban area trips in 1964 to 1 percent in 1970. Five of seven former line-haul bus routes contained long l-way loops used to expand area coverage. Most new areas of the city were not served. Headways were 30 minutes on four routes and 20 minutes on the remaining three. Meanwhile the city's population grew by 40 percent between 1960 and 1970, to approach 50,000 residents, including 20,000 University of Iowa students. The central business district and the adjacent university campus and hospital complex attracted over 25 percent of all urbanized area trips and thus provided a central activity focus inherently conducive to transit service.

Actions. The new municipal operator simultaneously reduced the 25¢ base fare to 15¢ and increased the number of routes from seven to ten. The prior routes were redesigned and through-routed to provide five cross-town route pairs. The new routings increased coverage by 20 percent, providing service within 3 blocks of most residential areas, and reduced average rider times. A 15¢ base fare was selected on the basis of ridership responses to fare variations instituted in conjunction with public and university transit subsidies between 1967 and 1970. This experience indicated that a 25¢ to 15¢ fare decrease alone should produce a 57 percent ridership increase. The old 31- and 35-passenger buses, averaging 14 years in age, were replaced with new 45-passenger models. An all day system-wide service headway of 30 minutes was established initially; however, in January 1972, 5 buses were leased to alleviate capacity deficiencies, and headways were reduced to 20 minutes in the peak periods. Service was provided between 6:30 AM and 6:30 PM, 6 days per week, as under private management.

Results. Transit patronage rose from 85,540 in September 1971, the first month of the new operation, to 136,582 in February 1972. Ridership for the 6 months was up 165 percent over the same period for the prior year. Parking revenues dropped by 11 percent over the prior year. The additional service added in late January 1972 prompted a 10 percent increase in ridership by the end of February. In general, daily transit ridership grew from 2,000 trips before the service improvements to 6,000 trips with the new system. Saturday patronage also increased three-fold because the lower fare was attractive to youths. The weekday proportion of all downtown oriented trips using transit increased from 3 percent to 11 percent with the new system.

University scheduling and climatic conditions normally generated variations in monthly ridership, ranging from August's 5.68 percent share of annual ridership to January's 11.22 percent share; however, these variations became less pronounced as the improvements attracted increased patronage from choice riders, shoppers, and youths. The service required subsidy, and the necessary subsidy increased when crowding required service expansion.

More . . . A free campus-oriented shuttle transit service was instituted in the spring of 1972 with university sponsorship. The average daily ridership of 7,000 primarily comprised diverted walk trips; however, it was estimated that 500 automobiles were eliminated from the central campus.

Source: Dueker, K. J., and Stoner, J., "Examination of Improved Transit Service." *Transportation Research Record 419* (1972).

Service Changes with Unlimited Travel Pass Partnerships in Boise

Situation. Boise Urban Stages (THE BUS) began operations in 1973, shortly after cessation of service by the prior operator. The economy of Boise had been steadily expanding. Population growth averaged 2 to 3 percent a year in the 1980 through 1996 period. Bus transit nevertheless experienced a slump in service provided and ridership around 1990, at which time 1 percent of journey to work trips in the region were made by transit. In 1992, a major program of service expansion coupled with development of unlimited travel pass partnerships was initiated. Throughout the service expansion, until January 1996, the route structure was basically a "spoke and wheel" system centered around downtown.

Actions. Boise Urban Stages service was increased by nearly half between 1991 and 1995. The bus miles and bus hours per year are listed in Table 10-30. This expansion was complemented by entering into a partnership with Boise State University to provide students, staff, and faculty with unlimited access to THE BUS fixed route services, with the cost of providing the service picked up by the University. That program was then extended by establishing similar partnerships with 14 other large public and private organizations in the region. The dual service expansion and pass partnership thrust was also accompanied by very personalized bus service and extensive public outreach. At the conclusion of the expansion program, a major service restructuring took place, as described under "More . . ."

Analysis. This evaluation was based on annual operating and ridership statistics along with population estimates by year for the city of Boise, which contributes over 80 percent of Boise Urban Stages ridership. Log arc service elasticities were calculated from the several perspectives identified below. Both bus miles and bus hours measures were used (the results were identical or very close) along with ridership normalized for population growth (bus rides per capita, using city population as the base). Fares were not taken into account, but elasticities were estimated with and without the ridership attracted by the pass partnerships. Multi-year service elasticities were all based on the initial and final data points only.

Results. The combined effect of service increases, unlimited travel pass partnerships, and population growth produced bus ridership increases that kept pace with the substantial service increases, as shown in Table 10-30. Operating efficiency stayed within the range of 1.24 to 1.45 boardings per bus mile (16.7 to 19.6 per bus hour).

Two aspects of the program make calculation of unambiguous service elasticities problematic: the period of time of the case study versus when the changes were made and the concurrent expansion of the free pass program. The peak service growth years were 1992 to 1995. If all ridership changes during this period are attributed solely to service changes, the derived service elasticity is +1.42 (+1.17 if adjusted for population growth by computing elasticity on the basis of rides per capita). The pass partnerships themselves were, however, estimated by Boise Urban Stages to have attracted 100,000 trips annually. If these 100,000 trips attributed to the pass partnerships are deducted, the corresponding service elasticity is +1.21 (+0.96 if adjusted for population growth). Lower elasticity estimates are obtained if data for the full 1991–96 case study time span are used because both the 1991–92 and 1995–96 periods saw declines in ridership. The overall service elasticity is +0.8 if all ridership changes during the case study period are attributed to service changes and is about +0.45 if adjusted for both the pass program and population growth.

Table 10-30 Boise Urban Stages Demographic and Service Parameters and Changes

Year	City Population	Annual Bus Miles	Annual Bus Hours	Annual Bus Rides	Annual Bus Rides/Capita	Passengers / Bus Mile	Passengers / Bus Hour
1991	133,000	613,100	45,000	801,200	6.02	1.31	17.8
1992	137,200	625,800	46,300	773,800	5.64	1.24	16.7
1993	142,300	675,800	49,900	847,000	5.95	1.25	17.0
1994	146,600	796,100	58,600	1,051,000	7.17	1.32	17.9
1995	150,600	912,100	67,400	1,320,000	8.76	1.45	19.6
1996	152,700	913,100	65,800	1,193,200	7.81	1.31	18.1
1991–96	+15%	+49%	+46%	+49%	+30%	0%	+2%

More . . . In January 1996, the entire fixed-route system was revised on the basis of exhaustive civic involvement. The "spoke and wheel" structure was transitioned toward a hybrid structure utilizing elements of both hub-spoke and grid route systems. The change involved adding bus miles but reducing bus hours, indicating that speeds were increased. Despite a major marketing campaign focused on educating existing passengers, including a "Bus Riding 101" course, passenger statistics indicate a 10 percent ridership loss from 1995 to 1996, stabilizing to a 1 percent loss from 1996 to 1997. The effect of the 1995 to 1996 ridership loss is included in the final set of service elasticities presented above.

Sources: Boise Urban Stages, Application to the American Public Transit Association for *Outstanding Transit System in North America* award. Boise, ID [1996]. • May, L., Boise Urban Stages, Boise, ID. Facsimile and e-mail to the authors (July 1 and July 28, 1998). • Michael Baker Corporation, Crain & Associates, LKC Consulting Services, and Howard/Stein-Hudson, "The Potential of Public Transit as a Transportation Control Measure: Case Studies and Innovations, Draft Document." Annapolis, MD (October, 1997). • Assembly of population data, calculations of elasticities, and interpretations are by Handbook authors.

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Service Restructuring and New Services in Metropolitan Seattle

Situation. A "Six-Year Transit Development Plan 1996–2001" was adopted in late 1995 by the Metropolitan King County Council for Seattle and its suburbs. Implementation began concurrently and is continuing. Plan objectives include: *Mobility*—Increasing access to a broader range of travel destinations using public transportation, *Market Share*—Targeting selected non-Downtown Seattle employment areas to increase public transportation market share, and *Cost and Efficiency*—Reinvesting unsuccessful services consistent with the overall service concept. Results to date are based on the 3-1/3 year span from the fall of 1994 to the spring of 1998. During the 1994–1997 three year period, King County inclusive of Seattle grew from 1,599,500 to 1,646,200 in population (up 2.9 percent) and from 1,054,600 to 1,179,200 in employment (up 11.8 percent); Seattle alone grew from 531,400 to 536,600 in population (up 1.0 percent) and from 458,000 to 531,000 in employment (up 15.9 percent).

Actions. King County Metro service restructuring and expansion under the Six-Year Plan has focused on establishment of a new multi-centered "hub and spoke" system, involving particularly services to the suburbs and outer Seattle neighborhoods; development of higher frequency services in key corridors, often by means of route consolidation; and addressing changing demographics with improved crosstown, community, and reverse-commute services. Service redesign has been an intensive, multistage process starting with a sample network for each subarea, for which local jurisdiction support was obtained, progressing through a community-based "Sounding Board" detailed design process, and culminating in securing political support for the final design. Census work trip origin-destination data at the traffic analysis zone level of detail, winners/losers assessments, on/off boarding data, special counts, non-user surveys, and staff and citizen local knowledge were all applied at appropriate stages.

Individual service changes are described in connection with results. Table 10-31 provides the overall picture, giving 1994 through 1998 annualized service (platform) hours and ridership (unlinked trips) exclusive of the Ride Free Area in Seattle's downtown. The east and south regional sectors are suburban; the west sector is Seattle plus the suburbs directly north. The table also gives efficiency in terms of boardings per service hour.

Table 10-31 King County Metro Service Hours, Ridership and Rides per Service Hour

	Service Hours (Thousands)				Unlinked Trips (Thousands)				Trips per Service Hour			
Year	East	South	West	Total	East	South	West	Total	East	South	West	Total
Fall 1994	514	633	1,671	2,818	8,112	12,744	55,885	76,741	15.8	20.1	33.4	27.2
Fall 1995	522	651	1,696	2,869	8,619	14,182	57,686	80,487	16.5	21.8	34.0	28.1
Fall 1996	553	699	1,714	2,966	9,490	15,459	59,956	84,905	17.2	22.1	35.0	28.6
Fall 1997	612	747	1,762	3,121	10,985	17,287	61,383	89,655	17.9	23.1	34.8	28.7
Spring 1998	615	753	1,780	3,148	10,675	17,771	62,887	91,333	17.4	23.6	35.3	29.0
Percent Growth	19.6	19.0	6.5	11.7	31.6	39.4	12.5	19.0	10.0	17.2	5.6	6.5%

Note: Percent Growth (positive in all cases) is calculated over the full 3-1/3-year time span.

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Analysis. Ridership data was primarily obtained in the form of unlinked trips estimated from automatic passenger counting. For specific corridors where possible changes in the transfer rate were of special concern, screenline counts were used to validate ridership growth observations. There were no fare changes that would affect the counts utilized, but there was significant growth in employer partnerships providing subsidization of employee transit passes. On the other hand, gasoline prices fell. Because of the particularly strong economy during the analysis period, more reliance is placed on trips per service hour performance comparisons than on the absolute ridership growth rates and elasticities are computed only to scale overall performance.

Results. Table 10-31 includes percentage growth in service, unlinked trip ridership and trips per service hour efficiency during the 3-1/3-year 1994–1998 period. Countywide, service was increased 11.7 percent, ridership gained 19.0 percent, and boardings per hour increased 6.5 percent. Service elasticities calculated directly from this data are +1.5 for the east sector, +1.9 for the south and west sectors, including Seattle, and +1.6 overall. Normalizing for population growth by computing elasticity on the basis of rides per capita dampens the regional average result to +1.3 overall. Compensating for the sharp growth of employment takes the elasticity down from the elastic to the inelastic range: +0.8 normalizing for the average of population and employment growth. However the computation is made, it is clear that King County Metro achieved a strong performance in the 1994–1998 period. The role of individual service changes is explored below, with emphasis on service restructuring and core route enhancement activities.

A major hub and spoke restructuring of bus service to and around Renton, south of Seattle, took the form of consolidating six routes between the Renton area and Seattle into three redesigned Renton-Seattle routes serving a Renton Transit Center hub and several community service routes focused primarily on the same transit center. The community service routes cover tails and other segments of the original routes. The Renton restructuring was in 1996.

Headway on the principal routes in the before condition ranged from 20 to 30 minutes peak and 30 to 60 minutes midday. In the after condition, the designated core route and a second more local route, both of which have I-5 express components, offer a 15 minute or better headway in the peak and 30 minutes midday, Saturday, and (one route only) Sunday. Most of the community service routes operate at a 30 minute headway all day, a major enhancement of midday service, and 60 minutes weekends. The trade-off for passengers in exchange for enhanced frequencies and route configurations is the need for through passengers to transfer from community routes to the Seattle routes at the hub. It should be noted that other 15 and 30 minute headway intrasuburbs routes feed and distribute from the Renton Transit Center.

Screenline counts taken north of Renton (toward Seattle) in 1995 and 1997 show a two-year ridership growth of 23 percent. Such counts totally avoid potential double counting of transfer passengers but miss short trips not crossing the screenline. Boardings, examining only routes connecting Renton with Seattle proper in the interests of not inflating the count with transfers, increased during the 3-1/3 years between 1994 and 1998 by 24 to 36 percent (including 16 to 26 percent in the peak and 28 to 45 percent in the midday). The lower growth values are computed for through routes only, assuredly understating overall corridor ridership growth, while the higher values include all routes penetrating Seattle, introducing a modest possibility of double counting. Other details are provided in Table 10-32, including a comparison with the Renton Highlands express routes via I-90, which were not involved in the service restructuring but received modest increases in platform hours of service.

Table 10-32 Renton Corridor Before and After Ridership, Service and Productivities

Time Period	Fall 1994	Spring 1998		1994–1998 Percent Change	
Category and Measure	Through Routes[a]	Comparable Routes[b]	Through Routes Only	Comparable Routes[b]	Through Routes Only
I-5 Corridor Peak Period					
Passenger Boardings	3,225	4,073	3,750	+26%	+16%
Bus Hours	141.0	113.6	101.4	–[c]	-28%
Passengers/Hour	22.9	35.8	37.0	–[c]	+62%
I-5 Corridor Midday					
Passenger Boardings	1,594	2,305	2,040	+45%	+28%
Bus Hours	54.7	74.4	61.8	–[c]	+13%
Passengers/Hour	29.1	31.0	33.0	–[c]	+13%
I-5 Corridor All Day					
Passenger Boardings	5,708	7,738	7,056	+36%	+24%
Bus Hours	251.1	252.0	216.2	–[c]	-14%
Passengers/Hour	22.7	30.7	32.6	–[c]	+44%
I-90 Express Peak Period					
Passenger Boardings	764	959		+26%	
Bus Hours	42	47		+12%	
Passengers/Hour	18.2	20.4		+12%	

Notes: [a] All routes connecting Renton with Seattle proper were through routes to downtown in Fall 1994 except for certain industrial services.

[b] Routes connecting Renton with Seattle proper, but not necessarily through to downtown as in Fall 1994. Comparability with Fall 1994 is limited by substitution of community service routes for tails of certain routes operated in 1994. Such routes are not included in the accounting if south or east of Renton, in order to minimize passenger double-counting.

[c] Exclusion of community service routes (see note above) results in an undercount of the bus hours required to maintain comparable service, invalidating the comparisons indicated. See Table 10-33 instead.

It appears that Renton Corridor ridership grew during peak periods at a rate similar to or perhaps slightly less than the I-90 Express "control group," but that more dramatic gains in off-peak ridership were obtained. At the same time, major increases were achieved in the efficiency of utilization of through buses to downtown Seattle. Peak period passengers per through-bus hour increased 62 percent. Use of the system's articulateds was enhanced, with average seat utilization increasing from 42 percent on 21 articulateds to 55 percent on 27 articulateds. All but 2 of 25 forty-foot buses were released from the service. Service hours gained were in part reallocated to midday service.

Community route passengers gained in the area south and east of Renton are in addition to the trips included in Table 10-32. Midday unlinked trips on all routes to and within the broader Renton service area increased by 54 percent over the 3-1/3 years between 1994 and 1998.

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"Before" transfer rate data is lacking, but comparison of the "after" transfer rate of 56 percent with the 49 percent rate for south King County as a whole suggests that the increase in midday linked trips might be roughly 47 percent or so. Ridership and service measures for the entire Renton corridor, including community feeders to the south and east, are discussed with respect to Table 10-33.

Table 10-33 summarizes full weekday ridership and service measures for the Renton hub-and-spoke service consolidation, a similar Bellevue hub-and-spoke service consolidation, and two other service consolidations designed to enhance core route service frequencies. Unlike the data presented in Table 10-32, the Renton Corridor data in Table 10-33 includes all of the feeder and other routes involved in the overall Renton area restructuring and consolidation.

Table 10-33 Core Route Consolidation Before and After Weekday Ridership, Service and Productivities

Time Period and Measure	Fall 1994	Spring 1998	Percent Change
Renton-Seattle CBD Restructuring - *I-5 corridor and other routes with associated changes*			
Weekday Passenger Boardings	7,458	11,304	+52%
Best Headways (Peak/Midday/Evening)	20/30/30[a]	7-15[b,c]/30/30[a]	
Weekday Bus Hours	364	447	+23%
Productivity (Weekday Passengers/Hour)	20.5	25.3	+23%
Bellevue-Seattle CBD Restructuring - *cross-lake and other routes with associated changes*			
Weekday Passenger Boardings	6,272	8,878	+42%
Best Headways (Peak/Midday/Evening)	15[b]/30/30	5-8[b]/15/30	
Weekday Bus Hours	292	389	+33%
Productivity (Weekday Passengers/Hour)	21.5	22.8	+6%
I-5 Northgate - Seattle CBD Restructuring - *I-5 routes and other routes with associated changes*			
Weekday Passenger Boardings	7,032	8,984	+28%
Best Headways (Peak/Midday/Evening)	4-8+[b,d]/15/30	4-7[b,e]/15[e]/30	See Note[f]
Weekday Bus Hours	253	305	+21%
Productivity (Weekday Passengers/Hour)	27.8	29.5	+6%
Bellevue - University District Restructuring - *S.R. 520 and associated Eastgate local services*			
Weekday Passenger Boardings	1,798	2,761	+54%
Best Headways (Peak/Midday/Evening)	20[b,d,g]/30[d]/60	15[g]/30/60	
Weekday Bus Hours	108	128	+18%
Productivity (Weekday Passengers/Hour)	16.6	21.6	+30%

Notes: [a] Via parallel route.
[b] Peak direction headway; lesser frequency in the reverse peak direction.
[c] Highest frequencies apply only as far as Renton Park and Ride (turnback point).
[d] Combined headway of two routes.
[e] Combined headway of two routes as integrated and shown on same schedule.
[f] Other changes include doubling previously hourly peak/midday Woodinville service.
[g] Applies only as far as Bellevue Transit Center; 30 minute headway beyond.

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The substantial ridership growth for each of these service consolidations, ranging from 28 to 54 percent over 3-1/3 years, is sufficiently above that for the regional sectors involved to give reasonable certainty that the difference is not simply an artifact of increased transferring. Growth in productivity for the Cross-Lake Bellevue—Seattle Corridor, which had only half a year to adjust at the time of evaluation, is 40 percent below the east sector productivity growth. Otherwise, growth in productivity, 6 to 30 percent, ranges from equal to the applicable regional sector average to three times the sector average productivity growth in the case of the Bellevue—University District consolidation. Three "control" routes similar to those directly involved in the Bellevue—University District consolidation, which were not altered significantly, had about the same riders and productivity in 1998 as in 1984.

Two additional existing core routes, both suburbs-to-suburbs in orientation, were improved within a time frame allowing evaluation. Route 181, interconnecting far south suburbs, received frequency improvement from a 60 minute all day headway to 30 minutes peak and midday and 60 minute evening along with interlining modifications. Ridership increased by 93 percent from the Fall of 1995 to the Spring of 1998; from 461 to 891 average weekday trips, but with a drop in productivity from 19.8 to 15.1 rides per platform hour. Route 240, providing mostly local hourly service between the major suburban centers of Bellevue and Renton, was given a more direct routing that saved about 10 percent in average travel time, and a 20 percent increase in bus trips that improved peak headway from 60 to 30 minutes. Weekday ridership increased by 58 percent during the 3-1/3-year period, from 762 to 1,207 on average, with a 48 percent increase in productivity from 13.0 to 19.2 rides per platform hour.

More . . . In the service restructuring designs adopted, additional transfers were accepted to obtain rationalized routings and enhanced frequencies. Observations at the Renton Transit Center indicated that final adjusted schedules resulted in 100 percent reliability of new transfer connections when traffic flow is normal. Renton rider satisfaction surveys indicated that although the number of transfers was objected to, overall satisfaction levels were as good among those having to transfer as among those not having to (over 80 percent graded the service "A" or "B"). In Bellevue, observed transfer connections were made 100 percent of the time in the midday but only 38 to 83 percent of the time in the PM peak. Here the percentages of riders grading the service "A" or "B" were also over 80 percent or nearly so, but there were 12 to 14 percentage point differences between those who did not have to transfer and the less satisfied transfer passengers. Bellevue schedules were further adjusted.

For information on additional King County Metro Six-Year Plan actions, see "Changed Urban Coverage"—"Crosstown Routes," and "Feeder Routes"—"Feeders to Trunk-Line Bus Routes," within the "Response by Type of Service and Strategy" section of this chapter.

Sources: King County Department of Transportation, Transit Division, Service Development Section, "Six-Year Transit Development Plan 1996–2001: Status of Service Implementation and Preliminary Results" (October, 1998b). • Harper, D., Rynerson, D., and Wold, M., King County Department of Transportation, Seattle, WA. Facsimiles and e-mail to the authors, with tabulations (October 27, 1998–January 5, 1999). • King County Department of Transportation. Bus Schedules, September 19, 1998 through February 5, 1999. Seattle, WA. "Metro Online." http://transit.metrokc.gov (Website accessed November, 1998a). • Assembly of demographics, estimation of elasticities, and certain other calculations and interpretations by Handbook authors.

Impacts of a Bus Transit Strike in the San Francisco East Bay Cities

Situation/Action. A 62-day bus strike began July 1, 1974, at the Alameda-Contra Costa Transit District (AC Transit) of the San Francisco Bay area. At the time of the strike, the district had a population of 950,000 in Oakland and the other East Bay suburbs, covered 200 sq. miles of area, and had 200,000 bus trips made each day. Of these, 33 percent were transbay to San Francisco, 8 percent transferred to the Bay Area Rapid Transit (BART), and 60 percent were internal. Trains of the Bay Area Rapid Transit (BART) kept running during the strike, but did not connect Oakland and San Francisco, as BART had not yet initiated transbay service. The majority of the AC Transit district population was beyond easy walking distance to BART, which served the district with 3 rapid rail lines and 18 of the 25 area BART stations. Of the 42,000 daily trips made on the 3 BART lines, 74 percent exited within the AC Transit district, and 25 percent of these transferred to local buses along with 5 percent to transbay buses.

Analysis. Vehicle and passenger counts on bridges, from AC Transit patronage and revenue forms, and at BART stations were analyzed to determine the relationship between BART and AC Transit usage as well as strike impacts on various groups of travelers. Shortly after the strike, in September, a feeder bus survey (430 interviews initiated, 86 percent completed) and a survey on AC Transit lines running parallel to BART in downtown Oakland (366 interviews initiated, 91 percent completed) were conducted.

Results. During the strike, BART patronage increased by a net of some 2,600 daily trips (7 percent). Revenues decreased 4 percent due to an 11 percent decrease in the average mileage fare collected. The lack of feeder bus service and connecting transbay bus service during the strike cost BART some 9,200 daily passengers in lost ridership, and the lost trips represented longer rides than the trips gained. Of those who had been feeder bus riders, 51 percent used an alternate access mode to BART (37 percent auto driver or passenger, 51 percent walk, 12 percent other means), 14 percent used an alternate mode for the entire trip (84 percent auto), and 35 percent suppressed (did not take) the trip.

The net gain in overall BART ridership during the strike suggested that 10 percent of the 120,000 daily non-feeder, non-transbay bus riders had been diverted to BART. Of those trips normally made on bus routes roughly paralleling BART to downtown Oakland, 35 percent were suppressed. For those trips still taken, the modes used were BART (41 percent), auto passenger (33 percent), auto driver (11 percent), walk (7 percent), hitchhike (4 percent) and taxi (4 percent). Average trip cost for those who continued to travel rose from 40¢ to 85¢.

Transbay bus riders had a 14 percent trip suppression rate, 26 percent drove automobiles by themselves, and 60 percent carpooled. Westbound vehicular traffic across the San Francisco-Oakland Bay Bridge increased 6.4 percent overall and 12.3 percent in the 3 hour AM peak period. AM peak auto occupancy rose from 1.44 to 1.75 and the period of AM congestion was extended from 30 minutes (non-strike) to 120 minutes (strike). Some traffic was diverted to the San Mateo-Hayward and Richmond-San Rafael Bridges, which showed 15.5 percent and 6.5 percent 24-hour traffic increases.

More . . . Some 46 to 59 percent of all non-work trips normally made on AC Transit buses were suppressed during the strike, as were 9 to 21 percent of work trips. The elderly suppressed 55 to 60 percent of all trips. The parallel bus route survey identified only 21 percent of the elderly as either owning a car or having a license to drive. There was a 50 percent trip suppression rate among the young, as evidenced in the feeder route survey, and 20 percent of the youth attending summer school in Oakland reported extreme travel difficulties or could not attend at all. Normally the young and the elderly constituted 65 percent of all non-work bus trips.

Source: Peat, Marwick, Mitchell and Company, "Assessment of the Impacts of the AC Transit Strike Upon BART." Prepared for the Metropolitan Transportation Commission, Berkeley, CA (1975).

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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
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
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