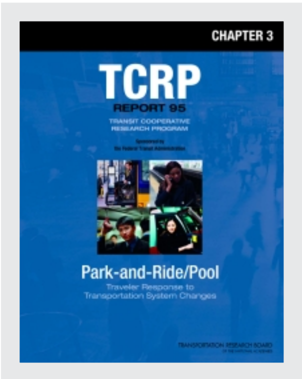

Traveler Response to Transportation System Changes Handbook, Third Edition: Chapter 3, Park-and-Ride/Pool

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 95

Traveler Response to Transportation System Changes

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TRANSIT COOPERATIVE RESEARCH PROGRAM

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

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

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

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

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

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

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

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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.

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FOREWORD

By Stephan A. Parker
Staff Officer
Transportation Research Board

Park-and-ride and park-and-pool (Park-and-Ride/Pool) facilities range from multi-story parking garages with customer amenities to simple surface parking lots. They may vary in purpose from serving a major intermodal transportation center to simply facilitating carpools. This chapter covers travel demand and related aspects of providing and supporting park-and-ride and park-and-pool facilities.

Specifically, this chapter addresses park-and-ride and park-and-pool facilities working together with supportive features and in coordination with high occupancy vehicle lanes; busways; bus rapid transit and other express bus services; and light rail transit, commuter rail, and heavy rail transit facilities and services. Chapter 3 does not, however, focus on supporting elements or the coordinated HOV or transit facilities and services in and of themselves. Thus, the reader may also wish to consult Chapter 2, “HOV Facilities,” Chapter 4, “Busways, BRT and Express Bus,” Chapter 5, “Vanpools and Buspools,” Chapter 7, “Light Rail Transit,” and Chapter 8, “Commuter Rail,” in particular. Park-and-ride facilities on the periphery of the central business district (CBD) are covered within Chapter 18, “Parking Management and Supply.” Walking and bicycling as transportation modes of access are addressed in Chapter 16, “Pedestrian and Bicycle Facilities.”

TCRP Report 95: Chapter 3, Park-and-Ride/Pool will be of interest to transit and transportation planning practitioners; educators and researchers; and professionals across a broad spectrum of transportation agencies, MPOs, 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		TCRP Report 95	
	First Edition	Second Edition	Source Data Cutoff Date	Estimated Publication Date
Ch. 1 – Introduction (with Appendices A, B)	1977	1981	2003[a]	2000/03/04[a]
Multimodal/Intermodal Facilities				
Ch. 2 – HOV Facilities	1977	1981	1999	2000/04[b]
Ch. 3 – Park-and-Ride and Park-and-Pool	—	1981	2003[c]	2004[d]
Transit Facilities and Services				
Ch. 4 – Busways, BRT and Express Bus	1977[e]	1981	2003[c]	2004[d]
Ch. 5 – Vanpools and Buspools	1977	1981	1999	2000/04[b]
Ch. 6 – Demand Responsive/ADA	—	—	1999	2000/04[b]
Ch. 7 – Light Rail Transit	—	—	2003	2004[d]
Ch. 8 – Commuter Rail	—	—	2003	2004[d]
Public Transit Operations				
Ch. 9 – Transit Scheduling and Frequency	1977	1981	1999	2000/04[b]
Ch. 10 – Bus Routing and Coverage	1977	1981	1999	2000/04[b]
Ch. 11 – Transit Information and Promotion	1977	1981	2002	2003
Transportation Pricing				
Ch. 12 – Transit Pricing and Fares	1977	1981	1999	2000/04[b]
Ch. 13 – Parking Pricing and Fees	1977[e]	—	1999	2000/04[b]
Ch. 14 – Road Value Pricing	1977[e]	—	2002–03[f]	2003
Land Use and Non-Motorized Travel				
Ch. 15 – Land Use and Site Design	—	—	2001–02[f]	2003
Ch. 16 – Pedestrian and Bicycle Facilities	—	—	2003	2004[d]
Ch. 17 – Transit Oriented Design	—	—	2003[d]	2004[d]
Transportation Demand Management				
Ch. 18 – Parking Management and Supply	—	—	2000–02[f]	2003
Ch. 19 – Employer and Institutional TDM Strategies	1977[e]	1981[e]	2003	2004[d]

NOTES: [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. Publication of the final version of Chapter 1, “Introduction,” as part of the TCRP Report 95 series, is anticipated for 2004.

[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 for the second half of 2004.

[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 3 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, Dr. Katherine F. Turnbull, Richard H. Pratt, and John (Jay) Evans are the lead authors for this volume: Chapter 3, "Park-and-Ride/Pool." Contributing author for Chapter 3 is Herbert S. Levinson.

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 all members who assisted are not listed here in the interests of brevity, their contribution is truly valued. Those who have undertaken reviews of Chapter 3 are Les Jacobson, Mark Paine, and Don Ward. In addition, Francis Wambalaba stepped in to provide an additional 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.

CHAPTER 3—PARK-AND-RIDE/POOL

CONTENTS

3 — Park-and-Ride/Pool

OVERVIEW AND SUMMARY

Park-and-ride facilities and associated transit services along with park-and-pool facilities formalize and make readily available the option of mixed-mode travel. The combination they facilitate allows use of a low-occupancy mode, most often driving alone, where travel densities are low and high-occupancy modes are inconvenient. It allows transfer to a high-occupancy mode — rail transit, bus, vanpool, or carpool — where travel densities become higher and more supportive of high-occupancy mode efficiencies. Park-and-ride and park-and-pool facilities range from multi-story parking garages with customer amenities to simple surface parking lots. They may vary in purpose from serving a major intermodal transportation center to simply facilitating carpools. This chapter covers travel demand and related aspects of providing and supporting park-and-ride and park-and-pool facilities.

This "Overview and Summary" section contains the following:

- "Objectives of Park-and-Ride/Pool Facilities," delineating the goals and purposes of these applications.
- "Types of Park-and-Ride/Pool Facilities," categorizing and describing the characteristics of the various approaches, treatments, and programs, for purposes of organization.
- "Analytical Considerations," describing the limitations of the available research and the constraints associated with the use of the data.
- "Traveler Response Summary," highlighting the travel demand findings presented in the remainder of the chapter.

After the four-part "Overview and Summary," the full presentation provides:

- "Traveler Response by Type of Park-and-Ride Facility," identifying individual applications within each category and presenting available usage characteristics, related travel data, and response to facility introduction and related services.
- "Underlying Traveler Response Factors," exploring the parameters that make successful park-and-ride and park-and-pool facilities attractive, and the mode choice mechanisms and decisions involved.
- "Related Information and Impacts," presenting connected subtopics including park-and-ride/pool user and usage characteristics, and effects on energy, air quality, and costs.
- "Case Studies," expanding on four examples of park-and-ride/pool facility applications ranging from metropolitan systems to individual lots.

Chapter users are urged to review the initial three subsections of this "Overview and Summary" before proceeding to the "Traveler Response Summary" and following sections, to be prepared with a fuller understanding of the context and the limitations of the information being provided.

This chapter addresses park-and-ride and park-and-pool facilities working together with supportive features and in coordination with high occupancy vehicle (HOV) lanes, busways, bus rapid transit (BRT) and other express bus services, and Light Rail Transit (LRT), commuter rail (CRR), and heavy rail transit (HRT/Metro) facilities and services. Chapter 3 does not, however, focus on supporting elements or the coordinated HOV or transit facilities and services in and of themselves. Thus the reader may also wish to consult Chapter 2, "HOV Facilities"; Chapter 4, "Busways, BRT and Express Bus"; Chapter 5, "Vanpools and Buspools"; Chapter 7, "Light Rail Transit"; and Chapter 8, "Commuter Rail" in particular. Park-and-ride facilities on the periphery of the central business district (CBD) are covered within Chapter 18, "Parking Management and Supply." Walking and bicycling as transit modes of access are addressed in Chapter 16, "Pedestrian and Bicycle Facilities."

Objectives of Park-and-Ride/Pool Facilities

A number of transportation system objectives may be addressed through the use of park-and-ride and park-and-pool facilities. Park-and-ride facilities and systems may be tailored to meet one or more of these objectives through proper design and location, and provision of appropriate supportive elements and services. Key objectives include:

- Increasing availability of alternatives to driving alone, by providing travelers with the opportunity to readily transfer from low- to high-occupancy travel modes and vice-versa. This opportunity affords an effective combination of passenger collection by automobile or bicycle, with trunk route travel via rail transit, bus, vanpool, or carpool.

- Concentrating transit rider demand to a level enabling transit service that could not otherwise be provided. In many low-density areas, without park-and-ride facilities and service, no attractive public transit could be effectively operated.

- Expanding the reach of transit into low-density areas, thereby bringing more riders to premium transit services like rail and express bus. For such services, park-and-ride users can represent a substantial portion of total ridership and induce demand concentrations sufficient to warrant the higher quality of transit service.

- Offering a convenient, safe meeting point and parking location for carpoolers and vanpoolers, to facilitate pool formation, and to support ridesharing in locations where sufficient demand might not otherwise occur for ridesharing to a common destination.

- Reducing vehicle-miles of travel (VMT) and possibly pollutant emissions. Encouragement of high-occupancy travel mode use and reduction in distances driven alone, as long as severe indirectness of travel does not result, can help reduce system VMT. With proper system design, VMT reductions can in most cases translate into air quality improvements.

- Shifting of parking away from the CBD and, to some extent, other dense activity centers. Thousands of parking spaces for a region's central core may be provided through park-and-ride and park-and-pool facilities. This transfer of parking can have significant effect on reducing CBD parking supply requirements and downtown street congestion.

- Relieving neighborhoods of uncontrolled informal parking caused by park-and-ride/pool activity occurring in the absence, or with insufficient capacity, of formal facilities.

An overall goal of park-and-ride and park-and-pool facilities is thus to provide the benefits of transit and carpooling to low density areas in particular while mitigating disincentives of these modes. Related goals may include maximizing the efficiency of the transportation system, increasing the person-carrying capacity of the system, providing more travel options to trip makers, and enhancing the central area environment. In the case of large, non-remote park-and-ride facilities there is a tension between addressing these goals via park-and-ride and addressing certain goals associated with Transit Oriented Development (TOD). Chapter 17, "Transit Oriented Design," covers that subject.

Types of Park-and-Ride/Pool Facilities

Park-and-ride facilities are an integral part of many transit systems in North America, including practically all medium and large city operations. Likewise, park-and-pool lots are provided along many highway systems focused on urban areas. Park-and-ride facilities are primarily oriented toward commuters changing from an automobile to a bus or a rail transit system, while park-and-pool facilities assist with the formation of carpools and vanpools. Access may also be accomplished by bicycling, and park-and-ride facilities may include bicycle storage lockers or racks. Short-term parking areas, termed kiss-and-ride facilities, are often provided to accommodate the dropping off and picking up of passengers, as an alternative to leaving a vehicle in the facility all day. Amenities such as lighting, shelters and benches, enclosed waiting areas, newspaper and other vending machines, and other types of services up to and including banks, dry cleaners, auto care, and most recently car-sharing rentals may be considered at park-and-ride/pool facilities, depending on facility size and function. (Car-sharing is addressed in Chapter 14, "Road Value Pricing," under "Response by Type of Strategy" — "Response to Vehicle Use Pricing Programs" — "Car-Sharing.")

Alternative Classification Systems

The many varieties of park-and-ride and park-and-pool facilities can be classified in numerous ways. Although this chapter uses a classification system chiefly based on the primary transportation modes that such facilities serve, it is useful to identify the other attributes that have served to organize classification schemes in other works. Other classifications have focused on facility location, design features, ownership, or a blending of one or more of these attributes. Each of these different attributes may play an important role in determining the traveler response to park-and-ride facilities, even though not employed in the classification adopted here. Following are alternative approaches to distinguishing among types of park-and-ride and park-and-pool facilities.

Peripheral, Suburban and Remote Facilities. Distinctions can be made between peripheral park-and-ride facilities and facilities in "suburban" and "remote" area types. Peripheral parking is located on the edge of a downtown area or other major activity center. Such facilities expand the amount of parking available in the central area and help intercept automobiles before they enter the congested core. Peripheral facility users make the major portion of their trip by automobile and then use transit or walk for the last short segment. Peripheral parking may be served by shuttle or local bus routes, often deployed in combination with a reduced fare or a free-fare zone, or by a variety of other mass transit and paratransit services. Peripheral parking may also be used to encourage ridesharing by providing reduced or free parking rates for carpools and vanpools. Peripheral park-and-ride facilities are also called "fringe" parking, but that term has been applied to outlying park-and-ride lots as well. Peripheral parking tends to be part of a central area parking management plan and thus is covered in Chapter 18, "Parking Management and Supply."

Suburban park-and-ride and park-and-pool facilities tend to be located relatively near the home origins of trips. The destinations of these trips are typically concentrated in a central employment area or areas, although there may be some dispersion within the urban area, particularly for park-and-pool activity. The presence of concentrated employment along transit lines or major routes served by the lot is an important usage determinant.

Remote lots tend to be situated in rural or small town settings. Trip lengths for both home-to-lot and lot-to-work are much longer for remote lots than for other types of park-and-ride facilities. Distance from the employment center, as well as its scale, are key factors in demand for remote facilities. This chapter is primarily concerned with facilities that are suburban or remote in character.

Large Versus Small Facilities. Park-and-ride facilities at a site can vary in size from a few to several thousand spaces. Large facilities are typically served with frequent, high-capacity transit services. These facilities are usually located in congested travel corridors in major metropolitan areas, and often feature parking structures and substantial passenger amenities. Small facilities may have little in the way of amenities and limited or even no transit service, with park-and-pool support of carpooling and vanpooling often their primary role. Medium-size facilities may share characteristics of both small and large facilities. The classification of a facility as small, medium, or large will depend upon the system context, but in general, lots with 200 or fewer spaces may be considered small and facilities with more than 1,000 spaces may be considered large.

Exclusive- Versus Shared-Use Facilities. Facilities can also be categorized as exclusive- or shared-use facilities. Exclusive-use facilities are usually planned, designed, constructed, and operated specifically to serve park-and-ride and park-and-pool functions. They commonly provide basic passenger amenities such as stations or shelters and usually offer advantages related to adequacy of automobile parking and transit stop and terminal space, efficiency of layout from both user and transit operator perspectives, and attention to minimization of potential automobile and pedestrian conflicts.

Shared-use facilities are established when shopping center, church, recreational, or other parking is put into joint use as park-and-ride and park-and-pool facilities. Such facilities may not have been designed as park-and-ride lots, but suffice to take advantage of parking supply that would otherwise go unused. Peak commuting periods are usually different than the peak shopping or special activity use, although holiday shopping peaks can be a problem. Shared-use facilities, depending on their original design and degree of retrofitting, may or may not be as attractive to riders as exclusive-use facilities, but they are an often-deployed low-cost solution.

Pay Versus Free Park-and-Ride Facilities. Essentially all park-and-pool lots and most park-and-ride facilities are free to the user unless they are associated with heavily patronized transit facilities, usually rail transit in the largest of metropolitan areas. At the free facilities, travelers do pay the appropriate rail or bus fares, which may be somewhat higher than for local transit services. Under some situations, parking charges are used to control demand at stations. Although facilities can be classified by whether they are free or paid, it is more useful in terms of traveler response to look at other primary characteristics, and then explore the incremental impact that parking charges might have. Pricing effects on park-and-ride facility and transit usage are introduced in the "Underlying Traveler Response Factors" section under "User Costs and Willingness to Pay." Park-and-ride facility pricing programs and characteristics are covered in the "Related Information and Impacts" section under "Parking Pricing at Park-and-Ride Facilities."

Formal Facilities Versus Informal Parking. All of the preceding classification options are expressed in terms of one form or another of formal park-and-ride/pool facilities or parking arrangements. Park-and-ride and park-and-pool activities are also known to take place on a completely informal basis, utilizing neighborhood curbside parking or other relatively unrestricted parking spaces. Analysis of this type of parking is extremely difficult and rarely attempted, except that spillover parking from formal facilities is sometimes counted and used to quantify the degree to which parking is over capacity. This chapter, except where explicitly noted, focuses on formal park-and-ride and park-and-pool facilities and associated travel.

Mode-Served Classification System

This chapter, as already noted, is organized chiefly around the modes served by the park-and-ride/pool facility. The following types of facilities are examined:

Rail Park-and-Ride Facilities. Rail transit stops and stations located within the denser parts of central cities tend not to have formal park-and-ride provisions, particularly in the case of older systems. Otherwise, park-and-ride facilities are essential elements of most commuter rail, HRT/Metro, and LRT operations. Facility size varies widely, ranging from 100-space or even smaller parking lots to several-thousand-space parking garages supporting HRT/Metro. Commuter rail lots are generally concentrated well out into the suburbs, while those serving HRT and LRT tend to be somewhat closer in to the regional CBD. Rail system park-and-ride facilities are primarily focused on stations where at least part of the tributary area is characterized by population densities too low to support frequent feeder bus service. They are typically exclusive facilities designed, constructed, and operated as an integral part of the overall system, featuring stations, passenger waiting areas, and often other amenities. Parking fees are often charged at HRT/Metro stations, and also at other rail service park-and-ride facilities when located in highly built-up areas.

Busway and HOV Lane Park-and-Ride Facilities. Substantial park-and-ride facilities are integral elements of many busway and HOV lane systems. The parking requirements involved vary greatly, with smaller facilities both in areas of more intensive local transit service and in association with individual routes branching out from the trunkline busways and HOV systems. A major example of larger facilities is provided by the HOV lane system Houston, Texas, which makes use of mid-to-large-size lots with 500 or more spaces. In the more highly developed examples, park-and-ride facilities serving busways and HOV lanes may have stations and other passenger amenities, with direct connections to the HOV lanes to facilitate park-and-pool activity. Busway and HOV park-and-ride facilities are not necessarily located directly on the busway or HOV lane, and may be on collector bus routes and arterials that feed the trunk route involved, in some cases relying on shared-use parking. Park-and-ride lots associated with busways tend to be closer in, as with LRT, while those associated with freeway HOV lanes are usually further out in the suburbs and exurbs. In either case, park-and-ride lots are normally provided free to the user.

Express and Local Bus Park-and-Ride Facilities. Park-and-ride lots are also used with express bus routes without priority treatments, and even some local routes. Facilities associated with these types of bus services are often located somewhat closer to the downtown area or major activity center, are smaller in size, and are free. Passenger shelters may be provided, along with limited amenities. Both shared-use and exclusive-use parking facilities are found in operation with express and local bus services.

Park-and-Pool Facilities. Park-and-pool lots are established to provide locations for the formation of carpools and vanpools and parking for the non-pool vehicles used for access. These lots, which in their basic form are not served by fixed-route transit systems, are usually smaller in size than transit park-and-ride lots, often providing less than 100 parking spaces. Park-and-pool lots are almost invariably free, and are typically located at farther distances from the CBD, often in exurban and rural areas. They may be shared-use facilities, and are frequently unadorned with waiting areas or other amenities, the vehicles themselves serving as shelters. Some transit park-and-ride facilities are intended to also serve a park-and-pool function, especially when located along HOV facilities, and many other park-and-ride lots serve a small amount of park-and-pool activity in addition to transit riders.

Peripheral Park-and-Ride Facilities. Described above, peripheral park-and-ride lots are, as already noted, covered in Chapter 18, "Parking Management and Supply." See both "Peripheral Parking Around Central Business Districts" under "Response by Type of Strategy," and "Peripheral Parking Tradeoffs" within the "Underlying Traveler Response Factors" section.

Analytical Considerations

Before and after evaluations, ongoing monitoring programs, surveys of individuals parking at facilities, and cause and effect explorations have all been used to examine travel behavior and related impacts of park-and-ride and park-and-pool facilities. Available literature, supplemented in some cases by more detailed information direct from operating agencies, has been the information source for this chapter. However, there is only very limited research into travel demand estimation, and hence traveler response, as pertains to park-and-ride and park-and-pool facilities.

The available travel data for park-and-ride/pool facility usage is likewise limited in scope. While some systems conduct before and after studies for new facilities and maintain ongoing monitoring programs of usage, others do not. Surveys of lot users to probe prior mode of travel, length of access trip, mode of access, and like characteristics of interest have been conducted in relatively few areas. Influences of external factors such as changes in service levels, transit fares, parking rates, and the local economy have not been well considered. All of these constraints should be taken into account when using the information presented here.

Additional measurement, evaluation, and application issues to be alert to in making use of this or any synthesis are covered in the "Use of the Handbook" section of Chapter 1, "Introduction." Included there is the key point that actual program implementation should be developed within the context of the specific locale and needs being addressed.

Throughout this "Park-and-Ride and Park-and-Pool" chapter, the occupancy rate of park-and-ride lots (maximum number of parked autos per spaces) is employed as a prime measure of the utilization of a particular service. Several potential flaws surround the use of this measure if it is used exclusively. First, it does not reflect actual volume of usage. Thirty autos in a 35 space lot cannot be considered more successful than 1,200 autos in a 1,600 space lot. Similarly, if one shopping center allocates 200 spaces to park-and-ride users and another allocates 400 spaces, but both serve 50 autos, the former is not necessarily more successful than the latter. Therefore volume, along with utilization, is cited when possible. In general, the two are very closely correlated in the literature. Secondly, neither volume nor utilization necessarily reflects the proportion or share of the market population that the facility serves. This estimate has rarely been made, making impossible any comparison of market penetration among different applications.

Given these data limitations, rather than labeling particular characteristics of park-and-ride facilities and associated transit service as either successful or unsuccessful, emphasis is placed on the tendency of particular characteristics to assist or detract from application of the park-and-ride/pool concept. As already noted, the focus is almost entirely on formal park-and-ride/pool facilities and operations, with no attempt to comprehensively address hard-to-measure informal parking.

Finally, there are special issues of what trip types are included in data on park-and-ride facility mode of access, which in turn raise corresponding questions of interpretation. These are highlighted at the outset of the "Mode of Access" subsection, under "Related Information and Impacts" — "Usage Characteristics of Park-and-Ride/Pool Facilities."

Traveler Response Summary

The size, amenities, and level or presence of transit service varies greatly among individual park-and-ride/pool lots. Utilization levels also vary by mode, by city, and by lots within a corridor, as do the proportions of transit riders and persons ridesharing who depend on park-and-ride access. Express transit operations in large metropolitan areas range from roughly 10 to 80 percent in the proportion of riders accessing the express service by some form or another of auto arrival, utilizing formal or informal facilities if the car is parked.

Park-and-ride facilities served by Metro/HRT rapid transit systems are typically large and generally well utilized. Lots or garages with 1,000 parking spaces or multiples thereof are common with such systems. In the most dense U.S. cities, many are regularly filled prior to the end of the morning rush hour, even where parking fees are charged. Where excess parking capacity is available, however, net revenue gains have been obtained by eliminating or selectively lowering parking fees. Reported systemwide average space utilization is typically 75 to 90 percent but ranges from roughly 50 to 100 percent. The proportion of Metro/HRT riders who utilize *formal* park-and-ride facilities and park their auto there ranges from on the order of 1 percent for older central city operations like Chicago's rapid transit system, to over 50 percent for some systems oriented to the suburbs.

Park-and-ride lots associated with commuter rail and LRT are smaller, frequently averaging 100 to 700 spaces each within a system, with individual lots down to 20 or so spaces. Commuter rail and LRT lots are well utilized on most systems. Systemwide park-and-ride space utilization is typically between 70 and 85 percent, although the reported range is 17 to 98 percent. With closer station spacing relative to population served, most commuter rail and LRT systems afford more walk-on opportunities, and the proportion of riders reliant on park-and-ride tends to fall in between the extremes exhibited by Metro/HRT systems.

Large to mid-sized park-and-ride lots are found with many HOV lanes. Facilities with 1,000 to 2,000 spaces are in operation with exclusive freeway HOV lanes. Lots in the range of 100 to 500 spaces are associated with concurrent flow freeway HOV lanes. Utilization rates for lots along a particular facility typically average between 50 and 80 percent, although the reported range is from 34 to 100 percent.

Still smaller facilities, including shared-use lots, are found with express and local bus services, although larger lots are associated with some express bus routes in major urban areas. Systemwide average lot sizes are mostly in the range of 30 to 250 spaces. Utilization rates for such facilities vary widely, with 60 percent occupancy as a rough median. Factors likely to be associated with success include substantial downtown parking costs, frequent bus service, and bus travel times reasonably competitive with the auto. Irrespective of transit mode, as metropolitan area size decreases, the role of park-and-ride changes from a major contributor to parking supply serving the regional core to that of a niche player.

Park-and-pool lots also vary in size and use, but most are smaller facilities. Observed data for six systems exhibits a range from 15 to 66 percent systemwide average utilization, with the median between 40 and 50 percent. Evidence from three programs suggests that one carpool is formed in park-and-pool lots for roughly every 2.5 vehicles entering the lot, or for every 1.5 vehicles parking in the lot. Whereas 80 percent or more of transit park-and-ride facility users — often nearly 100 percent — are headed for downtown areas, the destinations of park-and-pool lot users are much more dispersed.

Driving distance to park-and-ride facilities appears to vary somewhat by mode and size of the metropolitan area, with longer driving distances being associated with exceptionally good transit service and also outlying park-and-ride facility locations. The majority of park-and-ride users typically come from within 5 miles and more than 80 percent travel less than 10 miles to their facility. Access trips for end-of-line Metro/HRT park-and-ride facilities, outer commuter rail lots, and park-and-pool lots tend to be longer than average. For example, 56 percent of the automobile access trips to Tri-Rail in Miami were 5 miles or less, but 30 percent were 6 to 10 miles, 10 percent were 11 to 20 miles, and 4 percent were 21 to 40 miles.

In addition to parking cost and other travel cost saving opportunities, competitive travel times, and frequent transit service, factors that seem to contribute to use of park-and-ride facilities include direct priority transit service to the CBD, congested highway travel conditions, lack of convenient parking at the destination, and long travel distances. Key reported incentives for using park-and-ride/pool besides cost and time savings are avoidance of driving stress and allied benefits. Favorable facility siting indicators include location closer to commuters' residences than to their destinations (translating for most commuters into midway between the urban fringe and the CBD), location in advance of congested areas, easy highway access, and high visibility. The typical park-and-ride/pool patron learned about the facility he or she uses by seeing it. The most important features of park-and-ride/pool facilities, in the view of users, are attributes having to do with their transportation function — such as safety, service and shelter. While users rank safety high in importance, it appears that it will affect travel choices only when there is a perceived serious lack of it. Adjunct amenities at park-and-ride facilities, such as convenience retail and car care, are appreciated but unlikely to influence facility use in any major way.

Park-and-ride/pool users are inherently trip makers with choices, almost all having an auto available. Their incomes are higher than the average transit rider. Some 80 to 100 percent of weekday users are normally making work purpose trips — 95 to 98 percent is typical. The predominant mode of access to most park-and-ride facilities themselves is driving alone and parking. Carpooling to the facility is next most common, followed by being dropped off. Park-and-ride/pool has generally been shown to save VMT, but the fact that auto travel is still involved dampens the energy savings and environmental benefits.

Studies of outlying park-and-ride facilities show an average daily turnover of about 1.1 cars per space with about 1.2 transit passengers per parked car, suggesting a relationship of roughly 1.3 transit passengers (2.6 transit boardings daily) per occupied parking space. Some of these transit rides would occur anyway without park-and-ride, and some would be lost to transit. Looking at this relationship in reverse, Connecticut studies have estimated that a rough average of 0.2 new transit riders are gained for each additional space provided in capacity-constrained parking situations. Park-and-ride/pool facilities do attract travelers who formerly drove alone. Most surveys indicate that between 40 and 60 percent of users previously commuted by single-occupant vehicle. At the same time, travel demand modeling work from many locales demonstrates that there is a perceived "penalty" imposed on choice of the park-and-ride travel mode by aspects of the auto-to-transit transfer, the inability to avoid fixed costs of automobile ownership, or the lack of opportunity to make the auto available to other family members. Overestimation of new facility transit use results from ignoring this "penalty."

TRAVELER RESPONSE BY TYPE OF PARK-AND-RIDE FACILITY

Information on traveler response to individual categories of park-and-ride and park-and-pool facilities is presented in this section, starting with park-and-ride operations associated with rail systems. That is followed by facilities provided in conjunction with busways and HOV lanes, park-and-ride served by express and local bus lines, and park-and-pool lots. These categories are not mutually exclusive because one facility may serve more than one mode. Additional information on travel demand factors and characteristics is provided in the "Underlying Traveler Response Factors" and "Related Information and Impacts" sections.

Response to Rail Park-and-Ride Facilities

Table 3-1 lists data on rail transit park-and-ride from a variety of locations, giving number of individual facilities, amount of parking, and utilization levels. Additional information for selected systems, including some growth trend data, follows. Commuter rail (CRR) park-and-ride is addressed first, followed by heavy rail (or rail rapid) transit (HRT/Metro) and light rail transit (LRT).

In general, park-and-ride facilities associated with HRT systems are large and experience strong demand — even where parking fees are charged — but may be limited in number and total impact on older HRT systems. Commuter rail and LRT park-and-ride lots are typically well utilized relative to available spaces, although generally smaller than HRT facilities and usually free of charge. For commuter rail and LRT in particular, it is important to keep in mind that the level of transit service provided is an integral part of the attractiveness of the park-and-ride system. An illustration is provided by Chicago north suburbs survey findings included below under "Commuter Rail" — "Metra Park-and-Ride Lots."

Commuter Rail

Commuter rail stations may be found in old town centers as well as in low density suburban and even rural areas. The size of commuter rail park-and-ride lots thus varies substantially. In the Chicago suburbs, for example, the amount of formal and informal commuter parking available in the early 1990s at individual stations with parking ranged from about 20 to 1,500 spaces, and the average commuter parked at a station with 660 spaces available (Hart, 1992). Stations with the larger parking facilities tend to be those far enough out that commuter rail is a competitive mode (a threshold explored in Chapter 8, "Commuter Rail") but not so far out that there is not the population to support major facilities. Parking lot utilization rates above 80 percent (the typical design demand load) are common.

Park-and-ride patrons typically constitute a significant proportion of commuter rail riders overall, as illustrated by the 55 percent who drive alone to the Chicago area's Metra system and use either formal or informal parking. Stations further out from the central business district (CBD) tend to experience a higher proportion of access by auto, as illustrated further on for Metra in Table 3-3 (Ferguson, 2000). In addition to the statistics in Table 3-3 on Metra auto access proportions, more commuter rail examples are provided in the "Related Information and Impacts" section under "Prevalence of Park-and-Ride Activity" and also under "Usage Characteristics of Park-and-Ride/Pool Facilities" — "Mode of Access."

Connecticut Commuter Rail Park-and-Ride Lots. There are 49 commuter parking facilities located at Connecticut railroad stations, including the New Haven Line into New York (main line plus three branches), the Shore Line East feeding New Haven, and Amtrak stations. The overall average parking utilization in 1993 was reported at 66 percent, with approximately 11,280 cars parked per day in a total of 17,039 parking spaces (Connecticut Department of Transportation, 1996). The New Haven Line, operated by MTA Metro-North Railroad, accounts for the bulk of the station parking with 14,258 spaces provided at its 35 Connecticut stations. An average utilization rate of 85 percent and a median rate of 83 percent were reported for these stations in 1996. For individual stations, the utilization ranged from 3 to 144 percent (Connecticut Department of Transportation, 1997).

Table 3-1 Examples of Utilization of Rail Park-and-Ride Facilities

System (Year)	Number of Facilities	Number of Spaces	Parked Vehicles	Percent Capacity
Commuter Rail – North America				
Caltrain (1998)	34	4,125	3,210	78%
Connecticut – New Haven Line[s] (1996)	35 [a]	14,258	12,056	85%
Go Transit – Toronto (1998)	8	32,052	30,139	94%
MARC – Maryland/West Virginia (1995)	26	5,922	5,150	87%
METROLINK – Los Angeles (1999)	46	14,500	n/a	75%
Southeastern PA Transp. Authority (1993)	116 [a]	14,042	11,775	84%
Virginia Railway Express (1995)	13 [b]	3,901	2,411	62%
Heavy Rail – North America				
Chicago Transit Authority (1998)	15 [a]	6,506	5,1–5,500	78–85%
Metrorail – Miami (1993)	17	9,391	5,030	53%
Metrorail – Washington, DC (1995)	39 [a]	38,137	34,195	90%
Southeastern PA Transp. Authority (1993)	3 [a]	1,133	1,133	100%
LRT – North America				
Buffalo (1995)	2	1,400	n/a	70%
Calgary (1998)	11	7,354	7,126	97%
Dallas Area Rapid Transit (1998)	8	4,190	n/a	86%
Denver (1998)	4	1,675	1,634	98%
Edmonton (1993)	3	1,668	n/a	80%
Sacramento (1999)	9	4,120	n/a	55%
San Diego Trolley (1999)	23	5,553	1,471	26%
Santa Clara Valley Transp. Authority (1998)	10	5,950	990	17%
Southeastern PA Transp. Authority (1993) [c]	17	861	576	67%
LRT – Europe [a]				
Antwerp, Belgium (1993)	2	320	n/a	100%
Stuttgart, Germany (1993)	4	1,200	n/a	20%
Toulouse, France (1993)	3	950	n/a	80%

Notes: n/a - Information not available except by inference based on the "Percent Capacity" values, which come from estimates or other derivations used by the reporting agencies.

[a] Parking fee charged at several or all facilities (European situation not known).

[b] Parking fee charged at several facilities in the survey year (fees since removed).

[c] These LRT lines (former Philadelphia Suburban Transit routes) operate as feeders to the HRT.

Sources: City of Calgary (1998), Connecticut Department of Transportation (1997), Dallas Area Rapid Transit (1998), Dickins (1994), Foote (2000), Go Transit (1998), Metro-Dade Transit Authority (1993), Metropolitan Transit Development Board (1999), Metropolitan Washington Council of Governments (1996), Regional Transit District (1999), Santa Clara Valley Transportation Authority (1998), Southeastern Pennsylvania Transportation Authority (1993), Turnbull (1995), and inquiries of operators by Handbook authors.

The New Haven Line, including the main line and its three branches, captures 75 percent of the work trips bound for New York City according to 1990 Census data for Connecticut. A majority of these may be assumed to start their trip by auto, because 70 percent of Connecticut New Haven Line customers drive or carpool to their station and park. The corresponding auto arrival share for New York State customers of the New Haven Line is 45 percent. Parking capacity along the line continues to be expanded at an accelerated pace to meet demand, with 2,264 spaces constructed at 18 Connecticut stations between 1987 and 1996. These new spaces represent 16 percent of the 1996 supply (Connecticut Department of Transportation, 1997).

A study in 2000 looked at effects on inbound rail ridership of having added parking spaces for the New Haven, South Norwalk and Bridgeport stations. An attempt was made to explore the possible mode shift to commuter rail, resulting in "new riders," as contrasted with the ordinary, secular ridership growth occurring in the background. To do so, as set forth in Table 3-2, an estimate of ordinary growth was subtracted from the total ridership growth, isolating out the number of new riders then presumed to be attracted to commuter rail by the added parking. The Bridgeport station experienced a number of confounding changes during the study period, including a rail fare reduction, free parking, and a substantial improvement and cleanup of the station and its environs. Excluding the Bridgeport station, the overall ridership increase represented from 0.74 to 0.77 riders added per new parking space (over 14 years in the one case and 3 years in the other), including from 0.11 to 0.60 "new riders" presumed to have shifted to commuter rail in direct response to the enhanced parking supply.

Table 3-2. Changes in Parking Supply and Demand at Three Connecticut Stations

	New Haven	South Norwalk	Bridgeport
Time Period Studied	1985-1999	1996-1999	1985-1999
Parking Spaces Added	+628	+325	+500
Additional Rail Ridership			
Gross Ridership Increase	+467	+250	+736
Ordinary Growth (estimated 1.5%/year)	+400	+55	+277
Ridership Increase Attributed to Mode Shifts Induced by Parking ("New Riders")	+67	+195	+459
Additional Rail Ridership per Parking Space Added			
Gross Ridership Increase/Space Added	0.74	0.77	1.47
"New Riders"/Space Added	0.11	0.60	0.92

Note: External factors affecting Bridgeport included lowered train fares, free parking at State lot, and station area improvements.

Source: Adapted from Levinson and Weant (2000).

Other data examined in the same study included a survey conducted at a New Haven park-and-ride lot at a time that the parking was both newly provided and free. It was found that

22 percent of the users previously drove. This was taken to be equivalent to 0.22 new rail riders per commuter parking space added, a value in close correspondence with the elasticity of ridership to park-and-ride spaces of +0.2 suggested by Metro-North (Levinson and Weant, 2000).[1] This value falls within the lower third of the broad range of from 0.11 to 0.60 new riders per parking space developed in the multi-year ridership growth analysis of Table 3-2. Implicit in these relationships is a park-and-ride parking supply that is to some degree constrained. The +0.2 elasticity presumably reflects average Metro-North conditions, with a potential for stronger new rider response where parking deficiencies are greatest.

Metra Park-and-Ride Lots. The 495-mile, 230 station Metra commuter rail system serves Northeastern Illinois including Chicago. In the early 1980's, Metra experienced serious ridership declines. Between 1979 and 1983, average weekday passenger boardings fell from 271,455 to 203,971, a 25 percent decline in 4 years. A market research study undertaken in 1985 identified lack of parking at suburban rail stations as the largest factor contributing to the ridership losses (Metra, 2002; Ferguson, 2000).

As a result of this study, Metra planned a major expansion of its park-and-ride facilities. Between 1988 and 1995, 139 parking projects were completed, adding 17,267 new spaces and improving 7,005 existing spaces. Metra parking capacity grew from 54,121 spaces in 1986 to 68,301 in 1994, or 26 percent. At the same time, observed parking use grew from 46,997 in 1986 to 58,882 in 1994, or 25 percent — essentially parallel growth. Ridership gains over the same period, however, were only about 15 percent.

This led to concern that some of the park-and-ride gains were at the expense of other potentially less polluting modes of access, but a 1994 survey of Metra riders found virtually no instances of switching from walking to driving alone for Metra station access. Analysis of mode of arrival data vis-à-vis parking facility usage data ultimately led to the conclusion that the added parking had not only attracted new riders but also had caused parking shifts from spillover parking locations to parking in the formal station lots. In addition, there seemed to be non-Metra use of Metra lots within the Chicago city limits (Ferguson, 2000).

Metra park-and-ride facility use data and mode of arrival shares are displayed in Table 3-3, differentiated by station distance from the Chicago CBD. As might be expected, station access by driving alone increases in significance the further out the station. Beyond 10 miles from the CBD, however, the share of auto drop-off, carpool, bus and other modes is fairly constant, save for a reduction in bus access beyond 30 miles. Driving alone thus appears to substitute primarily for walking as distances increase and residential densities drop.

Prior to Metra formation, service to the north suburbs was provided by the Chicago and North Western (C&NW) and Milwaukee Road commuter rail lines along with Chicago Transit Authority (CTA) rapid transit. Service was significantly less frequent on the Milwaukee Road. Park-and-ride lot counts showed that one-half to two-thirds of all parked cars with identifiable municipality stickers were using stations within their own locality. Use of parking along the C&NW and Skokie Swift Rapid Transit by residents of the Milwaukee

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[1] An elasticity of +0.2 in this instance indicates a 0.2 percent increase (decrease) in ridership in response to each 1 percent increase (decrease) in park-and-ride spaces, calculated in infinitesimally small increments (see "Concept of Elasticity" in Chapter 1, "Introduction," and Appendix A, "Elasticity Discussion and Formulae").

Road service area was fairly common, however, while the reverse was not observed. These phenomena were presumably induced by the more frequent service of the C&NW and rapid transit lines, and demonstrate both the relevance of transit service levels and the inherent ability of the park-and-ride patron to drive to the best of competing services (Pratt and Bevis, 1971). Commuter rail service tends to be more uniform under Metra. Chicago area station choice modeling reported in 1992 was unable to calibrate a logical explanatory relationship between commuter rail service levels and station choice (Hart, 1992).

MARC Park-and-Ride Lots. Maryland's MARC commuter rail system was established in the early 1980s, taking over scanty services previously operated by the railroad companies. The MARC services and associated park-and-ride lots have been extended and expanded over two decades. Three MARC lines provide service in the Baltimore – Washington, DC – West Virginia region. Park-and-ride facilities operated in conjunction with MARC have been increased since the early 1980s from 19 lots with some 1,500 spaces to 26 lots with 5,922 spaces in 1998. Lot sizes range all the way from 13 to 815 spaces each. MARC also shares park-and-ride lots at New Carrollton, Greenbelt, and Rockville, Maryland, with Washington's HRT/Metro system, Metrorail.

The number of parked vehicles at MARC facilities more than tripled between 1983 and 1995, increasing from 1,296 in 1983 to 5,150 in 1995. System-wide parking space occupancy rates were 87 percent in 1995. Utilization at 14 lots was at or over capacity, while seven were between 65 and 95 percent, and five were under half full. The increase in park-and-ride use corresponds with MARC ridership growth, which increased by 13 percent annually between Fiscal Years 1989 and 1994 and has been concentrated primarily at farther out stations (Metropolitan Washington Council of Governments, 1990 and 1996).

Virginia Railway Express Park-and-Ride Lots. Service on the Virginia Railway Express (VRE) between Fredericksburg and Manassas, Virginia, and Union Station in Washington, DC, was initiated in 1992. A 1995 survey of park-and-ride lots and use associated with VRE service found 2,411 vehicles using the 3,901 parking spaces in the 13 facilities then in operation, for an overall occupancy level of 62 percent. One facility was over capacity, while six lots were at or below 50 percent. Eight lots carried daily charges ranging from $1.00 to $1.25.

In May 2002, VRE parking capacity had grown to about 5,700 spaces at 13 stations, now with parking fees eliminated. Seven of these facilities were at or above 95 percent utilization and none had utilization below 55 percent (Metropolitan Washington Council of Governments, 1996; Virginia Railway Express, 2002). The Franconia-Springfield station, which now has a large paid-parking facility shared with and used mostly by Metrorail, is not included in any of the figures above. An examination over time from 1955 through 1995 of the regional park-and-ride context within which the MARC and VRE systems operate is provided in the first case study of this chapter, "Park-and-Ride/Park-and-Pool in the Washington, DC, Metropolitan Area."

Heavy Rail Transit (HRT)

HRT/Metro systems support some of the largest park-and-ride facilities and highest parking demand, especially at stations in the suburbs with good highway access and at end-of-line

Table 3-3 Metra Park-and-Ride Usage Characteristics and Mode of Arrival

	Station Distance to CBD (Miles)				Overall System
	0-10	10-20	20-30	30+	
Weekday boardings (AM peak inbound)					
1986	6,250	40,574	42,000	9,800	98,624
1994	7,938	44,226	46,494	14,742	113,399
Change 1986-94	1,688	3,652	4,494	4,942	14,775
Change 1986-94	27%	9%	11%	50%	15%
Station parking capacity					
1986	2,918	20,676	22,591	7,936	54,121
1994	3,824	24,047	28,134	12,296	68,301
Change 1986-94	906	3,371	5,543	4,360	14,180
Change 1986-94	31%	16%	25%	55%	26%
Station parking use (observed)					
1986	2,493	17,937	20,029	6,538	46,997
1994	3,079	19,647	25,631	10,525	58,882
Change 1986-94	586	1,710	5,602	3,987	11,885
Change 1986-94	24%	10%	28%	61%	25%
Average parking space occupancy					
1986	85%	87%	89%	82%	87%
1994	81%	82%	91%	86%	86%
Mode of station access (1994)					
Drove alone	25%	43%	61%	71%	55%
Walked	59%	34%	12%	6%	21%
Dropped Off	10%	13%	14%	14%	13%
Carpool	3%	5%	6%	6%	6%
Bus	2%	4%	5%	2%	4%
Other	1%	1%	1%	1%	1%

Source: Ferguson (2000).

stations in particular. The number of facilities and the corresponding proportion of riders using them may, nevertheless, be extremely limited on HRT systems located primarily within dense central cities. Less than 1 percent of riders on Chicago's CTA subway and elevated rail rapid transit lines utilize formal CTA park-and-ride facilities (Foote, 2000), although over 8 percent report some form of auto driver access (McCollom Management Consulting, 1999). In contrast, when the Lindenwold High Speed Line was opened between New Jersey suburbs and Philadelphia, 83 percent of all riders were found to be utilizing some form of auto access, and the parked-auto proportion of riders was 57 percent (Ellis, Burnett and Rassam, 1971). Additional auto access data for HRT/Metro are provided within the "Related Information and Impacts" section in two locations: under "Prevalence of Park-and-Ride Activity" and also under "Usage Characteristics of Park-and-Ride/Pool Facilities" — "Mode of Access."

End-of-line HRT/Metro stations often have more than 1,500 spaces while many closer-in stations may have few if any parking spaces. For example, Atlanta's MARTA offers approximately 26,000 spaces at its 38 rail stations. Of these, over 50 percent are concentrated at the seven largest facilities, all located at (or one stop away from) the end of a line. Systemwide utilization is approximately 75 percent (MARTA, 2002). Similarly, in Baltimore, nearly 50 percent of the Metro station parking (3,591 spaces of the 7,482 spaces) is provided at the end of line stop in Owings Mills. The remaining parking is spread among six other stations (Maryland Transit Administration, 2002). Information from the Chicago and Washington, DC, systems is presented in more detail below.

Chicago Transit Authority (CTA) Park-and-Ride Facilities. Although users of formal CTA park-and-ride facilities make up less than 1 percent of the Chicago Transit Authority's rail rapid transit system ridership (2.3 million of 445 million annual rides), they generate high per-passenger revenue through parking charges of $1.75 to $1.50 per day. In 1998, the CTA had 15 park-and-ride facilities providing 6,500 parking spaces, mostly at the ends of individual HRT lines. Of these, between 5,100 and 5,500 spaces were used each weekday. The newer Orange Line, serving Chicago's Southwest Side and Midway Airport, was built with five park-and-ride lots, usually filled each day. The Brown and Blue Lines had unused capacity, including the Cumberland park-and-ride garage, CTA's largest and only enclosed facility.

In the fall of 1998, a survey was made of weekday CTA park-and-ride users to help build a profile of their characteristics. The 1,758 respondents equated to 18 percent of survey forms distributed, which were both handed out and left on parked autos. The user characteristics identified and expanded upon under "Characteristics of Park-and-Ride/Pool Facility Users" in the "Related Information and Impacts" section depict a relatively high income clientele, with a mean household auto availability of 2.1 cars: clearly riding transit out of choice. This view of park-and-ride users as persons with options, and the finding that almost 27 percent of respondents had only been using their CTA facility for less than one year, led the study authors to conclude that improved promotion efforts could help attract new users. Most users, 63 percent, learned about their parking facility of choice by seeing it rather than through advertising or literature. Only 7 percent learned about it through advertising.

Work purpose and work related travel constituted 88 percent of all surveyed park-and-ride trips. Trip destinations were located overwhelmingly in the Chicago CBD. Reasons CTA riders gave for choosing to park-and-ride are presented under "Choice of Park-and-Ride and Park-and-Pool" — "Insights from Preference Surveys" in the "Underlying Traveler Response Factors" section. Details on user trip purposes and the prior modes of travel reported by survey respondents are similarly found under "Trip Purpose and Orientation" and "Prior Mode of Park-and-Ride/Pool Facility Users" in the "Related Information and Impacts" section. Only 25 percent of park-and-ride customers had used transit for the full length of their trip prior to choosing to park-and-ride, suggesting that efforts to boost park-and-ride use did not come primarily at the expense of existing feeder bus riders (Foote, 2000).

Washington, DC, Metrorail Park-and-Ride Facilities. Park-and-ride facilities have been a feature of Washington's Metrorail since the opening of the first rail segment in 1976. Lots were integrated into station area designs, although expansions at major locations have now been taken well beyond original expectations. As of 2002, 33 out of 83 stations had all-day park-and-ride facilities with 44,300 spaces in operation by or in arrangement with the Washington Metropolitan Area Transit Authority (WMATA). Approximately 55 percent of these spaces were at the last station on a line. Multi-story parking garages are located at several stations, with 16 stations having more than 1,000 spaces. Parking fees of $1 to $2.25 a day in 2002 were charged to riders at the facilities operated by Metrorail itself (Washington Metropolitan Area Transit Authority, 2002a), with rates up to $5.00 at independent facilities serving a park-and-ride function.

The number of parking spaces and the number of parked vehicles has increased substantially as the rail system has been expanded. The number of spaces increased from 1,509 to 38,137 between 1977 and 1995, and the number of parked vehicles grew from 1,098 to 34,195. The overall utilization rate also went up, from 73 percent to 90 percent. Of the individual facilities, 29 are at capacity despite the parking charges, usually filling by 8:30 AM (Metropolitan Washington Council of Governments, 1996). Parking at Metrorail stations is in such high demand that in 1998, Metrorail implemented a reserved parking program, which provides a guaranteed space for a higher fee. For a brief description, see "Parking Pricing at Park-and-Ride Facilities" in the "Related Information and Impacts" section. The upward park-and-ride/pool usage trends in the region are examined for each individual travel mode in the case study "Park-and-Ride/Park-and-Pool in the Washington, DC, Metropolitan Area."

In January 2001, the last segment of the originally planned 103-mile, 83 station Metrorail system was opened, but expansion of park-and-ride facilities in response to demand in excess of capacity has continued, especially at terminal stations. Recent park-and-ride garage construction locations include the western end of line station of the Orange Line in Virginia (bringing the long-term parking total to 3,643 spaces), the northwestern terminal of the Red Line in Maryland (to approximately 5,810 total) and the southwestern terminal of the Blue Line in Virginia (to some 5,015 total long-term spaces) (Montgomery County, Maryland, 2001; Washington Metropolitan Area Transit Authority, 2001 and 2002b).

Light Rail Transit (LRT)

LRT park-and-ride facilities have usually proven popular with riders, but are generally smaller than those associated with HRT/Metro. Similar to the HRT mode, end-of-line stations often have the largest parking facilities. The lesser demand per facility found on certain LRT systems may be a function of less frequent service, lower travel time savings, shorter station spacing, or simply the relatively smaller size or lower densities of the employment centers served. Experience in Calgary, Denver, and in Europe is reported below. Parking space and usage totals for other systems were provided in Table 3-1.

Example drive-alone access percentages of LRT riders systemwide who park-and-ride in either formal or informal parking facilities include 18 percent for LRT in Buffalo, 22 percent in Sacramento, 26 percent in Portland, Oregon, and 36 percent in Pittsburgh (McCollom Management Consulting, 1999). For additional LRT mode of access data see Chapter 7, "Light Rail Transit" — "Related information and Impacts" — "Mode of Access and Egress to LRT."

Calgary LRT Park-and-Ride Facilities. In Calgary, the initial south LRT line was opened in 1981, followed by the Northeast Line in 1985, and the Northwest Line in 1991. The primary access modes to the LRT system at suburban stations are feeder buses and park-and-ride. In 1992, 11 park-and-ride lots with 6,800 parking spaces were in operation with the three lines. This number had increased to 7,354 by 1998, with additions along the Northwest and South lines. Current system-wide utilization is approximately 97 percent, with lots at terminal stations and those along the Northwest and South lines at 100 percent. Stalls with auto heater plug-ins for use in winter are provided at many of the lots. In 1992, park-and-ride accounted for 20 percent of the access/egress on the Northwest line, 15 percent on the Northeast line, and 21 percent on the South line. Being dropped off accounted for 4 percent along the Northwest line and 7 percent on both the Northeast and the South lines. Access/egress by feeder bus accounted for about half the trips in each corridor, and walk/other represented between 21 and 25 percent (City of Calgary, 1998; Hubbell et al., 1992).

Denver LRT Park-and-Ride Facilities. The opening of the initial Denver LRT line in 1996 included four park-and-ride lots with 1,074 spaces in total. The lots, ranging in size from 27 to 650 spaces, have been well used from the outset. An average of 988 vehicles parked in lots in 1996, an occupancy rate of 93 percent. The two largest lots were expanded in 1997 and 1998, bringing total spaces to 1,675. In 1998, with some 1,634 vehicles parked, the occupancy rate was 98 percent and two of the lots were at or over capacity (Regional Transit District, 1999).

European LRT Park-and-Ride Facilities. Park-and-ride facilities are used less with LRT systems in Europe than those in North America. As highlighted in Table 3-1, the LRT systems in Antwerp, Stuttgart, and Toulouse have two, four, and three park-and-ride lots, respectively. Reported utilization rates ranged from a low of 20 percent in Stuttgart to a high of 100 percent in Antwerp (Dickins, 1994). System total spaces are fewer than for eight of the nine North American LRT systems listed. The scarcity of park-and-ride lots with LRT systems in Europe may be presumed a reflection of the more dense development patterns and intensities of local transit service encountered.

Response to Busway and HOV Park-and-Ride/Pool Facilities

Most busway and HOV systems have park-and-ride facilities associated with them. The size of park-and-ride facility needed is influenced by the volume of travel and frequency of service in the corridor, the distance to other facilities, and the distance to and density of the employment served. Parkers tend to use the first lot encountered along their travel path, and if lots are too closely spaced, they may be underutilized (Center for Urban Transportation Research, 2001).

The potential importance of park-and-ride to busway and HOV facilities may be inferred in part from the example of the San Bernardino Transitway east of Los Angeles, where post-implementation surveys showed 72 percent of the Transitway's bus riders to be utilizing some form of auto access (Crain & Associates, 1978). Park-and-ride access proportions for urban busways should be comparable to or less than the four-city 18 to 36 percent range reported above for drive alone to LRT. To the extent that busway service features routes extending off-busway into neighborhoods for passenger collection, the need for park-and-ride may be reduced relative to LRT. The South Miami-Dade Busway has a park-and-ride access share of only 6 to 7 percent of busway riders (see "Related Information and Impacts" — "Usage Characteristics of Park-and-Ride Facilities" — "Mode of Access," specifically Table 3-18 and its footnote "[a]," for more). Differences in demand for park-and-ride between urban rail and busways/BRT are explored in Chapter 4, "Busways, BRT and Express Bus," with related mode of access data on a route level in that chapter's "Related Information and Impacts" section under "Mode of Access and Egress to BRT/Express Buses."

Table 3-4 presents information on park-and-ride lots associated with HOV facilities. Such park-and-ride lots tend to have a degree of park-and-pool activity associated with them. Lot sizes vary by the type of HOV lane. The exclusive Houston HOV lanes and San Bernardino Transitway HOV facility have lots with 1,000 to 2,200 spaces. Concurrent flow HOV lane park-and-ride lots tend to be smaller, ranging from 100 to 600 spaces. Selected examples of park-and-ride lots associated with busway and HOV facilities are summarized next. Some of the park-and-ride lots discussed in the "Response to Express and Local Bus Park-and-Ride Facilities" subsection may also be linked to HOV lanes, but are not presented here because of difficulty in separating specific HOV-served lots from the totals provided for an area.

Pittsburgh Busway Park-and-Ride Lots. The Port Authority of Allegheny County operates three busways in and around Pittsburgh, Pennsylvania. The individual bus routes that serve them board roughly 50,000 riders per weekday in total. Over half those riders use the Martin Luther King, Jr. East Busway, opened in 1983. It connects downtown Pittsburgh with the eastern suburbs via its 6.8 mile exclusive facility utilized by 36 bus routes. Six stations serve walk-in, drop-off and transferring passengers. Off-line park-and-ride facilities are called on by buses that then use the busway. None of the original East Busway stations themselves featured park-and-ride lots, but a new 2.3 mile extension has added four stations (one a replacement) and over 1,000 spaces. The West Busway opened in 2000. Featuring six stations, the five mile facility enroute between downtown Pittsburgh and the airport attracts some 8,000 riders per day. Its initial 700 park-and-ride lot spaces are filled daily, and approximately 2,100 additional spaces are under construction (Port Authority of Allegheny County, 2002 and 2003; Pittsburgh Business Times, 2002). More information on Pittsburgh busway usage is provided in Chapter 4, "Busways, BRT and Express Bus," most particularly in the "Pittsburgh Busways" case study.

Houston HOV Lane Park-and-Ride Lots. Park-and-ride lots and express bus services are an integral part of the Houston HOV lane system. In 1998, 22 lots with 26,089 parking spaces were located adjacent to the five freeways with HOV lanes. Fourteen of the lots contain spaces for between 950 and 2,246 automobiles each. Some 12,650 vehicles parked in the lots on a daily basis in 1998, an overall occupancy rate of 48 percent. As shown in Table 3-4, usage levels by corridor range from 34 percent along the Southwest Freeway, the newest of the HOV lanes, to 61 percent along the Katy Freeway. Utilization varies by lot as well, with some close to capacity. The number of lots, spaces, and daily users has grown steadily, as detailed in the case study, "HOV Lane Park-and-Ride/Pool Facilities in the Houston Area." The HOV lots are oriented toward suburban commuters (Stockton et al., 1997; Texas Transportation Institute, 1998). The primary express transit routes serving them are the major part of Houston Metro's "Commuter Bus" operation. Of "Commuter Bus" riders, 75 percent park in the HOV system park-and-ride lots. Another 4 percent arrive as auto passengers, in vehicles parked or dropped off, for a grand total 79 percent auto arrival mode of access (Houston-Galveston Area Council, 2001).

Minneapolis I-394 Park-and-Ride Lots. There were no formal park-and-ride lots in the Highway 12 corridor on the west side of Minneapolis prior to its reconstruction into the I-394 freeway in the late 1980s and early 1990s. Seven park-and-ride lots were opened in the course of completing the freeway and HOV lanes. In 1993, there were 936 parking spaces and

Table 3-4 Examples of Utilization of HOV Park-and-Ride Facilities

HOV System (Year)	Number of Lots	Number of Spaces	Parked Vehicles	Percent Capacity
Houston				
I-45 North (1998)	5	7,386	3,643	49%
US 290/Northwest (1998)	3	3,852	2,069	54%
I-10 West/Katy (1998)	3	4,525	2,764	61%
US 59 South/Southwest (1998)	8	7,308	2,481	34%
I-45 South/Gulf (1998)	3	3,018	1,694	56%
Los Angeles-San Bernardino Transitway				
El Monte Station (1994)	1	2,100	2,100	100%
Minneapolis - I-394 (1993)	7	936	558	60%
Seattle - I-5 North/Community Transit (1998)	18	4,200	n/a	89% [a] 91% [b]

Notes: n/a - Information not available except by inference based on the "Percent Capacity" values, which come from estimates or other derivations used by the reporting agencies.

[a] Major lots.

[b] Minor lots.

Sources: Community Transit (1998); SRF, Inc. (1995); Texas Transportation Institute (1998); Turnbull (1994).

overall utilization was 60 percent. Two facilities were regularly full by 8:00 to 9:00 AM, while two lots averaged between 60 to 70 percent full, two were in the 30 to 40 percent range, and one was less than 20 percent utilized. Field observations provided information on lot usage patterns. Seventy-three percent of the park-and-ride lot users taking the bus parked their vehicle in the lots, 11 percent were dropped off, 8 percent walked, 7 percent rode a feeder bus, and 1 percent biked. In addition, approximately 75 carpools, involving some 154 people, were formed at the park-and-ride lots (SRF, Inc., 1995). More information on I-394 HOV lane, bus, and parking usage over time is provided in Chapter 2, "HOV Facilities." See in particular the "I-394 HOV Facilities" case study.

San Bernardino Transitway Park-and-Ride Lots. A major park-and-ride lot is located at the El Monte Station, the eastern terminus for the San Bernardino Transitway HOV facility. It initially had 1,000 parking spaces, and 700 more were added in the first years of operation. The facility was used to capacity, and lack of available spaces was considered a limiting factor to increasing bus ridership (Crain & Associates, 1978). Although now expanded to 2,100 spaces, it still regularly fills up. As of 1994, some 20 park-and-ride lots were located in the San Bernardino Freeway corridor supporting transitway functions and the newer METROLINK commuter rail line (Turnbull, 1994).

Snohomish County, Washington, Community Transit Park-and-Ride Lots. Community Transit operates 18 park-and-ride lots with express bus service to downtown Seattle and the University of Washington. Buses operating out of the lots use the I-5 North HOV lanes. Approximately 4,200 parking spaces are available at eight major and ten minor lots. The major lots have between 200 and almost 500 spaces. Parking space occupancy rates in 1991 were 96 percent for the major lots and 76 percent for the minor lots (Ulberg et al., 1992). Three of the facilities were added and one expanded between 1994 and 1996. Utilization rates in 1998 with the increased spaces were 89 percent for the major lots and 91 percent for the minor lots (Community Transit, 1998).

Response to Express and Local Bus Park-and-Ride Facilities

Park-and-ride lots that are not directly associated with rail transit, busways or HOV lanes accompany many express and some local bus lines throughout North America. These lots tend to be smaller in size, often in the range of 25 to 100 spaces, although larger lots are found in some metropolitan areas. They primarily serve commuters in corridors destined for the CBD or a major employment center. Table 3-5 highlights examples of park-and-ride lots with express and local bus services. Specific cases are expanded upon following the table.

The proportions of local and express bus riders systemwide who gain access by driving alone and parking in either formal or informal parking spaces range from less than 1 percent for small city systems to on the order of 6 to 8 percent in cities like Portland, Oregon, or Pittsburgh (McCollom Management Consulting, 1999). For individual express services, however, proportions of riders driving and parking can be much higher, approaching 100 percent usage of some form of auto access in the case of express routes focused exclusively on park-and-ride lots. Limited additional systemwide bus system mode of access data is provided in the "Related Information and Impacts" section under "Prevalence of Park-and-Ride Activity." For more comprehensive detail, see Chapter 10, "Bus Routing and Coverage" — "Related Information and Impacts" — "Mode of Access and Egress to Bus Service."

Two special points need to be made with regard to the data in this subsection, including Table 3-5. First, some bus routes operating out of individual park-and-ride lots may use HOV lanes. Because it is difficult to separate these lots from the totals provided for many areas, the information presented here includes them, most notably in the case of Seattle. Second, shared-use facilities at existing shopping or church parking lots are in use in many areas. In these cases, the specific number of parking spaces is often not available from the transit agency, and usage levels may be harder to gauge.

National studies in the 1970s and circa 1980 concluded that lots constructed specifically for park-and-ride/pool were not more heavily used than shared-use facilities (Pratt and Copple, 1981). Limited newer information presents a mixed picture. Seattle area experience, presented below, suggests that shared-use facility occupancy rates may be less than average. Specifically constructed major facilities may tend to be located in the prime locations. Shared-use lots may not be as well identified and visible. Alternatively, any differential may simply be an artifact of the measurement problems noted above for shared-use facilities.

Table 3-5 Examples of Utilization of Express and Local Bus Park-and-Ride Facilities

System (Year)	Number of Lots	Number of Spaces	Parked Vehicles	Percent Capacity
Buffalo-Niagara Frontier (1995)	6	200	n/a	50%
Calgary (1998)				
North	6	186	129	69%
Southwest	2	103	103	100%
Cincinnati Region (1998-1999)	25	2,089	1,296	62%
Denver – Regional Transit District (1998) [a]	55	11,251	8,199	73%
Des Moines Transit Authority (1995)	3	n/a	n/a	50%-80%
	1	n/a	n/a	10%
Duluth Transit Authority (1995)	1	22	n/a	50%
Houston – US 59 North/Eastex (1998)	3	2,418	1,130	47%
Maryland – State Highway Admin. Lots (2003)	23	5,219	3,792	73%
Sacramento (1989)	3	154	60	39%
Santa Clara Valley Transportation Authority (1998) [a]	17	820	260	32%
Seattle (1998)				
North District [a]	26	4,115	3,025	74%
East District [a]	43	6,235	4,964	80%
South District [a]	57	7,536	5,554	74%
Miami Valley [Ohio] Regional Transit Authority (1995)	26	960	n/a	75%
Metro-Dade (1993)	8	1,767	883	50%
Norfolk-Tidewater Transport District (1995)	5	700	400	57%
San Diego (1998)	31	2,125	850	40%

Notes: n/a - Information not available except by inference based on the "Percent Capacity" values, which come from estimates or other derivations used by the reporting agencies.

[a] Some buses operating out of these lots use the various HOV lanes and other priority treatments.

Sources: Al-Kazily (1991), City of Calgary (1998), King (2003), Metro-Dade Transit Authority (1993), Metropolitan Transit Development Board (1999), Municipality of Metropolitan Seattle (1998), Ohio Kentucky Indiana Regional Council of Governments (1999), Regional Transit District (1999), Santa Clara Valley Transportation Authority (1998), Stockton et al. (1997), Turnbull (1995), and inquiries of operators by Handbook authors.

The Maryland State Highway Administration (SHA) sometimes solicits shared use options because many already have the best locations along primary routes. The SHA improves leased lots with paving, lighting and maintenance, and takes advantage of the security provided by the joint use. Spring of 2003 observations found average space utilization of SHA's 2 leased lots with bus service to be 77 percent, compared to a 72 percent average for the 21 owned lots. On the other hand, the 8 leased park-and-pool lots were observed to have only a 29 percent average utilization, compared to 41 percent for the 61 state-owned park-and-pool lots (King, 2003). For more SHA park-and-ride and park-and-pool information, see "Maryland Park-and-Pool Lots" in the "Response to Park-and-Pool Facilities" subsection below. For further exploration of park-and-ride locational considerations, see "Access Travel Distance and Facility Location" within the "Underlying Traveler Response Factors" section.

Demonstrations and Trials. Demonstrations and trials of park-and-ride facility and bus service combinations carried out over the years have demonstrated both the criticality of bus service levels to the facility/service combination, and the importance of the type of destination served. While it has proved difficult to identify particular bus park-and-ride services or their characteristics as categorically successful or unsuccessful, use of express and local bus park-and-ride is in general more sensitive to destination parking costs, travel time and transit service frequency characteristics than is usage of rail-oriented park-and-ride facilities. For example, an early analysis of discontinued park-and-ride lots identified five where low downtown parking costs appeared to be a contributing factor, while the failure of several lots in Washington, DC, was attributed to bus service frequencies of only every 20 to 30 minutes (Pratt and Copple, 1981; Deen, 1965). Cost, time and frequency effects are each explicitly examined in the "Underlying Traveler Response Factors" presentation.

Successful transit park-and-ride is very much a CBD oriented phenomenon. Attempts at establishing park-and-ride circulator bus services dedicated solely to serving suburban employment destinations have been largely unsuccessful. In 1994-1995, New Jersey Transit (NJT) implemented 40 bus and rail experimental services oriented to the suburbs, including bus circulators from park-and-ride lots to suburban employment centers. Of the 40 services, 23 successfully achieved NJT's farebox recovery requirements — 15 percent at the end of year one, increasing stepwise to 25 percent for the third year. None of the park-and-ride bus services met the farebox recovery requirements, and all were eliminated (Michael Baker et al., 1997). Similarly, a new bi-directional shuttle provided by King County Metro at a 10 minute frequency between park-and-ride lots and Microsoft campuses in Redmond, Washington, was terminated for lack of ridership in February 1997 (Volinski, 1997). It appears that in the instances reported, the distances between the lots and destinations have been relatively short. It may be hard to locate sufficient rider density to potentially support longer distance connections to suburban centers, but could it be done, the longer distance might help some.

Denver Park-and-Ride Lots. The Regional Transit District (RTD) operates an extensive park-and-ride lot network in the Denver-Boulder region. Bus routes serving some of these lots use the HOV lanes of the area, while others operate entirely in mixed traffic on freeways and arterial streets. In 1994, there were 49 lots with 9,544 spaces and 4,934 automobiles parked, giving an overall occupancy rate of 52 percent. By 1998, the supply had grown to 55 facilities with 11,251 spaces total, ranging in size from 14 to 1,540 spaces. Systemwide, 8,199 autos were parked, an overall occupancy of 73 percent. Eight lots were at or over capacity, while 13 were less than 50 percent occupied, with the remaining 34 lots attracting intermediate levels of usage (Regional Transit District, 1999).

Houston US 59 (Eastex) Freeway Park-and-Ride Lots. Most of Houston's park-and-ride lots are oriented to that area's extensive system of HOV lanes. However, three lots, with no HOV lanes as of 1998, are located in the US 59 (Eastex) Freeway corridor. The numbers of lots, spaces, and vehicles parked have increased from one lot with 200 spaces and 344 parked vehicles in 1980 to three lots with 2,418 spaces and 1,130 parked vehicles in 1998. Current parking space occupancy rates are approximately 47 percent (Stockton et al., 1997; Texas

Transportation Institute, 1998). This degree of utilization, while significant, is less in terms of the parked vehicle count than in the five corridors with HOV lanes (see Table 3-4).

Seattle Park-and-Ride Lots. An extensive network of permanent and leased park-and-ride lots are in operation in the Seattle – King County area. Buses serving some of these facilities operate on the region's HOV lanes. The number of lots and utilization levels have both grown significantly since the opening of the first lot in 1970. Between 1980 and 1998, the number of permanent lots increased from 14 to 50, and the number of leased and shared-use facilities grew from 8 to 76. The total number of lots and spaces increased from 22 lots with 6,328 spaces to 126 lots with 17,886 spaces. Usage levels more than doubled during the 18-year period, increasing from 5,629 to 13,543. Utilization levels have been higher at the permanent lots — over the years — with occupancy rates ranging from 71 percent to 89 percent, compared to 45 percent for the leased lots. As shown in Table 3-5, the number of lots and spaces, and the occupancy levels, vary by sector of King County (Rutherford and Wellander, 1986; Municipality of Metropolitan Seattle, 1998).

Illustrating difficulties in even obtaining consistent tallies of lots and spaces, an alternative accounting for King County reported 115 park-and-ride lots with a total of 25,528 spaces circa 1996-98. The reported average lot utilization was 71 percent of available spaces, including 95 percent at 12 of the largest facilities. Modeling analyses for 17 of the relatively large lots, covering 7,428 spaces 89 percent occupied, suggest that 85 percent of the parkers were taking transit, with 15 percent forming carpools (Hendricks and Outwater, 1998).

A circa 1995 survey of permanent park-and-ride lots in the north and southeast corridors found 70 percent of the users (among the 95 percent making work trips) to be headed for downtown Seattle. Of those, 3 percent derived from park-and-pool activity (Rutherford and Wellander, 1986). This finding, although from a different source, compares logically with the 1998 estimate reported above that 15 percent of King County park-and-ride lot users are forming carpools. As noted in the following subsection, park-and-pool activity is much less oriented to regional CBDs than park-and-ride. Thus excluding non-CBD travel from a park-and-pool versus park-and-ride activity accounting should drastically lower the park-and-pool activity proportion. More details on Seattle area facilities are presented in the case study "Park-and-Ride and Park-and-Pool Facilities in King County, Washington."

Response to Park-and-Pool Facilities

Park-and-pool facilities are lots that do not have regularly scheduled transit services, but do provide a place for carpoolers and vanpoolers to meet. In general, these types of facilities are smaller than transit park-and-ride lots, and have few amenities. They tend to be located further away from activity centers, in areas that do not have the density of trips to a common destination needed to support transit. Early studies of park-and-ride users showed that while virtually all transit users were destined to the CBD, a large portion of carpoolers were bound for suburban destinations. For this reason it was said that park-and-pool and park-and-ride facilities did not really compete for riders (Pratt and Copple, 1981). Today, more suburban activity centers with transit-supportive densities exist, so there may be somewhat more potential for competition. It is still the case, however, that carpools have the advantage of greater flexibility in serving dispersed final destinations. Examples of park-and-pool facilities are highlighted in Table 3-6 and additional information is selectively summarized below.

Table 3-6 Examples of Utilization of Park-and-Pool Facilities

System (Year)	Number of Lots	Number of Spaces	Parked Vehicles	Percent Occupancy
With HOV Facilities				
Houston – I-10 West/Katy (1998)	3	1,169	184	15%
Without Priority Treatments [a]				
Cincinnati Region (1998-1999)	6	225	148	66%
Connecticut (1996)	115	7,763	4,128	53%
Maryland (2003)	69	5,367	2,142	40%
Sacramento (1989)	35	1,231	629	51%
San Diego (1998)	30	1,306	529	40%

Note: [a] A minority of lots within the total count may have access to HOV priority treatments.

Sources: Al-Kazily (1991), King (2003), Metropolitan Transit Development Board (1999), Ohio Kentucky Indiana Regional Council of Governments (1999), Stockton et al. (1997).

It is difficult to ascertain what proportion of ridesharing activity overall might be aligned to use of park-and-pool facilities or park-and-pool activity at park-and-ride lots. At what is probably one extreme, a 1989 survey in the metropolitan Washington, DC, region found that 98 percent of the 1,100 vanpools in the region form at meeting places other than home (not necessarily park-and-pool lots) (Metropolitan Washington Council of Governments, 1990). The corresponding proportion for carpools would, because of their smaller size and a tendency toward family ridesharing, logically be less.

A related question is what proportion of users of transit-oriented park-and-ride facilities or mixed park-and-ride/pool systems are forming carpools instead of taking transit. This proportion will vary widely according to the focus of the parking system. Estimates and survey results addressing this question are found in the previous subsection for King County, Washington (15 percent park-and-pool), and in Table 3-18, footnotes "d" through "g" (7 to 82 percent park-and-pool), found in the "Related Information and Impacts" section under "Usage Characteristics of Park-and-Ride/Pool Facilities" — "Mode of Access."

Dallas and Miami Park-and-Pool. Early studies of park-and-pool activity found that average auto occupancy for the trip from home to park-and-pool lots was 1.08 persons in Miami and 1.38 in Dallas, while average carpool occupancy leaving the lots was 2.75 in Miami and 3.76 in Dallas. This limited evidence suggested to researchers that one carpool is formed in park-and-pool lots for every 2.5 to 2.7 vehicles entering the lot, or for every 1.5 to 1.7 vehicles parking in the lot (Allen, 1979; Wattleworth et al., 1978).

Connecticut Park-and-Ride Lots. In 1996, the state of Connecticut counted 237 facilities in its commuter parking network. Of these, 188 lots with 17,615 spaces represented non-rail parking. The average use of these non-rail facilities was approximately 6,500 cars parked per day, or a utilization of 37 percent. Over 60 percent of these lots, 115 in all, are used exclusively for carpooling and vanpooling. The average park-and-pool lot size is 68 spaces and the median is 51 spaces, with a size range of 12 to 257 spaces. In 1995 surveys conducted at a sample of lots, the average occupancy of vehicles entering the lots was 1.17 persons per car and the average occupancy of vehicles departing the lots was 3.00 persons per car. This ratio equates to one carpool formed for every 2.5 vehicles entering. Contributing to carpool formation were the 7 percent of travelers using the lot who were dropped off. Comparing occupancies revealed in the 1980 and 1990 census data, the study authors concluded that park-and-ride lots greatly facilitated ridesharing and led to more and larger carpools and vanpools. They note that overall usage of commuter parking facilities in Connecticut had declined in recent years, perhaps due to increasing dispersion of employment (Connecticut Department of Transportation, 1996).

Houston I-10 West (Katy) Park-and-Pool Lots. In the Houston area, three park-and-pool lots are located to the west of the HOV lane on the Katy Freeway. These lots, in operation since 1986, do not have direct access to the HOV lane. Rather, carpools leaving the lots access the freeway first, and then enter the HOV lane. No amenities are provided at the lots. In 1986, some 84 vehicles were parked in the 1,169 available spaces in the three lots, a 7 percent park-and-pool lot occupancy rate. In 1998, approximately 184 vehicles were parking in the lots, for a 15 percent occupancy rate.

Sacramento Region Park-and-Pool Lots. There were 35 park-and-pool lots in the Sacramento region in 1991, providing 1,231 spaces. These facilities were not served by regular bus routes. Some 629 vehicles used the lots on a daily basis, an occupancy rate of 51 percent. Usage levels varied significantly among facilities, with some almost empty and some at capacity. The most heavily used lots served major commute corridors and long distance trips to the San Francisco-Oakland area or Stockton. A 1989 survey of lot users found that 60 percent traveled 5 miles or less to the facility, while 22 percent traveled between 6 and 10 miles, and 18 percent had trips of over 10 miles (Al-Kazily, 1991).

San Diego Area Park-and-Pool Lots. In 1998, there were 30 park-and-pool lots in operation in the San Diego metropolitan area, with 1,306 spaces. These facilities ranged in size from 10 to 108 spaces. Overall utilization levels were 40 percent. There was great variation in use among the lots, however, with two over capacity, four over 60 percent, and six at 10 percent or below. The lots with the highest use are located close to the major freeways in the area (Metropolitan Transit Development Board, 1999).

Maryland Park-and-Pool Lots. Of the 64 park-and-ride/park-and-pool lots in Maryland operated by the State Highway Administration (SHA) as of 1988, 58 were oriented entirely to carpools and vanpools, with bus service provided to 6 lots. The corresponding 2003 SHA inventory lists 92 lots total, 69 oriented to park-and-pool only, and 23 lots with bus service. Supply and usage of Maryland's SHA ridesharing lots grew sharply from 1,240 spaces and 730 vehicles parked in 1978 to 4,510 spaces and 2,530 vehicles parked in 1983, and then more gradually to 6,310 spaces and 3,720 vehicles parked in 1989. Corresponding parking supply and usage for 2003 had expanded to 10,586 spaces with 5,934 vehicles parked despite a program of transferring lots, predominantly ones in more urban settings, from SHA to the Maryland Transit Authority or local jurisdictions. Corresponding SHA systemwide utilization rates have oscillated from 59 percent in 1978, to 56 percent in 1983, 59 percent in 1989, and 56 percent in 2003 (Maryland Department of Transportation, 1988/90; King, 2003).

The Maryland SHA lots devoted exclusively to park-and-pool activity tend to be smaller and with lower absolute and relative utilization compared to the SHA average. In the spring of 2003, SHA reported 69 park-and-ride facilities oriented exclusively toward carpools and vanpools statewide, ranging from 9 to 489 spaces in size and totaling 5,367 parking spaces. The average size was 78 spaces and the median was 60 spaces. Overall utilization was 40 percent for park-and-pool lots as compared to 73 percent for the lots with bus service, which averaged 227 spaces in size. Utilization of individual park-and-pool lots ranged from 0 to 107 percent, compared to a range of 10 to 190 percent for lots with bus service. Historically the SHA program has concentrated on smaller, more rural lots intended for park-and-pool. The demand at many carpool lots throughout Maryland is reported to have slowed, however, resulting in retrofitting of selected existing lots for bus service and development of new bus-served lots. Growth in demand for park-and-ride spaces has continued unabated (King, 2003).

Maryland State Highway Administration park-and-ride/pool lot user surveys in 1988 ascertained that 18 percent of lot users departed for their destination via bus or other transit, relative to 59 percent in carpools and 23 percent in vanpools. Also obtained was information on occupancy levels of car- and vanpools formed at the lots. The combined average was 3.2 persons per vehicle, just slightly above the 3.0 occupancy figure obtained more recently by Connecticut (see above). Of car- and vanpools formed, 43 percent were 2-person, 14 percent were 3-person, 19 percent were 4-person, and 23 percent were 5-or-more-person. All persons parking in the park-and-ride/pool lots, including the 18 percent taking transit, were asked if they had participated in "ridesharing" before starting to use the facility. Some 46 percent responded that they had not done so (Maryland Department of Transportation, 1988/90).

UNDERLYING TRAVELER RESPONSE FACTORS

Understanding the underlying traveler response factors influencing choice of park-and-ride or park-and-pool as a travel mode, and the selection of which park-and-ride/pool facility to use, can lead to better siting of facilities and improved estimates of parking demand. As the park-and-ride experiences presented in the previous section illustrate, while many park-and-ride facilities are well utilized and demand in excess of capacity is not uncommon, others were substantially overbuilt, especially on certain HOV and bus-based systems.

In the subsections that follow, the primary factors influencing travelers' decisions with regard to park-and-ride facility use are explored. First, relevant insights into mode and facility choice from both travel demand modeling and surveys are reviewed. Then the implications of travel distance, lot location, travel time, transit level of service and user costs are examined, with a referral to the following "Related Information and Impacts" section for trip purpose and orientation, and facility characteristics and amenities. Finally, this underlying factors section concludes with a look at what is known about overall effects on transit mode share of providing or not providing a park-and-ride system.

Choice of Park-and-Ride and Park-and-Pool

Commuters and others who elect to drive and park at park-and-ride/pool facilities are inherently trip makers with choices. The fact that an auto is driven for one leg of the trip shows that they have an auto available and could, if they wanted, go all the way by auto. Moreover, the fact that their auto is left behind at the park-and-ride/pool facility indicates that they do not have to have their auto at their destination. Those who park at park-and-ride/pool facilities can thus reasonably be characterized as “choice” users, not “captive” to public transit, and also not generally “captive” to their auto. The one travel option they may well not have is the option of using transit service for the entire trip. Transit service may simply not be available at the outlying trip end, typically the traveler’s residence, or errand running or family chauffeuring duties may mitigate against using transit all the way.

There are, however, segments of park-and-ride/pool facility users overall who do not necessarily fit the “choice” users category. Park-and-pool carpool drivers may take that role because they do need their auto at their destination. Persons arriving at a park-and-ride/pool facility as auto passengers, either in cars parked or in a “kiss-and-ride” mode, may not have the option of driving. These two segments of users are a minority of park-and-ride/pool facility users, but are prevalent enough to complicate the picture. (Refer to Chapter 1, “Introduction” — “Use of the Handbook” — “Demographic Considerations” for further discussion of “choice” and “captive” characterizations of trip makers.)

Insights from Travel Demand Modeling

Travel demand modeling reflective of park-and-ride activity includes regional travel modeling and modeling of individual facility usage, with facility use modeling often done in context with the area’s regional travel model system. Before examining insights from facility use modeling, it is important to highlight a key finding from regional models: Park-and-ride is not as attractive to the average traveler as being able to use transit service of equivalent quality somehow delivered within a short walk. This finding is examined under “Overall Effects on Transit Mode Share” — “The Park-and-Ride Mode Change Penalty” at the end of this “Underlying Traveler Response Factors” section.

Efforts to model — and thus be able to understand and forecast — the usage of individual facilities highlight the particular travel choices involved in park-and-ride/pool facility usage (Hendricks and Outwater, 1998; Parsons Brinckerhoff, 1994):

- A demand for (choice of) travel per se, mainly commute to work travel, in the corridor which the facility serves.
- Traveler choice of mixed-mode auto/transit or low-occupancy-auto/carpool travel in preference to either walking to or being dropped off at a transit stop, or driving all the way, or carpooling for the full distance.
- Choice of which route to take, which may involve selecting among alternative transit modes (for example, commuter rail or bus) and their accompanying park-and-ride facilities, or choosing among highway routes, with their park-and-pool lots.
- Choice of intermediate stop location, i.e., election of which park-and-ride/pool facility to use along the chosen transit system or highway route.

Estimation of park-and-ride activity has been shown both in greater Seattle (bus transit park-and-ride) and in Maryland (commuter rail park-and-ride) to be enhanced by joint consideration of the characteristics of all components of the auto/transit mixed-mode trip (Hendricks and Outwater, 1998; Parsons Brinckerhoff, 1994):

- The utility of the auto portion of the trip, between the origin and the park-and-ride facility (travel time and cost).

- The utility of the transit portion of the trip, between the park-and-ride facility and the final destination (travel time, including the wait for a bus or train, and user cost).

- The utility of the park-and-ride facility itself (user cost, available capacity, walk from parking space to transit stop, and intangibles — potentially including safety).

Several of these factors are discussed further in the subsections that follow. Not only will the commuter or other trip maker be concerned with all three portions of the mixed-mode trip in selecting which park-and-ride/pool facility is the best to use, he or she will also be evaluating the utility (travel time, operating cost and parking cost) of the option of driving or carpooling for the entire trip. The primary choice determinants appear to be the time and costs associated with all components of the trip options, along with the availability of parking spaces at the desired mode change location (Hendricks and Outwater, 1998). The preference surveys discussed next bring in the factor of driving stress, an intangible not well addressed through conventional travel demand model investigations.

Insights from Preference Surveys

A few surveys of park-and-ride and park-and-pool lot users have included questions on the reasons people choose these travel options over driving alone. The responses add further insight into the factors influencing use of these facilities. The four surveys reported on here were conventional user preference surveys. Taking the results of all four together, the major incentives come out to be saving money, saving on driving stress, and saving time. Although there was not much consistency among surveys in order of preference, saving of money and avoidance of driving stress seemed to rank higher on average than other factors.

The Santa Clara Valley Transportation Authority (VTA) in the greater San Jose, California, area conducted a survey in 1998 of park-and-ride lot users in Alameda, Santa Cruz, and Santa Clara Counties. Approximately 1,400 of 4,000 surveys left on windshields of cars parked at the lots were completed and returned, a 30 percent response rate. Reasons identified as the most important for using the park-and-ride lots were: driving alone is stressful, 32 percent; costs less, 23 percent; saves time, 12 percent; cost to park at destination, 9 percent; good for the environment, 6 percent; employer provides incentive, 5 percent; parking at destination is hard, 5 percent; use carpool lane, 2 percent; and other, 6 percent. Combining related categories, the factors ranked highest appeared to be cost savings and incentives, 37 percent; reducing stress, 32 percent; and saving time, 14 percent (Santa Clara Valley Transportation Authority, 1999).

A similar question was included on a 1996 survey of users at 68 park-and-ride lots in the San Francisco/Oakland Bay Area. Approximately 39 percent of 4,419 surveys left on windshields were returned. The percentages obtained add up to more than 100 percent as respondents were allowed to select as many factors as they wished. The most important reasons for choosing park-and-ride reported by respondents were: easy access to transit services, 56 percent; saves money, 53 percent; good for the environment, 39 percent; driving alone is too stressful, 32 percent; parking at destination is difficult, 24 percent; saves time over driving alone, 17 percent; good location to meet carpool, 14 percent; enjoy company on trip, 9 percent;

and other, 14 percent. Responses varied slightly by the seven counties in the region. Easy access to transit service was rated higher among users in counties with good transit service (Marin and San Mateo) and low in Santa Cruz County, which has less service (Lave, Billheimer and McNally, 1997).

Users of Chicago Transit Authority's heavy rail transit (HRT) park-and-ride facilities were also surveyed as to their motivations in choosing to do so. In this survey, respondents were asked for their one most important reason for using park-and-ride. The lead reason was that it was the fastest way to make their trip (35 percent). This was followed by persons who disliked driving (24 percent) or found the cost of parking at their destinations to be high (21 percent) (Foote, 2000). A similarly constructed question posed of surveyed Delaware park-and-ride/pool lot users was tabulated separately for lots with rail service and non-rail lots. The top two reasons reported for electing to park-and-ride/pool were high cost of parking at the destination (19 percent/34 percent rail/non-rail) and a dislike of driving or desire to reduce frustration (24/22 percent rail/non-rail). Answers close behind were highway congestion (22/18 percent rail/non-rail) and desire to do other things during the trip (21/14 percent rail/non-rail) (Urbitran Associates and SG Associates, 1999).

Access Travel Distance and Facility Location

Facility Access Travel Distance

The distance an individual must travel to arrive at a park-and-ride facility is a significant determinant of usage. Trip makers tend not to patronize park-and-ride lots that are too far from home relative to the length of the overall trip, and where there is competition between closely spaced facilities, driving distance from home is a key attribute in selecting which lot to use. Distance from home is thus an important factor in planning location and size of park-and-ride facilities.

Many park-and-ride direct demand estimation techniques rely on determination of the "market shed" for the proposed facility. The term "market shed" refers to the area around the park-and-ride facility from which most users are drawn. It is a manifestation of the distance travelers are willing to go to reach the facility. Most patrons for a particular facility, in a suburban context where facilities are widely spaced, come from an area primarily upstream from it. Users rarely choose to backtrack, though there are exceptions. A parabolic shape most nearly represents this draw area, with the directional axis oriented toward the central business district (CBD).

A study completed in the Seattle metropolitan area evaluated the observed market areas for 31 large suburban park-and-ride lots. When the origins of individual users were plotted, it was found that parabolic shapes could be overlaid at each facility to capture 85 percent of the market. The parabolas extended 2.0 to 2.5 miles towards the primary CBD downstream from each facility, and the demand extended back along the major freeway or arterial closest to the lot about 10 miles. The spread of the demand was approximately 12 miles. Interestingly, 50 percent of the market for most park-and-ride lots in the study was contained within the circular region extending about 2.5 miles from the lot. Indeed, this latter observation led to a simplifying assumption in related modeling work (Spillar, 1997).

Similar findings pertaining to market shed shapes were obtained in research conducted in several Texas metropolitan cities. In the Texas study, the parabolic shape was found to extend 0.5 to 1.5 miles downstream from the lot and upstream 5.0 to 7.0 miles. The width was 6.0 to 8.0 miles. The smaller dimensions in the Texas case could relate to differences in lot spacing, central city parking costs, extent of the transit network, or congestion within the region. The shape of the market shed appears more consistent from one metropolitan area to the next than the actual market shed dimensions (Spillar, 1997).

Where trunkline transit routes and park-and-ride facilities are relatively close together, as with Metra's Chicago area commuter rail services, the areas of influence for individual stations become more compressed. In modeling studies of Metra commuter rail stations with park-and-ride, the expected "comet-tail" shaped commutersheds could be discerned for a number of stations, but the effect was muted and considerable overlap was estimated. Model calibration showed distance from home to station to be the dominant factor in station choice. The only other model variable found to have both significance and a logical sign on its coefficient was train travel time to the CBD, and the train travel time coefficient was smaller than that for home to station distance (Hart, 1992).

These findings complement those of studies that have collected data on travel distance. The majority of park-and-ride users come from within 5 miles and more than 80 percent come from within 10 miles, although distances for individual lots can vary widely. For example, facilities located at end-of-line HRT/Metro stations usually see longer driving distances than at closer-in stations. Limited evidence suggests that the longer distances pertain to drive-alone and carpool arrivals, but not much if any to passenger drop-off activity. Park-and-ride facilities with exceptionally good transit service will also likely be associated with longer driving distances than those with only limited service. The type of lot, its distance to downtown, the location of competing lots, and the presence of heavy downstream congestion all influence the distance commuters will drive (Ewing, 1997; Spillar, 1997; Pratt, 1987).

Table 3-7 presents findings on distributions of distance traveled to park-and-ride lots from Maryland, the Sacramento region in California, and Tri-Rail in Florida, a commuter rail operation. The statewide average driving distance for park-and-ride and park-and-pool lot access in the Maryland study, which focused on State Highway Administration lots, was 7.6 miles. The facility average ranged, across 64 lots, from 2.5 to 25 miles (Maryland Department of Transportation, 1988/90). For Tri-Rail, weekend distances were not notably different than those shown for a Thursday in Table 3-7. An earlier survey in 1991, the third year of TriRail operation, reported more Thursday trips of 5 miles or less (61 percent) and fewer of 6 to 10 miles (25 percent), thought possibly to reflect less familiarity with the fairly new system (Center for Urban Transportation Research, 1993).

A 2001 study of Florida's remote lot users found that approximately 50 percent live within three miles of the lot and 90 percent come from within 19 miles (Center for Urban Transportation Research, 2001). A 1996 San Francisco Bay Area survey at 68 facilities found an average travel distance to park-and-ride lots of 5.7 miles, varying by county from a low of 4.6 miles in Alameda/Contra Costa to a high of 7.3 miles in San Mateo County (Lave, Billheimer and McNally, 1997). Finally, license plate analysis of commuter rail park-and-ride station choice on Chicago's Metra system found auto travel distances ranging from 0.04 to 59.7 miles, averaging 3.9 miles. Inner stations were excluded in this analysis, and mileage was computed in terms of quarter section to station airline distance (Hart, 1992), which would suggest an average in the suburbs of roughly 5-1/2 miles over the road.

Table 3-7 Distributions of Distances Traveled to Park-and-Ride Lots

Locale (Year of Data)	0-5 miles	6-10 miles	10-20 miles	20+ miles
Maryland (1988) [a]	53%	28%	13%	6%
Sacramento (1989)	60%	22%	18%	
Tri-Rail – Florida (1993)	56%	30%	10%	4%

Notes: [a] Lots operated by the State Highway Administration only. Includes no lots with urban rail service. Does include park-and-pool lots and users.

Sources: Al-Kazily (1991), Center for Urban Transportation Research (1993), Maryland Department of Transportation (1988/90).

A 1971 license plate survey at Boston metropolitan area rail transit stations, summarized in Table 3-8, provides additional perspectives on the range of distances traveled to access park-and-ride facilities. Although the data are old, the relative values are intriguing. The longer average and median driving distances to the HRT Red line may possibly have been due to the substantial travel time savings its then new extension offered to downtown compared to the Southeast Expressway (22 minutes versus 45 minutes), more time savings than the HRT Blue line offered in the Northeast Expressway corridor (20 minutes versus 30) (Wilbur Smith and Associates, 1974). Similarly suggestive information on parking space utilization is discussed under "Travel Time and Transit Level of Service."

Table 3-8 Distances Traveled to Rail Station Parking Lots in the Boston Region

Line or System	Average	Median	Maximum
Red Line (HRT)	6.9 miles	5.5 miles	23.0 miles
Blue Line (HRT)	5.0	3.8	27.0
Penn Central	3.0	2.4	16.0
Boston & Maine	2.5	2.2	16.0

Notes: The Penn Central and the Boston & Maine were the commuter rail services to the southern and northern sectors of the region, respectively, prior to their upgrading as part of the regional public transit system.

Compiled from 1971 MBTA License Plate Survey.

Source: Wilbur Smith and Associates (1974).

Other Facility Location Factors

Although the distance required to reach a park-and-ride facility from a commuter's residence is a key factor in facility siting, there are other location-related factors that do or may influence lot usage. It does not appear that these factors have been much examined in studies or research designed to utilize large samples, compensate for confounding influences, or even use success measures more meaningful than lot occupancy, a flawed measure the limitations of which were discussed under "Overview and Summary" — "Analytical Considerations." What is presented here, then, is a mix of observations based on limited studies mainly within individual corridors or jurisdictions, informal surveys, and general experience and logic as expressed in industry rules of thumb. Some of these observations are undoubtedly better founded than others. Pending more demonstrably rigorous derivation, they all should be applied with extra caution and a realization that there may be a number of important exceptions.

Distance to Destination. Park-and-ride lots that are very close to the intended destination experience different responses than park-and-ride lots located farther away. If the time spent getting to the park-and-ride lot and changing to an alternate mode is very long as compared to the remaining travel time to the destination, it is thought that a park-and-ride lot is unlikely to be well used. In addition, the potential to reduce vehicle miles of travel (VMT) is greatly reduced when a park-and-ride facility is located close to the destination (Spillar, 1997). When located directly on the fringe of a CBD, park-and-ride lots are termed peripheral lots. The performance of peripheral lots themselves is a mix of successes and failures, as covered in Chapter 18, "Parking Management and Supply," under "Response by Type of Strategy" — "Peripheral Parking Around Central Business Districts."

Best results are generally achieved with transit park-and-ride lots located no closer than 5 miles and preferably 10 miles or more from the activity center being served. In most cases, the access portion of the park-and-ride trip should represent less than 50 percent of the total journey time from the patron's home to the final destination (Spillar, 1997). Park-and-pool lots appear to work best where the commute trip is more than 15 miles long (Weant and Levinson, 1990).

These locational guidelines are for the most part consistent with characteristics reported for park-and-ride lots selected by 24 surveyed transit agencies as their "most successful" (see also "Indicators of Success" under "Related Information and Impacts"). The lots so identified are generally equidistant between the urban area outskirts and the CBD. The lots are on average located about 11 miles from the CBD and 9 miles from the outer edge of metropolitan area development. This location is observed to make sense because it strikes a balance between having a large catchment area to draw from and providing commuters with the opportunity to avoid driving a significant length of congested corridor. Such guidelines pertain most importantly to location of the first or the premier park-and-ride site in a corridor (Rathbone, 2003). Additional park-and-ride sites in a given corridor will obviously have to differ in distance along the corridor.

Heavy Congestion. Lots located in corridors with severe traffic congestion typically experience stronger demand than those in free-flowing corridors, especially when transit services or carpools leaving the lot receive priority treatment. Longer trip times and less-pleasant driving conditions likely contribute to this phenomenon. Congestion is also an indicator of overall traffic volumes and thus greater market size. It is for these reasons that some park-and-ride estimating procedures compute projected demand as a function of traffic volumes on adjacent facilities. Corridors operating at traffic Level of Service (LOS) E or worse are said to have the highest potential for park-and-ride usage. Locating the facilities in advance of the congestion is believed to facilitate the highest demand levels (Weant and Levinson, 1990; Turnbull, 1995; Center for Urban Transportation Research, 2001; Spillar, 1997).

High Visibility. Park-and-ride facilities are best located at sites that are highly visible from approach roads, preferably roads that serve as major commuting corridors (Weant and Levinson, 1990). This is done chiefly to build awareness of the site, but can also add to the perception of security at a facility (Turnbull, 1995). A 1998 survey of Delaware park-and-ride/pool lot users showed that 31 percent of users of lots with rail service and 43 percent of users of all other park-and-ride/pool lots found out about the facility by driving past it (Urbitran Associates and SG Associates, 1999). A Chicago Transit Authority study the same year found that 63 percent of the park-and-ride patrons surveyed learned about their facility by seeing it (Foote, 2000). An earlier national survey of 150 lots indicated that the majority of users learned of their lot by driving past it (Flora, Stimpson and Wroble, 1980).

Easy Access. Parking lots that are difficult to access, even though they may be highly visible, may exhibit reduced demand relative to facilities with quick and convenient access. Park-and-ride lots preferably should be located such that commuters do not have to backtrack to reach them. Lots adjacent to expressways generally experience higher demand than other facilities (Turnbull, 1995; Spillar, 1997). Several studies from the 1970s noted that for both transit and park-and-pool lots, distances greater than 1/2 to 3/4 mile from the auto travel direct route adversely affected usage (Pratt and Copple, 1981). Among lots identified by 24 transit agencies as their "most successful," 70 percent are located within 1/2 mile of a major highway (Rathbone, 2003). The second most frequently reported reason for success was "located close to a major highway, good access" (Urban Transportation Monitor, 2003b).

The most highly used park-and-ride lot in Florida — the Tri-Rail Golden Glades facility in Dade County—is located at the junction of five major commuting highways, which carried in excess of 370,000 vehicles per day in 1989 when commuter rail service to it was initiated (Center for Urban Transportation Research, 2001). When asked how they chose which lot to use, respondents to the 1998 survey of Delaware park-and-ride/pool lot users most frequently chose "convenient location" at the top of the list, above even "close to home" and a number of quality of service descriptors (Urbitran Associates and SG Associates, 1999).

Lot Spacing. Park-and-ride lots located close to one another have been observed to behave, in terms of demand, more like combined facilities than separate facilities. At the very least, extensive market area overlap occurs, with the facilities in effect competing with one another for much of the same market share. If not sized accordingly, lower than average percentage utilization may be experienced. In general, spacing should be dictated by the type of transit service provided and the characteristics of the area (Hart, 1992, Turnbull, 1995).

Surrounding Density. The surrounding development density at park-and-ride facilities relates to usage in that higher densities provide a larger tributary area population (Spillar, 1997). It would not be the density within easy walking distance that would be of interest for park-and-ride, however, but rather the density of broader areas. Locating park-and-ride lots in areas with other businesses may encourage use by providing patrons with easy access to desired services (Turnbull, 1995). However, to the extent that surrounding density makes it less quick and convenient to access a park-and-ride facility, negative effects on parking demand may be experienced.

In considering park-and-ride in conjunction with Transit Oriented Design and other planned development concepts, there is obviously a trade-off between maximizing walk-on transit patronage with higher development densities close-in to the transit stop and facilitating park-and-ride patronage with easy auto access and ample parking. Researchers in the land use/transportation field warn that the impact of automobile parking as a landscape feature is largely neglected in travel studies and research, and that expanses of parking (such as a park-and-ride lot can be) create dead spaces and unattractive access for pedestrians (Ewing and Cervero, 2001). At a minimum they create extra walking distance. These particular types of issues are further examined in Chapter 17, "Transit Oriented Design."

Travel Time and Transit Level of Service

Both modeling studies and preference surveys, as previously noted, identify travel time as one of the most important considerations for travelers in choosing whether or not to use a park-and-ride facility. Facility access time, transit service headways and transit travel time are three main determinants of the travel time for transit park-and-ride users. Park-and-pool users experience facility access time, meeting delay time, and driving time to the destination. In deciding to use a park-and-ride facility, most travelers appear to take into consideration the relative travel time by automobile versus using the park-and-ride facility. They may also take into account the hours during which transit service is provided. It has been suggested that for maximum attractiveness park-and-ride facilities should provide time savings of over five minutes during peak-travel periods (Weant and Levinson, 1990).

Figures 3-1 and 3-2 summarize data from 37 bus and 139 rail park-and-ride facilities, relating parking utilization to characteristics of the transit service at the facilities studied. Park-and-ride lots with higher transit frequencies and more hours of service perform better than facilities with lower transit frequencies and fewer hours of service. Usage of rail park-and-ride lots appears to be less sensitive to waiting time for service than is usage of bus-oriented lots (Institute of Traffic Engineers, 1973). Although the data was published some time ago, the general relationships between demand and each attribute appear still to hold. The relationships may be exaggerated, however, if correlations between transit frequencies, hours of service, and other factors such as downtown parking costs were not controlled for.

Figure 3-1 depicts the effect of transit frequency on park-and-ride lot utilization. Experience indicates that as headways (time between buses or trains) become longer, park-and-ride lot demand declines, sharply so in the case of bus service headways in excess of 15 minutes. People appear to especially dislike waiting for transit, a topic explored comprehensively in Chapter 9, "Transit Scheduling and Frequency." There, under "Underlying Traveler Response Factors" — "Wait and Transfer Time Savings," it is noted that, roughly speaking, travel demand research suggests each minute spent waiting may feel like two or more when measured in terms of minutes spent riding in the vehicle. There has been no explicit research on the perception of time spent waiting at park-and-ride facilities, but there is no reason to believe the perceived penalty would be less than normal.

Frequent express service is identified as one of the primary demand generating characteristics of successful park-and-ride facilities. In an analysis of 11 park-and-ride bus lots in Pittsburgh, for example, the three lots with the highest rate of usage (and highest demand) had the shortest headways, while the three with the lowest rate of usage had the longest headways (Southwestern Pennsylvania Regional Planning Commission, 1975). Similarly, in a survey where 24 agencies chose their "most successful" park-and-ride lot, the most frequently offered reason for success was "served by frequent transit service, many routes." About 60 percent of the lots had transit/rail service at 10-minute or closer intervals during the peak period and

83 percent received service at 15-minute or closer intervals (Urban Transportation Monitor, 2003b).

Commuter rail station choice modeling efforts in the Chicago area provide, however, some support for the indication in Figure 3-1 that service frequency is of lesser importance for park-and-ride facilities serving rail lines — at least in the specific case of commuter rail. Nevertheless, earlier evidence from the same area suggests that the importance of rail service levels cannot be ignored (Hart, 1992; Pratt and Bevis, 1971). For a more complete discussion of these particular findings, refer back to "Metra Park-and-Ride Lots" under "Response to Rail Park-and-Ride Facilities" — "Commuter Rail." The relatively lesser adverse reaction of commuter rail riders to infrequent service is fully explored in Chapter 8, "Commuter Rail."

Figure 3-2 illustrates the observed relationship between hours of transit service and parking lot utilization (Institute of Traffic Engineers, 1973). Midday and evening service, by providing flexibility for regular commuters and an alternative for non-peak riders, can enhance park-and-ride performance. Even if such off-peak services do not experience much ridership themselves, their availability provides leeway for commuters and can increase demand for the peak services. Failure to provide adequate off-peak service has been cited as a contributing factor in the discontinuance of some park-and-ride operations (Deen, 1965).

Transit travel time, especially relative to the travel time by automobile, plays an important role. Table 3-9 shows that Boston area stations where transit travel time was less than auto travel time exhibited stronger park-and-ride lot demand than was observed at stations where the transit travel time exceeded the travel time by automobile. The south corridor's HRT Red Line, providing the greatest time savings, had its parking facilities filled at or near capacity. In the north corridor, HRT Blue Line lots were 70 to 80 percent filled. Those on the much slower LRT Green Line, where travel via the Massachusetts Turnpike was twice as fast, were generally only half filled (Wilbur Smith and Associates, 1974).

Table 3-9 1971 Boston Modal Travel Times and Station Lot Occupancy

	From North	From West	From South
Auto Travel Time (min.)	30	20	45
Transit Travel Time (min.)	20	40	22
Percent Occupancy of Transit Parking Lots	70-80%	40-60%	90-100%

Source: Wilbur Smith and Associates (1974).

Figure 3-1 Effect of transit frequency on park-and-ride utilization

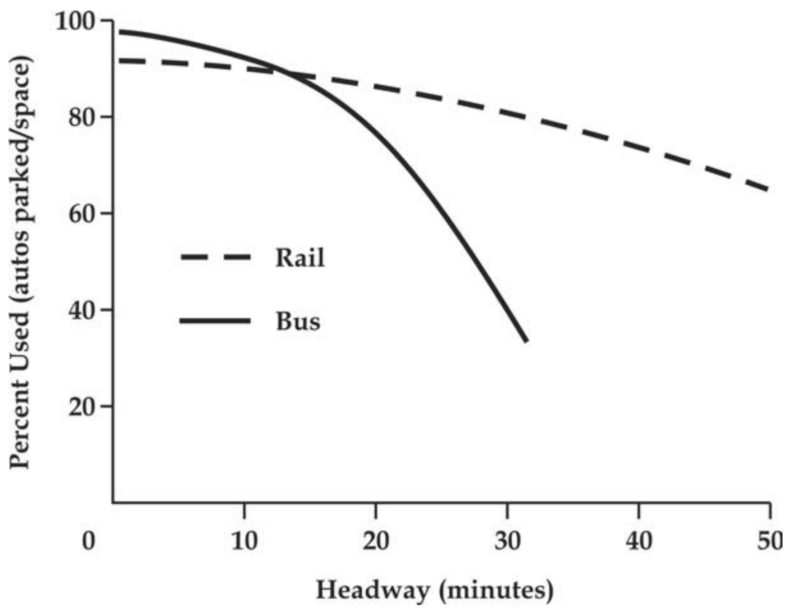
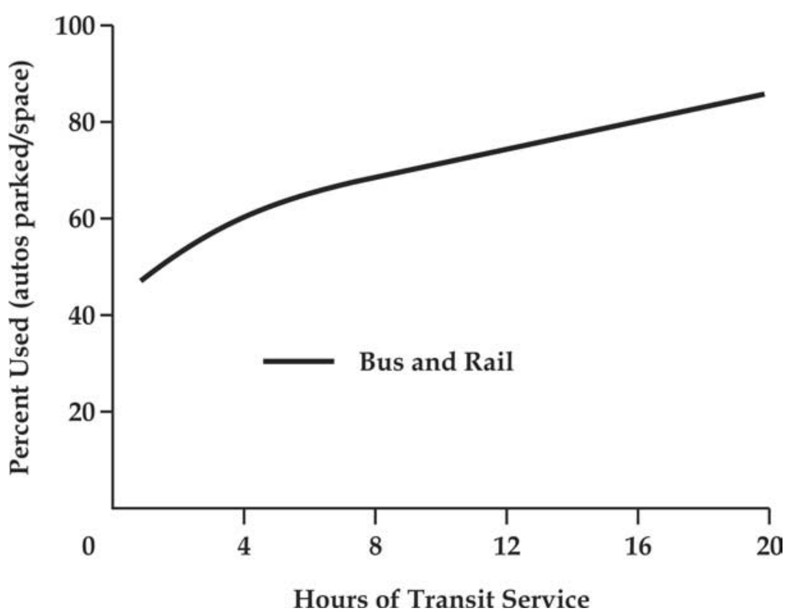


Figure 3-2 Effect of transit service hours on park-and-ride utilization



Source: Both Figures – Institute of Traffic Engineers (1973).

More recent studies confirm that demand for park-and-ride facilities can be enhanced through the provision of high-speed transit options or priority lane facilities that decrease travel times (Turnbull, 1995). The previously mentioned Chicago area modeling efforts that addressed commuter rail station choice by park-and-ride users found the one model variable besides distance from home to station that could be successfully calibrated — with a coefficient exhibiting both statistical significance and a logical sign — was train travel time to the CBD

(Hart, 1992). Of park-and-ride lots picked by 24 transit agencies as their "most successful," 90 percent "are served by some form of express transit service and/or a transit service with priority" (Rathbone, 2003). The third most frequently reported reason for park-and-ride facility success was "served by fast, direct transit service to major attraction" (Urban Transportation Monitor, 2003b).

Riders appear well-informed about the travel times associated with transit services offered at park-and-ride facilities. A Seattle study found that at park-and-ride facilities with access to multiple transit services, boardings tend to be highest on routes that offer the best travel time. Moreover, riders appear reluctant to use routes that are more than 15 minutes slower than the quickest bus service offered to their destination (Spillar, 1997).

Additional transit level of service characteristics of importance to park-and-ride patrons have been reported. In particular, applications where the transit service was circuitous or crowded buses required standing for long distances were found to have low utilization despite significant cost savings and comparable travel times (Pratt and Copple, 1981).

User Costs and Willingness to Pay

Park-and-ride facility users face both automotive operating costs and transit fares, and may also have to pay park-and-ride parking fees. Park-and-ride lot usage can reduce or eliminate some costs for a driver while introducing new ones. For example, direct auto operating costs — such as gas and oil — may be scaled back and downtown parking charges may be avoided, but a transit fare may be added. To the extent that the overall cost of the trip using a park-and-ride facility is less than the cost of the trip using the automobile only, demand for park-and-ride tends to be higher. Similarly, increased auto driving cost at the destination end of the commute trip, such as an increase in parking charges, will make transit more competitive (Spillar, 1997).

In a 1996 survey of San Francisco Bay Area park-and-ride and park-and-pool lot users, 67 percent of those parking to take transit reported they would have had to pay for parking at their destination if they drove all the way. The corresponding proportion for those parking to carpool or vanpool was 24 percent. Of those who would have had to pay, the daily rate they estimated having avoided averaged $9.53 for transit riders and $8.13 for car- and vanpoolers. The study focused on park-and-ride lots other than the facilities along main rail transit lines into San Francisco (Lave, Billheimer and McNally, 1997). Had those been included, the parking fee avoidance would, without much doubt, have been even more pronounced.

Fees that park-and-ride facilities themselves may charge for parking are covered in the "Related Information and Impacts" section, under "Parking Pricing at Park-and-Ride Facilities." Such pricing is usually at a substantial discount to the prevailing CBD parking rates. Washington, DC, Metrorail parking facilities, for example, charge about one-fifth the fee encountered at downtown parking. It is thought that there are probably no instances of parking fees being charged at lots intended primarily for park-and-pool use, and correspondingly, no analyses of the rather unlikely possibility.

At least a portion of drivers in larger urban areas appear willing to pay park-and-ride parking charges, especially when they come with increased capacity. A stated preference survey in the Seattle area found 35 percent of respondents willing to pay $2.00 or more for additional spaces and increased security (Hendricks and Outwater, 1998). The Washington, DC, Metrorail in effect offers guaranteed capacity for an added price. As further described under "Parking Pricing at Park-and-Ride Facilities," for about a 45 percent parking fee surcharge — $20.00 extra a month — Metrorail promises a "guaranteed parking space" (Washington Metropolitan Area Transit Authority, 2002c). Nevertheless, few if any cases of charging for park-and-ride parking are found outside of the largest and densest urban areas.

A 1984 evaluation concluded that, in cities with high CBD parking costs and/or limited downtown parking supply, reasonable increases in parking charges at urban rail park-and-ride lots did not lead to a long-term decrease in use. The study, based for the most part — out of necessity — on anecdotal evidence, covered ten metropolitan areas, six with priced parking at rail stations, including four with actual experience in raising the fees. The rail systems involved were mostly HRT, with some LRT and one busway. Most transit operators reported some short-term decrease in usage at certain or all facilities with an increase in fees, but the evidence was unclear, because the parking price changes had occurred at the same time as transit fare hikes, and — in one case — reductions in service frequency. Interviewed transit operators noted that it is more difficult to introduce charges to a free parking facility than to raise prices at facilities that already charge (Douglas & Douglas and Ecosometrics, 1984).

The 1984 evaluation was done on behalf of the MARTA system in Atlanta. Starting in 1985, MARTA began charging $1.00 to park in its park-and-ride facilities, generating $2,000,000 annually in revenues. Most MARTA parking fees were removed after six years, however, in an effort to enhance ridership. It is reported that this move was a success, with new riders making up the lost parking revenues. Today MARTA primarily uses parking charges to control overnight use of their parking facilities by patrons flying out of Hartsfield International Airport, which the system directly serves (Shelton, 2001). The MARTA rapid transit system differs from the typical system that levies charges, however, in that its park-and-ride system is less capacity constrained. This may be seen by comparing the reported 76 to 90 percent utilization of rail park-and-ride facilities for systems with parking charges, set forth earlier in Table 3-1, with the 75 percent utilization MARTA reports (MARTA, 2002).

Differential parking charges have been used to shift demand to park-and-ride facilities with more capacity, in at least two instances, reported on under "Related Information and Impacts" — "Parking Pricing at Park-and-Ride Facilities." Known characteristics of travel choices would suggest that facility choice sensitivities to pricing would be more pronounced than mode choice sensitivities (Ferguson, 2000). In other words, imposing or raising park-and-ride fees will have more impact on park-and-ride facility use than on transit riding, because many users of pay lots will have one or more transit alternatives, such as parking in informal lots or on neighborhood streets, taking a feeder bus, or arranging to be dropped off. Nevertheless, known choice responses would also imply that there should be some effect on the decision to use or not to use transit. Indeed, the reported experience of MARTA in Atlanta provides confirmation under conditions of ample parking supply.

Trip and Facility Characteristics

The interplay of travel choices with the various factors listed above, most notably travel time and willingness to pay, is influenced by the purposes for which park-and-ride/pool trips are normally made, along with trip orientation. As quantified in the "Related Information and Impacts" section, park-and-ride trips are predominantly work purpose trips oriented to the downtown areas of cities. Park-and-pool trip destinations may be more dispersed. Refer to the "Trip Purpose and Orientation" subsection.

Parking in and getting around the park-and-ride or park-and-pool facility itself is clearly an important element of the user's trip. Implications of intra-facility walking distances, and preferences concerning facility attributes and amenities, are part of the discussion offered in the "Related Information and Impacts" section under "Facility Size and Amenities."

Overall Effects on Transit Mode Share

Provision of park-and-ride systems as an added transit service feature should logically attract more riders. One attempt to quantify that positive effect, measured in terms of commuter period transit mode share to downtown, is presented immediately below. Park-and-ride appears to be, however, a less attractive substitute for the often theoretical alternative of being able to ride equally good transit service all the way from origin to destination. Evidence, which derives from travel demand modeling, is presented here as the final traveler response factor discussed. Equivalent demand model investigations of park-and-pool activity apparently do not exist, although it is generally believed that the effect on choice of carpooling as a travel mode could be nothing but positive.

The Effect of Park-and-Ride Availability

The availability and capacity of park-and-ride facilities has a fairly obvious first-order relationship to transit riding. If there is no space, there can be no formal parking, and use by those who wish to drive to the station or stop may be discouraged. There is, however, little available quantification of this relationship.

In one study, this discouragement of transit use has been modeled in reverse, focusing on the positive effect on ridership of more park-and-ride spaces. The study involved is presented in fuller detail in Chapter 18, "Parking Management and Supply," under "Response by Type of Strategy" — "Maximum and Minimum Parking Requirements" — "Parking Supply and Transit Use." As presented there in Table 18-3, data for eight Canadian cities were used, six with park-and-ride. Employing a ratio of parking spaces per CBD employee as the primary metric, and in this manner quantifying both parking in the CBD and in park-and-ride lots, the following linear regression equation for morning peak downtown transit share was obtained (Morrall and Bolger, 1996):

AM Peak CBD Percent Transit = 68.2 - 81.0 x (CBD spaces/CBD employee ratio) + 138.1 x (park-and-ride spaces/CBD employee ratio)

This equation has an r^2 of 0.83 and the estimated parameters for both variables are statistically significant. As explained by the study authors and in Chapter 18, however, key variables such as quality and cost of transit service relative to auto were not investigated (Morrall and Bolger, 1996). The equation, given its lack of non-parking variables, should be used only with the greatest of caution. Nevertheless, it serves as an illustrative indicator of the positive role of park-and-ride parking space supply in mode choice. The equation's combination of a negative coefficient on CBD parking spaces and a bigger, positive coefficient on park-and-ride spaces indicates that this positive role would be especially pronounced when park-and-ride spaces are in substitution for CBD parking spaces. These findings mesh well with the concept that park-and-ride should be looked upon as a "*transfer* of parking spaces from the city center outward along express transit routes" (Weant and Levinson, 1990).

Studies of outlying park-and-ride facilities show an average daily turnover of about 1.1 cars per space with about 1.2 transit passengers per parked car (Weant and Levinson, 1990). This suggests a relationship of roughly 1.3 transit passengers (2.6 transit boardings daily) per occupied park-and-ride space. What such statistics cannot tell, however, is how many of these transit rides would occur anyway without park-and-ride, and how many would be lost to transit. Some idea, although the relationship is more implied than direct, may be gained from examining the modes that users chose before shifting to park-and-ride. For this, see "Prior Mode of Park-and-Ride/Pool Facility Users" in the following "Related Information and Impacts" section.

The Park-and-Ride Mode Change Penalty

Even as park-and-ride enhances transit ridership, it remains an imperfect substitute for somehow providing everyone at their street corner with the same quality of transit service (competitive time, frequency, etc.) that is attainable by driving to a park-and-ride facility. Although to do so would often be totally impractical or at least not cost-effective, the imperfect nature of the park-and-ride substitute remains a very important consideration. It needs to be taken into account to properly estimate transit use or assess the value of placing more residences proximate to good transit service, whether by means of service expansion or land use changes as in Transit Oriented Design, the subject of Chapter 17.

The biggest detriment of the park-and-ride mode to the user is probably the fact that it ties up one's automobile, affording no opportunity to avoid fixed costs of auto ownership or to make the auto available to other family members. In the past, a number of transit ridership forecasts — particularly for rail transit — have been overly optimistic because of not properly accounting for these and related effects.

The effects in question have been termed a park-and-ride mode change or access penalty, or intermodal auto-to-transit transfer penalty. The term "penalty" is perhaps imperfect, to the extent that it may be too strongly equated with the penalty associated with having to make a transfer between transit routes (see the first subsection in the "Underlying Traveler Response Factors" sections of Chapter 9, "Transit Scheduling and Frequency"; and Chapter 10, "Bus Routing and Coverage"). Auto ownership and availability considerations appear to play a more significant role in the park-and-ride mode change than inconvenience of the transfer per se. As demand modeling findings illustrate, the park-and-ride mode change "penalty" is greatest for lower income groups, where one might expect that auto ownership and thus availability would be lower.

Recent regional travel demand model sets employing nested logit choice models offer better quantification of this penalty or impedance than has been available before. Because driving and walking to transit service are alternatives, a useful way of measuring the auto-transit mode change penalty is to express it in walk time equivalents: the number of minutes spent walking that in the eye of the traveler would be equal to the penalty of having to access transit by driving and changing mode to transit. Table 3-10 tabulates the auto-transit mode change penalties of the Atlanta and New Orleans model sets in equivalent walking minutes.

Demand-model-derived auto access penalties differ from region to region for many reasons, including artificial differences in elements of the demand modeling sets. What is of primary interest here is the presence of penalties and how they vary by income and trip purpose. As illustrated in Table 3-10, the auto-transit access penalties are in general very significant. They are larger — in most cases — for lower income groups, who on the whole will have fewer automobiles available, and for non-work travel purposes. In Atlanta, for work-purpose trips, the penalty diminishes to essentially nothing at the highest income level. Note that both the Atlanta and New Orleans mode choice models were calibrated by using the walk time coefficient instead of the in-vehicle time coefficient to weight the minutes spent driving to a park-and-ride facility. Had this not been done, the auto-transit mode change penalties would have been larger (Schultz, 2003; Parsons Brinckerhoff, 2003 and 2002).

Table 3-10 Auto-Transit Mode Change Penalties for Three Trip Purposes and Four Income Levels, Expressed in Equivalent Walking Minutes

Trip Maker Income Quartile	Atlanta Mode Choice Model			New Orleans Mode Choice Model		
	Home-Based Work	Home-Based Other	Non-Home Based	Home-Based Work	Home-Based Other	Non-Home Based
Lowest	145	353	34	9	95	90
Low-Medium	41	105	34	17	60	90
High-Medium	13	61	34	22	39	19
Highest	-1	19	34	13	23	13

Notes: Equivalent walking minutes calculated by dividing the income and purpose-specific drive bias constant (typically negative) by the purpose-specific walk coefficient (negative).

Identical values in the same column indicate that the income levels in question were examined jointly rather than separately.

Sources: Schultz (2003), Parsons Brinckerhoff (2003 and 2002).

A research model developed with data for the New York-New Jersey commute corridor has been used to estimate impact on travel forecast accuracy of not considering the intermodal automobile-to-transit transfer penalty. The simplified model derived implies a transfer penalty of 6 equivalent walking minutes, smaller overall than for the more elaborate Atlanta and New Orleans models. Nonetheless, use of the model to simulate effects on ridership indicate that work purpose rail transit ridership could be overestimated by a factor of two were the effect of the automobile-to-rail-transit mode change not considered (Liu, Pendyala and Polzin, 1998).

All this is not to say that park-and-ride facilities won't attract additional transit riders. They will, but the average user is burdened with some degree of disadvantage that holds ridership down over what it might otherwise be. If transit capital and operating cost and other factors were not constraints, even more riders could be attracted by having fully equivalent transit service within close walking distance — obviating the need to use an auto at all. It is fortuitous that the penalty tends to be least in high income, high auto ownership areas, as they often are the same places where low residential densities make park-and-ride the only economic approach. Realities of transit operator cost considerations are discussed in the next section under "Bus System Cost and Service and Other Economic Effects."

RELATED INFORMATION AND IMPACTS

Prevalence of Park-and-Ride Activity

Park-and-ride and park-and-pool provisions and activity have become fully established and have continued to grow steadily throughout the latter half of the 20th Century and beyond, as seen in the time series parking space and parked vehicle counts presented in the case studies, "Park-and-Ride/Park-and-Pool in the Washington, DC, Metropolitan Area," "HOV Lane Park-and-Ride/Pool Facilities in the Houston Area," and "Park-and-Ride and Park-and-Pool Facilities in King County, Washington." In terms of share of the transit market, arrivals via all forms of auto access constitute anywhere from 2 percent of persons accessing transit from their home in the case of small city bus systems to on the order of 80 percent for certain express systems in large urban areas. Table 3-11 illustrates this range in shares for a variety of transit service types and metropolitan area sizes. Note that in contrast to much of the discussion in this chapter, this subsection and Table 3-11 focus on total auto access, whether utilizing formal or informal parking and drop-off arrangements, and including all forms of auto access rather than purely the drive-and-park mode of access.

The focus in Table 3-11 on all auto access — whether involving use of formal park-and-ride facilities or not — is probably why, for example, the auto driver access share for CTA's HRT system in Chicago is reported here to be 8.5 percent and in earlier discussion of formal CTA park-and-ride parking to be less than 1 percent (see "Traveler Response by Type of Park-and-Ride Facility" — "Response to Rail Park-and-Ride Facilities" — "Heavy Rail Transit [HRT]"). Much if not all of the difference is presumably in rider use of "informal" parking, including curb spaces and privately owned and operated parking lots and garages. The 1998 San Francisco area survey that found 49 percent of all BART HRT riders to be using auto access from the home also specifically inquired about informal parking. It was found that among those who parked-and-rode, 79 percent used a BART lot while 21 percent parked off-site (BART Customer and Performance Research et al., 1999). For the typical small bus transit system, it may be assumed that effectively all park-and-ride activity is informal.

The percentages in Table 3-11 illustrate that the highest relative use of auto access is to reach the express transit systems in the larger metropolitan areas, ranging from the 40 percent total auto access share for commuter rail (CRR), express bus and ferry in greater New York to 79 percent for "Commuter Bus" in the Houston area. The Houston commuter buses make extensive use of Houston's "Transitway" HOV lanes. Light rail (LRT) auto access shares appear to decline with metropolitan area size, from 46 percent in Pittsburgh to 21 percent in Buffalo. This appearance is in part misleading, however, as LRT auto access shares on the older systems in dense cities such as San Francisco and Philadelphia are undoubtedly more in line with or lower than the 12 percent found for HRT in Chicago. Urban bus system auto access shares range from 2 to 3 percent in Chicago up to 11 percent in Pittsburgh (where busway services are included in with local buses), then gradually decline with metropolitan area size back down to 2 percent or so of all transit access from the home. Additional transit service and park-and-ride/pool facility access mode information is provided below in the subsection "Usage Characteristics of Park-and-Ride/Pool Facilities" — "Mode of Access."

Another perspective from which to judge the prevalence and role of park-and-ride is to compare the number of park-and-ride spaces in a region with the number of downtown

Table 3-11 Prevalence of Auto Access Among Transit Riders (Percent of Access)

Urban Area (CMSA or MSA)	Populatio n (2000 Census)	Transit System	Transit Mode	Year of Data	Auto Driver	Auto Passen-ger	Drop-off	Total Auto Access
New York – No. New Jersey, NY-NJ-CT-PA	21,200,000	LIRR, Metro North, NJT, and others [a]	"Premium": CRR, ferry, express bus	1998	32%	8%		40%
Chicago, IL-IN-WI	9,160,000	Metra	CRR	1994	55	6	13	74
		CTA	HRT	1997	8.5	<0.7 [b]	3.0	12±
		CTA	Bus	1997	1.3	<0.5 [b]	1.1	2.5±
San Francisco – Oakland – San Jose, CA	7,040,000	Caltrain	CRR	2001	40.3		12.8	53.1
		BART	HRT	1998	39	10		49
Houston – Galveston, TX	4,670,000	Metro	Commuter bus (HOV)	1995	75.0	4.1		79.1
		Metro	Express bus	1995	18.8	5.0		19.8
		Metro	Local bus	1995	1.6	2.1		3.7
Pittsburgh	2,360,000	PAT	LRT	1996-97	36.5	1.1	8.0	45.6
		PAT	Bus incl. busway	1996-97	7.7	0.2	2.9	10.8
Portland, OR-WA	2,260,000	Tri-Met	LRT	1997-98	25.9	1.1	6.1	33.1
		Tri-Met	Bus	1997-98	6.1	0.4	2.2	8.7
Sacramento-Yolo, CA	1,800,000	RT	LRT	1996-97	22.5	0.5	5.1	28.1
		RT	Bus	1996-98	2.7	<0.5 [b]	3.6	6.5±
Austin, TX	1,250,000	Capital Metro	Bus (excl. UT service)	1996-98	4.9	<1.9 [b]	2.9	7 to 8
Buffalo, NY	1,170,000	NFTA	LRT	1997-98	17.7	1.0	2.0	20.7
			Bus	1997-98	2.5	0.1	2.1	4.7
Grand Rapids, MI	1,090,000	GRATA	Bus	1997-98	n/a	n/a	n/a	<3.0 [c]
Lincoln, NE	250,000	StarTran	Bus	1997-98	n/a	n/a	n/a	<2.7 [c]
Kenosha, WI (Chicago CMSA)	150,000 (PMSA)	Kenosha Transit	Bus	1997	0.6	0.2	1.6	2.2

Notes: [a] Does not include the MTA New York City Transit subway system.

[b] Percentage shown is for "other" mode of access, including auto passenger (in parked auto), thus the true auto passenger percentage is less. The corresponding total auto access percentage is necessarily approximated (by the Handbook authors).

[c] Percentage shown is for "other" mode of access, including all auto access modes, thus the true total auto access percentage is less than the value shown.

Sources: Parsons Brinckerhoff et al. (2000), Ferguson (2000), McCollom Management Consulting (1999), Caltrain (2003), BART Customer and Performance Research et al. (1999), Houston-Galveston Area Council (2001), U.S. Census (2003).

parking spaces intended for commuter parking. This comparison is made relevant by the fact that most users of park-and-ride are headed to the central business district (CBD), such that park-and-ride spaces may be considered a fair substitute for long-term parking spaces in the CBD. A full set of such comparative data is available for six Canadian cities. It shows Toronto to have 4 park-and-ride spaces for every 10 long-term parking public spaces in the CBD. This is clearly a major contribution to the parking supply serving the CBD. The smaller cities of Calgary, Edmonton, Ottawa, and Vancouver along with Canada's largest city, Montreal, average 1 park-and-ride space for every 10 CBD long-term parking public spaces (Morrall and Bolger, 1996). Similarly consistent data for U.S. Cities have not been encountered. On the basis of comparing data from different sources and decades, it appears that Dallas and Baltimore probably have ratios of park-and-ride to CBD parking spaces roughly similar to Toronto, or perhaps higher in the case of Baltimore (Weant and Levinson, 1990; DART.org, 2004; Maryland Transit Administration, 2004).

Characteristics of Park-and-Ride/Pool Facility Users

Park-and-ride and park-and-pool users are inherently, as discussed at the outset of the "Underlying Traveler Response Factors" section, trip makers with choices. In Delaware, surveys of rail, bus and park-and-pool lots indicate that only half of one (0.5) percent of users have no vehicle available. In contrast, 16.0 percent report having one vehicle available, 59.1 percent report having two, and 24.4 percent report having three or more (Urbitran Associates and SG Associates, 1999). Similarly, 100 percent of surveyed Chicago Transit Authority users of CTA's HRT park-and-ride facilities report having an auto available to their household. This is in contrast to CTA rail and bus riders overall, 30 percent of whom report having no car available (Foote, 2000).

Table 3-12 provides family income, age and gender information for Delaware lot users. The data is separately shown for New Castle County, which includes Wilmington, most of Delaware's suburbs, and all of the park-and-ride facilities at rail stations; and for Kent and Sussex Counties, which are farther south and mainly exurban or rural. Differentiation between lots served by rail and lots with no rail service is available for user gender. The split is 54 percent male and 46 percent female at lots with rail service. At other Delaware park-and-ride/pool lots, the split is 37 percent male and 63 percent female (Urbitran Associates and SG Associates, 1999).

Confirming the tendency toward higher incomes are data from CTA in Chicago. CTA park-and-ride user household incomes were found to be $51,400 on average as compared to $33,400 for all CTA riders. Only 4 percent of CTA park-and-ride users reported household incomes below $20,000, as compared to 28 percent of riders overall. On the other hand, while one in four park-and-ride users reported incomes over $50,000, the proportion was the same for all CTA riders taken together. Most of the parking facilities are along the periphery of the Center City of Chicago, and the users tend to be suburbanites, though some live in the city. CTA park-and-ride users were found to exhibit an age distribution consistent with that of a working population. Female users predominated, with 38 percent male and 62 percent female (Foote, 2000).

Table 3-12 Income, Age and Gender of Delaware Park-and-Ride/Pool Users

User Characteristic	New Castle County	Kent and Sussex Counties
Family Income		
Under $25,000	3.9%	10.7%
$25,000 to $49,999	22.0	32.2
$50,000 to $74,999	27.2	26.8
$75,000 to $99,999	21.5	5.3
Over $100,000	25.4	25.0
User Age		
20 to 35	25.5%	21.4%
35 to 45	28.3	42.1
Over 45	46.3	36.4
User Gender		
Male	44.6%	20.7%
Female	55.4	79.3

Note: From a study of 66 park-and-ride/pool lots, all that could be identified in the state of Delaware, including 46 in New Castle County, 14 in Kent County and 6 in Sussex County. See the preceding text for a description of the three counties. Delaware licensed vehicles in a commuter rail lot across the line in Pennsylvania were included. Most lots had some form of bus service, and four had commuter rail service into Philadelphia. A survey form was left on the windshields of all vehicles, of which there were 1,410 in the 6,587 available spaces, and 433 were returned (a 31 percent return rate).

Source: Urbitran Associates, Inc. and SG Associates, Inc. (1999).

The Chicago data also showed a high turnover in HRT park-and-ride users, with 27 percent of survey respondents having used their selected facility for less than a year (Foote, 2000). It is tempting to take this as further evidence reinforcing identification of park-and-ride patrons as travelers with a uniquely high degree of travel options. However, relatively high turnover is a characteristic of transit riding in general. This finding is demonstrated in Chapter 11, "Transit Information and Promotion" — "Underlying Traveler Response Factors" — "Rider Turnover and Frequency of Use" in connection with the need to continually provide information to potential new riders. Table 3-13 utilizes two different surveys to show that CTA park-and-ride facility use turnover in Chicago is indeed relatively high, but similar to overall CTA rapid transit rider turnover, though slightly higher than for bus riders.

Trip Purpose and Orientation

Park-and-ride/pool facilities are largely used for commuting trips. In one examination of observations from on the order of 100 U.S. lots, the share of park-and-ride users at specific lots making work or work-related trips was found to range from 83 to 100 percent. As shown in Table 3-14, work trips on average accounted for 97 percent of the usage of the studied lots (Weant and Levinson, 1990).

Table 3-13 Tenure of Park-and-Ride and Regular CTA Transit Riders (Percent)

Months of Use [a]	Park-and-Ride	HRT Riders Overall [b]	Bus Riders Overall [b]
Less than 6 months	17%	19%	18%
6 to 12 months	10	10	9
12 to 24 months	17	16	13
More than 24 months	56	55	60

Notes: [a] Individual facility use in the case of park-and-ride, use of "the bus/train" in the case of riders overall.

[b] Excludes riders 12 years of age or younger. (A roughly comparable exclusion affects most park-and-ride users, to the extent that all but auto passengers must be drivers.)

Sources: Foote (2000), McCollom Management Consulting (1999).

More recent studies confirm the trip purpose ranges illustrated in Table 3-14. A California study indicated that 98 percent of park-and-ride users accessed such facilities for the purpose of making home-to-work commute trips (Spillar, 1997). In a Seattle region investigation, only 5 percent of current demand for park-and-ride lots was for non-work trip purposes (Hendricks and Outwater, 1998). Surveys of Delaware park-and-ride/pool lots found 97 percent of users of lots in closer-in New Castle County to be making work related trips. In the outer counties, the work purpose accounted for 80 percent of users, with the remainder evenly divided between school and other purpose trips (Urbitran Associates and SG Associates, 1999). In three counties arrayed around San Jose, California, 85 percent of park-and-ride lot survey respondents gave work as their trip purpose, followed by school or college, 7 percent; recreation/entertainment, 4 percent; and personal business/errands and shopping, 2 percent each (Santa Clara Valley Transportation Authority, 1999).

Table 3-14 Summary of Trip Purpose of Park-and-Ride Facility Users (Percentages)

Trip Purpose	Range	Number of Lots	Average
Work or business	83% to 100%	107	97.2%
School	0 to 11	80	2.3
Other	0 to 17	80	0.5

Note: The "average" values shown are weighted by the number of park-and-ride lots surveyed. Partial or missing data from certain studies may cause the percentages not to total 100.

Source: Derived from Bowler et al. (1986) as presented in Weant and Levinson (1990).

In Chicago, 92 percent of CTA park-and-ride patrons reporting their trip purpose were making either work or work related trips, with the remainder evenly divided between school and personal business trip purposes (Foote, 2000). This distribution stands in marked contrast to average CTA bus and rail rapid transit riding overall, where — depending on the source of information — work or work related trips account for between 38 percent of the total (bus and rail combined), or 53 percent (bus) to 60 percent (rail), with the latter pair of percentages excluding riders 12 years of age or younger (Foote, 2000; McCollom Management Consulting, 1999).

Park-and-ride facilities do not tend to attract large numbers of non-work trips for several reasons. First of all, park-and-ride is a travel mode most attractive for long trips destined to central areas, and non-work travel typically involves trips that are shorter and more dispersed. Many non-work trips occur outside peak travel periods, while many park-and-ride facilities are provided with transit service designed primarily to facilitate peak travel. Transit service tends to be less frequent during the midday, especially in the case of conventional express bus systems. Moreover, many park-and-ride facilities are full after the morning peak. Carpools are unattractive for most non-work trips because trip origins and destinations are rarely the same from day to day (Hendricks and Outwater, 1998).

Park-and-ride lots located at transit stations featuring all-day service and adequate parking capacity would appear to have potential to attract somewhat higher shares of non-work trips. The data required to test this hypothesis have not been encountered, however.

Park-and-ride trips are generally known to be very much oriented to CBDs. Central business districts are, after all, where parking costs usually produce maximum savings for those choosing the park-and-ride mode. Available statistics demonstrating this orientation are limited but fairly conclusive. Desire-line analysis of CTA park-and-ride patrons found that, "Most survey respondents were traveling to or from the CBD of the city of Chicago." A few respondents were making trips to other destinations accessible from the rail rapid transit system (Foote, 2000). The major destinations for surveyed Delaware park-and-ride/pool lot users were the downtown areas of Wilmington (58 percent) and Philadelphia (24 percent), leaving 18 percent headed for other destinations (Urbitran Associates and SG Associates, 1999).

An early study contrasting transit park-and-riders with park-and-poolers found that while virtually all the transit users were destined for a CBD, almost the opposite characterized carpoolers. Of park-and-pool lot users, 79 percent ended their trip in suburban or outlying areas, another 11 percent were headed for non-downtown areas of cities, and only 10 percent were CBD-destined. The study was conducted mainly at interchanges along toll roads in Pennsylvania, Connecticut, New Jersey and Massachusetts (Barton-Aschman, 1970). Similar results were obtained in a 1970s study in Miami, with only 7 percent of carpoolers oriented to the CBD. When an HOV lane was added, however, the percentage of CBD-bound carpools jumped up to 44 percent, with 13 percent of the carpoolers being prior bus riders (Wattleworth et al., 1978).

Prior Mode of Park-and-Ride/Pool Facility Users

The intent of park-and-ride and park-and-pool facilities is to provide a safe and convenient location for travelers to change from a low-occupancy mode to a higher-occupancy mode, be that carpool, vanpool, bus, or rail. Ideally, park-and-ride lots should help attract new riders to these modes. Surveys have been conducted in some areas to obtain information from commuters using park-and-ride facilities, including user characteristics such as presented above. Questions on the prior mode of travel are often included. Table 3-15 presents aggregated prior mode information obtained from surveys in multiple metropolitan areas. Generally, 40 to 60 percent of park-and-ride lot users previously drove alone.

Table 3-15 Summary of Prior Mode of Park-and-Ride Facility Users (Percentages)

	Number of Lots	Range	Average
Drove alone	305	11% to 65%	49.2%
Carpool/vanpool	303	5 to 28	23.2
Transit (bus or other)	304	5 to 49	10.4
Did not make trip	303	0 to 29	14.9

Note: The "average" values shown are weighted by the number of park-and-ride lots surveyed. Partial or missing data from certain studies may cause the percentages not to total 100.

Source: Derived from Bowler et al. (1986) as presented in Weant and Levinson (1990).

Table 3-16 gives information on the prior mode of park-and-ride/pool lots users as obtained from various individual surveys. Although differences exist in the exact wording of questions used on these available surveys, the results serve to indicate that availability of park-and-ride facilities has attracted substantial shares of travelers who previously drove all the way alone.

Shifting among travel modes can become quite complex in an urban area with many transit options. When asked about mode used before parking at the surveyed facility, users of CTA's park-and-ride facilities in the Chicago area reported the non-auto prior modes of taking a CTA bus to rail service (26 percent) and other non-auto means of travel (less than 1 percent). Reported prior modes that involved auto travel included driving all the way (26 percent), getting a ride all the way (2 percent), getting a ride to CTA service (8 percent), taking Metra commuter rail — presumed to involve auto access (9 percent), using another CTA lot (8 percent), other means involving an auto (2 percent), and "new trip, diverted from auto" (18 percent) (Foote, 2000). The number switching from using bus/rail transit all the way to park-and-ride were roughly equal to the number explicitly reporting a switch from driving all the way to park-and-ride.

Prior mode data specific to park-and-pool activity alone is available from the 1970s. Before opening of a large fenced and lighted carpool and transit fringe parking lot in the Miami area, 60 percent of the carpoolers surveyed had driven alone (Wattleworth et al., 1978). A survey of 150 lots nationally also found 60 percent of carpoolers to have been single occupant drivers (Flora, Stimpson and Wroble, 1980). These percentages may have been inflated to some unknown extent by the gasoline shortage crises of the 1970s. Normal carpool breakup and reformation may also account for some fraction of these survey results. A study from the same era noted three locations in California where positive effects on carpool formation appeared to have been much less significant (Pratt and Copple, 1981).

Table 3-16 Prior Mode of Park-and-Ride and Park-and-Pool Facility Users

	Previous Mode (Percent)					
Locale	**Number of Lots Surveyed**	**Drove Alone**	**Carpooled or Vanpooled**	**Bus**	**Did Not Make Trip**	**Other**
California						
San Francisco/Los Angeles	15	22%	9%	38%	29%	2%
Connecticut						
Hartford/New Haven	14	40%	22%	7%	27%	4%
Texas						
El Paso	5	62%	20%	7%	8%	3%
San Antonio	6	57%	10%	10%	20%	3%
Dallas/Garland	1	50%	11%	11%	25%	3%
Houston	11	49%	17%	8%	24%	2%
Houston	8	45%	20%	6%	26%	3%
Houston West Belt	1	31%	5%	47%	15%	2%
Houston Mason	1	25%	11%	49%	15%	
Houston Addicks	1	25%	11%	49%	15%	
Fort Worth	8	63%	15%	8%	9%	5%
Urban Fringe Lots	25	58%	24%	11%	4%	3%
Urban Lots	32	57%	25%	7%	8%	3%
Florida						
Miami	n/a	46%	14%	16%	24%	
Dade County	n/a	65%	12%	17%		6%
Wisconsin						
Milwaukee	n/a	25%	18%	38%		19%
Milwaukee-Mayfair	1	33%	7%	40%	20%	
Milwaukee-Bayshore	1	38%	12%	35%	15%	
Milwaukee County	13	47%	15%	32%	6%	
Washington						
Seattle	1	65%	12%	23%		
Seattle	1	59%	11%	29%	1%	
Seattle [a]	26	34%	11%	55%		

Notes: [a] Trips to the CBD only. The breakout for the bus previous mode was 22.5% walk to transit and 32.1% drive to transit.

Sources: Seattle 26-lot survey —Rutherford and Wellander (1986), all others —Bowler et al. (1986).

Usage Characteristics of Park-and-Ride/Pool Facilities

Mode of Access

A park-and-ride/pool usage characteristic of particular interest is the mode of access used to reach the facility from place of residence. Travelers may access park-and-ride/pool facilities by a variety of modes, but the great majority of users arrive by driving alone.

It is not always clear from reports of park-and-ride survey results whether the modes of access obtained pertain to users of the transit station or stop as a whole, or only to persons literally using the parking facility to store their car or drop someone off. Whenever "walk" or "bus" access is reported, there is fair certainty that the findings pertain to the station or stop as a whole. Lack of reported "walk" or "bus" access is not necessarily an indication that only persons literally using the parking facility were included, however. Outlying park-and-ride lots served by bus or oriented to park-and-pool activity may be quite isolated.

At rail station facilities, likely to be less isolated, there is often more variety in the mode of access than at non-rail facilities. This is especially so when rail station facilities are in higher density areas. Pedestrian and bicycle access provisions, including bicycle storage lockers or racks, become an important consideration in such areas. (Walking and bicycling as transit modes of access are addressed in Chapter 16, "Pedestrian and Bicycle Facilities.") At rail stations in particular, short-term "kiss-and-ride" parking areas are often provided to accommodate drivers serving travelers who are dropped off and picked up.

Another aspect of mode of access information that is not always clear is whether the data are for the home end of a trip only ("access mode") or include the travel data for persons at the other, non-home end of their trip ("egress mode"). Unless otherwise noted, information presented here in Tables 3-17 and 3-18 is thought to be either for the home end of trips only, or the rough equivalent, access and egress during some number of morning hours. The systemwide auto mode of access information presented above in the "Prevalence of Park-and-Ride Activity" subsection, Table 3-11, is known to be either from the access-from-home or morning perspective.

Table 3-17 highlights information aggregated from across multiple metropolitan areas on modes used to access different park-and-ride facilities. Table 3-18 presents available information on the mode of access to individual heavy rail transit (HRT) stations with major park-and-ride facilities, individual commuter rail and busway lines, and also park-and-ride/pool systems of various types. The Handbook user should refer to other chapters for additional and more extensive systemwide information covering all means of access. Depending on the transit mode of interest, the reference should be to Chapter 4, "Busways, BRT and Express Bus"; Chapter 7, "Light Rail Transit"; Chapter 8, "Commuter Rail"; or for predominantly local bus service, Chapter 10, "Bus Routing and Coverage."

Table 3-17 Summary of Access Mode of Park-and-Ride Facility Users

Access Mode	Range in Percent	Number of Lots	Average Percent
Drove alone	38% to 91%	146	72.6%
Shared ride	3 to 36	146	11.0
Dropped off	0 to 31	117	11.1
Walked	0 to 21	132	4.4
Bus	0 to 10	132	1.3

Note: The "average" values shown are weighted by the number of park-and-ride lots surveyed. Partial or missing data from certain studies may cause the percentages not to total 100.

Source: Derived from Bowler et al. (1986) as presented in Weant and Levinson (1990).

In general, a greater share of patrons arrive by driving alone at facilities located farther away from the CBD. This phenomenon is examined further below in the context of experience with Chicago's Metra commuter rail system, and was dramatically illustrated earlier in Table 3-3. Parking facilities at the end of rail transit lines tend to be the largest facilities and are associated with correspondingly large shares of patrons arriving by driving alone. Sample findings from several locations, some supplemental to and some in addition to information given in Table 3-18, are presented in the sections that follow. Interrelationships between mode of arrival and carpool formation were presented for Connecticut park-and-pool activity under "Traveler Response by Type of Park-and-Ride Facility" — "Response to Park-and-Pool Facilities" — "Connecticut Park-and-Ride Lots."

Bay Area Rapid Transit (BART). A 1992 survey of 35,000 BART HRT riders and a 1993 inventory of BART stations provided information on user mode of access and travel distances that has been extensively analyzed. There were park-and-ride facilities at 24 of the 34 stations in operation in 1993. Of these, 19 were located in surroundings given a research classification of "Low Density Areas" and five were in "Suburban Centers." Stations without parking were all within "Urban Districts" or the Oakland and San Francisco downtowns. The "Low Density Areas" mode of access from home to BART at stations with parking but located in fairly built-up urbanized areas, such as in Berkeley or San Francisco's Mission District, included about 50 percent coming by auto, 8 percent by bus, and 37 percent on foot. At the more outlying suburban stations, the proportions were more on the order of 85 percent by auto and less than 5 percent on foot or bicycle. A major determinant seems to be the nature and density of land uses within or beyond certain critical distances.

Use of auto for egress from station to work was found to be minor, with the exception of shares on the order of 20 percent beyond walking distance at "Suburban Centers" (Cervero et al., 1995). Under most circumstances, it is difficult for commuters to somehow have an automobile available at the non-home end of a transit or carpool trip. "Station Car" proposals, in early stages of development and implementation, seek to change this on BART and elsewhere with station-oriented car-sharing rental systems.

Table 3-18 Modes of Access for Stations with Major Park-and-Ride Facilities and for Route-and-Area-Based Systems of Park-and-Ride/Pool Facilities (Percent)

<table>
<tr><th></th><th>Walk</th><th>Bus</th><th>Drive Alone</th><th>Car-pooled</th><th>Dropped Off</th><th>Other</th></tr>
<tr><td>Boston – MBTA Red Line HRT (1984)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Braintree Station</td><td>5%</td><td>10%</td><td colspan="2">58%</td><td>27%</td><td>1%</td></tr>
<tr><td>Quincy Adams Station</td><td>6</td><td>3</td><td colspan="2">80</td><td>10</td><td><1</td></tr>
<tr><td>Quincy Center Station</td><td>24</td><td>41</td><td colspan="2">21</td><td>13</td><td>1</td></tr>
<tr><td>Wollaston Station</td><td>44</td><td>2</td><td colspan="2">40</td><td>15</td><td>0</td></tr>
<tr><td>North Quincy Station</td><td>33</td><td>4</td><td colspan="2">52</td><td>10</td><td>1</td></tr>
<tr><td>All Five Stations</td><td>25</td><td>12</td><td colspan="2">46</td><td>16</td><td>1</td></tr>
<tr><td>Miami-Dade Transit (2001)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>South Miami-Dade Busway [a]</td><td>64</td><td>24 [b]</td><td colspan="2">4</td><td>7</td><td>1</td></tr>
<tr><td>Maryland – Statewide (1981-82)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Brunswick Commuter Rail Line [c]</td><td>11</td><td><1</td><td>57</td><td>15</td><td>15</td><td>2</td></tr>
<tr><td>Highway Administration Lots [d]</td><td>—</td><td>7</td><td>79</td><td>14</td><td>—</td><td>—</td></tr>
<tr><td>Delaware – All Lots Statewide (1998) [e]</td><td>—</td><td><1</td><td>97</td><td>2</td><td><1</td><td><1</td></tr>
<tr><td>San Francisco Bay Area (1996)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Park-and-Ride Lots [f]</td><td>—</td><td>—</td><td>93</td><td>5</td><td>2</td><td>—</td></tr>
<tr><td>Santa Clara Valley Transit (1998)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Park-and-Ride Lots [g]</td><td>—</td><td>—</td><td>90</td><td>6</td><td>—</td><td>4</td></tr>
</table>

Notes: [a] The South Miami-Dade Busway access data were not surveyed/processed on the basis of either access to transit from the home only, access to transit in the morning only, or access to outlying stations only, deflating the auto access percentages relative to those presented for other operations. The Handbook authors estimate that auto access percentages developed on the basis of access from the home only would be roughly 6% to 7% for "auto driver (park-and-ride)," 6% for "dropped off," and 12% to 13% for auto access in total.

[b] Includes transfers from Miami-Dade Metrorail, which the busway connects to and feeds.

[c] Includes West Virginia commuter rail stations.

[d] Modes from lot to destination (1988): Transit [primarily bus], 18%; carpool, 59%; vanpool, 23% (Maryland Department of Transportation, 1988/90).

[e] Survey of lot users only. Modes from lot to destination: Commuter rail, 36.7%; bus, 53.0%; 2 person carpool, 2.9%; 3+ person carpool, 2.5%; vanpool, 1.4%; other, 3.4%.

[f] Survey of lot users only. Modes from lot to destination: Transit [primarily bus, but also including VTA LRT and ferry], 76%; carpool, 9%; vanpool, 12%; other, 3%.

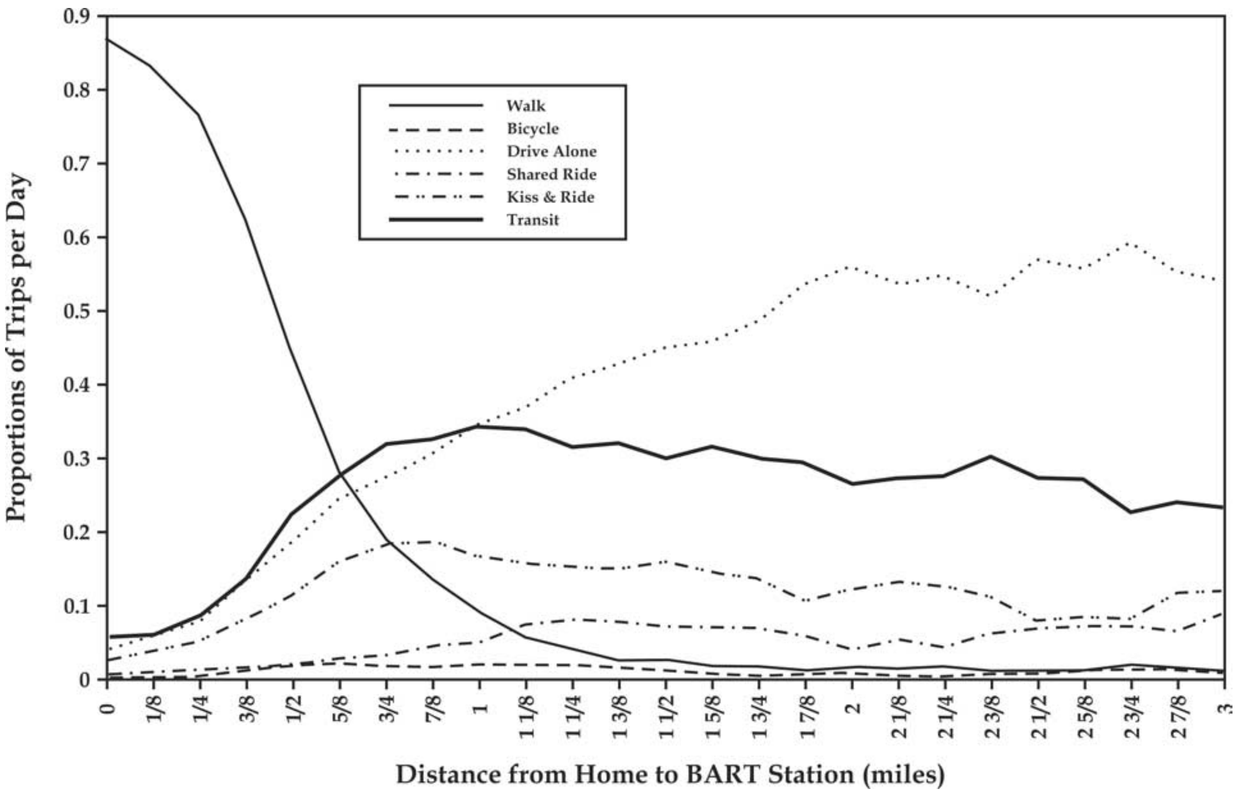
[g] Survey of lot users only. Modes from lot to destination: Commuter Rail, 45%; LRT, 21%; VTA bus, 18%; shuttle, 2%; carpool/vanpool, 11%; other, 3%.

Sources: Wilson (1984); Perk, Baltes, and Perone (2002); Maryland Department of Transportation (1981 and 1982); Urbitran Associates, Inc. and SG Associates, Inc. (1999); Lave, Billheimer and McNally (1997); Santa Clara Valley Transportation Authority (1999).

BART mode of access was found to vary sharply according to access trip length. Figure 3-3 shows the variation in mode of access as a function of access trip length for all BART home-to-station commute trips. As with all similar data plots available from analysis of the 1992 BART survey, the maximum access trip distance examined is three miles.

Walking is the access mode of choice for the majority of short trips, up to 5/8 of a mile for "Urban Districts" and 3/8 of a mile for "Low Density Areas" and "Suburban Centers." Motorized travel modes are in the majority for longer access trips. Transit dominates among motorized access modes for trips between 5/8 and 1-3/4 miles in "Urban Districts," but never surpasses drive-alone park-and-ride in more suburban and outlying areas. Beyond two miles, drive-alone picks up on the order of 60 percent of BART access trips at lower density and outlying stations, roughly comparable to similar findings from Toronto and Washington, DC.

Figure 3-3 Mode of access for commute trips from home to all BART stations



Source: Cervero et al. (1995).

Carpooling gains in importance over 1 mile, but except for "Urban Districts" anomalies, attracts less than 10 percent of access trips. Passenger drop-off or "Kiss & Ride" peaks at roughly 20 percent at about 7/8 of a mile on average, holding up best at closer-in stations. Interestingly, "Suburban Centers" stations attract roughly half as much again in passenger drop-off shares compared to the averages shown in Figure 3-3 (Cervero et al., 1995), suggesting that trip linking opportunities may play a role.

What a display like Figure 3-3 cannot fully illustrate is the interplay between mode of access shares by distance, housing density, and decline in choice shares for the trunk-line transit mode with distance from the station. All three of these factors working together, along with various other considerations highlighted in the "Underlying Traveler Response Factors" section, contribute to determining park-and-ride use. Implications of the interplay of shares and density with distance from a stop or station, as well as egress mode characteristics, are further explored in Chapter 17 from the perspective of that chapter's concern, namely, "Transit Oriented Design."

Boston's Red Line. A 1984 survey of riders at the five HRT South Shore Red Line stations in the Boston metropolitan area provided information on mode of access tied to rider tenure. As displayed in Table 3-18, access mode varied considerably among stations. A comparison of the responses of new and continuing riders found that new riders were somewhat more likely to use park-and-ride lots and somewhat less likely to walk than long term riders. The overall proportions for other modes of access were similar, however (Wilson, 1984).

Chicago's Metra. The Metra commuter rail services radiate out from the Chicago CBD into Northeastern Illinois and have stations in both urban and suburban settings. For the system as a whole, 55 percent of all inbound morning peak period commuters drive alone to their preferred rail station. The share of commuters arriving by driving alone increases with distance from the Chicago CBD. This increase in driving alone with distance is in apparent substitution for walking, as the percentages for other arrival modes do not vary widely. These findings were displayed earlier, under "Traveler Response by Type of Park-and-Ride Facility" — "Response to Rail Park-and-Ride Facilities" — "Metra Park-and-Ride Lots," in the Table 3-3 presentation of percentage shares as related to distance for all arrival modes.

In addition to distance from the CBD and accompanying densities, parking at Metra stations is also influenced by parking supply and pricing policies, but to a lesser extent. First and foremost, these factors affect the extent of spillover parking that occurs. At stations with severe areawide parking shortages, unless other access modes are substantially improved, the Metra experience suggests that commuter rail ridership will be adversely affected (Ferguson, 2000).

A 1992 study of Metra's Brainerd Station provides a snapshot of parking and mode of access at a closer-in commuter rail station. At 11 miles from downtown Chicago, Brainerd Station is one of the innermost on Metra's Rock Island line. In 1992, the station had a total of 124 parking spaces located off-street (one lot), on-street (two areas), and on the railroad right-of-way (two areas). This was down from 152 spaces in 1987. Vehicles parked at the station totaled 83 in 1987, 71 in 1990, and 76 in 1992. The 1992 mode of access survey found 49 percent of riders walking to the station, 1 percent biking, 38 percent driving and parking, 1 percent riding with another park-and-ride patron, and 11 percent being dropped off (Metra, 1993). These mode of access percentages mesh reasonably well with those predicted in Table 3-3 as a function of distance from the CBD.

Maryland Park-and-Ride Lots. Commuter rail patronage estimation studies for Virginia Railway Express included station-by-station examination of the mode of arrival data summarized in Table 3-18 for the Brunswick commuter rail line in Maryland and West Virginia. Focusing on the auto-access modes of arrival, it was found that driving alone constituted about 68 percent of auto-mode arrivals at inner stations (stations within 20 miles of the downtown terminal), but dropped toward roughly 50 percent at 60 miles from downtown. Carpooling was in the 10 to 11 percent range at inner stations, but increased in importance to almost 30 percent of auto arrivals at stations 60 miles out. The drop-off mode of arrival ranged from 22 percent of auto arrivals at innermost stations to 19 percent at 60 miles.

Stations with end-of-line characteristics proved to be an anomaly with respect to the drive-alone and drop-off modes. The drop-off percentages at these stations were only half what the distance out from downtown would indicate, with the drive-alone mode absorbing the difference (Pratt, 1987).

San Francisco Bay Area Park-and-Ride Lots. In a 1996 survey of park-and-ride lot users at 68 facilities in the nine county San Francisco Bay area, the overall results of which are displayed in Table 3-18, mode of arrival percentages were observed to vary by county. Driving with others was slightly elevated relative to the overall average 5 percent rate in the Alameda/Contra Costa area, and in San Mateo and Marin Counties, together representing the first ring of counties outside of San Francisco proper (Lave, Billheimer and McNally, 1997).

Other Usage Characteristics

Frequency of Use. Park-and-ride facility users have a fairly high regularity in their use of these facilities. Aggregated survey results for on the order of 100 lots nationwide show 87 percent reporting usage for five or more round trips per week, followed by 8 percent for four round trips per week, and 7 percent for three or less (Weant and Levinson, 1990).[2] Not quite so high a degree of regularity was reported in the 1998 surveys of park-and-ride/pool lots in Delaware and the Santa Clara Valley Transportation Authority (VTA) service area around San Jose, California. In Delaware and California, 68 and 63 percent of surveyed users, respectively, reported five or more days a week use; 19 and 28 percent, three to four days a week; and 5 and 6 percent, one to two days a week; with 7 and 3 percent reporting less frequent use (Urbitran Associates and SG Associates, 1999; Santa Clara Valley Transportation Authority, 1999). Of CTA park-and-riders, 71 percent reported using the service 5 or more days in the previous week; 15 percent, three to four days; and 8 percent, one to two days; with 6 percent reporting no use during the previous week (Foote, 2000).

The aggregated data for U.S. park-and-ride lots suggest a higher regularity of use than for transit riding overall, but the Delaware, VTA and CTA results do not. Survey results on frequency of overall transit use for nine U.S. systems in 1997-98, with separate data for bus and rail, indicate a range from 83 percent reporting five or more day-a-week use (university bus routes in Austin, Texas) down to 59 percent (LRT riders in Portland, Oregon). The 9-system, 15-strata average was 72 percent riding five or more days a week. All the 9-system findings exclude riders 12 years of age or younger (McCollom Management Consulting, 1999).

The preceding frequency of use data is calculated — in essence — as percentages of *trips made* in the respective categories. Care must be taken not to compare such statistics with frequency of use data computed as percentages of *persons using transit*, i.e., customers, which gives a

[2] Percentages do not total to 100 due to both rounding and the treatment of information involving partial or missing data from certain of the aggregated studies.

different perspective indicative of lesser frequency or regularity of use. The difference and the implications are fully discussed and demonstrated in Chapter 12, “Transit Pricing and Fares,” under “Underlying Traveler Response Factors” — “Transit Use Frequency.”

Arrival and Departure Times and Turnover. User arrival and departure times at park-and-ride facilities will be influenced by local and regional factors ranging from whether the facility reaches capacity or not to the travel time incurred by users after they reach the facility. Table 3-19 gives morning arrival times at the lot and time of return to the lot (essentially lot departure time) for the park-and-ride/pool facilities in Delaware and the VTA service area around San Jose. Arrival times at Delaware lots are influenced by the fact that approximately one quarter of all users are destined to downtown Philadelphia, roughly an hour by SEPTA commuter train from Delaware. A similarly long commute, to San Francisco, is faced by 16 percent of the San Jose area park-and-ride survey respondents. Both park-and-ride/pool systems serve multiple modes (see Table 3-18 footnotes “[e]” and “[g]” respectively).

Table 3-19 Distribution of Park-and-Ride/Pool Facility User Arrival and Return Times

Morning Arrival Time at Lot	Percentage		Time Returning to Lot	Percentage	
	Delaware	VTA (CA)		Delaware	VTA (CA)
Before 5 AM	6.8% before 6 AM	2.3%	12 Noon to 2 PM	1.1%	6.5% before 4 PM
5 AM to 6 AM		17.4	2 PM to 3 PM	1.1	
6 AM to 7 AM	42.0%	34.8	3 PM to 4 PM	4.9	
7 AM to 8 AM	42.1	30.5	4 PM to 5 PM	20.7	12.0%
8 AM to 9 AM	5.4	10.3	5 PM to 6 PM	45.2	34.1
9 AM to 10 AM	1.1	4.7% after 9 AM	6 PM to 7 PM	21.3	30.4
10 AM to 12 Noon	0.5		7 PM to 8 PM	5.8% after 7 PM	11.5
After 12 Noon	2.1		After 8 PM		5.5

Note: Developed from responses to self-administered windshield surveys — not counts. See note, Table 3-12, for Delaware survey description.

Sources: Urbitran Associates, Inc. and SG Associates, Inc. (1999); Santa Clara Valley Transportation Authority (1999).

Results from the 1996 survey of lots throughout the San Francisco Bay Area were used to calculate average duration of park-and-ride/pool parking. County-level average duration ranged from 10.1 to 11.6 hours across the 7 counties surveyed, with an overall average of 10.6 hours (Lave, Billheimer and McNally, 1997). Nevertheless, not everyone parks for the full average duration, making some spaces available for more than one car during the day. As noted earlier, studies of outlying facilities have shown the average daily park-and-ride space turnover to be about 1.1 cars per parking space (Weant and Levinson, 1990).

Facility Size and Amenities

Facility Size and Internal Walk Distances

Park-and-ride facilities vary greatly in size, from as little as 20 to several thousand spaces, as covered in the "Traveler Response by Type of Park-and-Ride Facility" presentation. In addition to providing parking spaces, the available real estate must support internal and external circulation and access, and appropriate landscaping and amenities. Appropriate levels of transit service must be provided to support the size of the facility. Rail transit stations often feature facilities with significantly more spaces than most bus park-and-ride lots. Facilities are generally sized and serviced with the design objective that they be about 80 to 90 percent utilized. This allows for the minor variations in day-to-day demand that may be experienced (Weant and Levinson, 1990).

It has been pointed out that in the case of transit-oriented park-and-ride facilities, the extremes in facility size are best avoided. Small lots will not provide enough parking to justify frequent services, while very large facilities require long walking distances (Weant and Levinson, 1990). Commuters appear to accept walking distances of between 400 and 1,000 feet from their parked vehicle to the transit loading area. However, walking distances greater than 650 feet may be shunned by some users and result in illegal parking closer to the transit area or lost patrons. Facilities with especially good transit service characteristics may support longer walks. The Washington, DC, Metrorail system has several fully used lots that have spaces with walking distances greater than 1,000 feet (Turnbull, 1995).

There has not been enough study of park-and-ride intra-facility walking distance issues to really know how to judge the walking distance threshold or continuum, whichever it is. In one demand model application for estimation of mode, route and commuter rail station choice carried out for Maryland's MARC, good results were obtained through use of detailed measures of all components of the trip. This included individual measurement for each station of the average walking distance from parking to platform, along with an indicator of parking capacity limitations. Walk times were initially assigned a model coefficient that equated each minute of walking to 3.37 minutes of in-vehicle riding time, in conformance with the then-current Metropolitan Washington Council of Governments logit mode choice model. The best results in matching actual station-by-station passenger volumes for both the present and 10 years previous were, however, obtained with revised coefficients equating each minute of walking to 2.0 minutes of in-vehicle time (Parsons Brinckerhoff, 1994).

Facility Design and Amenities

Where park-and-ride spaces are oversubscribed and facilities cannot easily be expanded, inducement of passenger drop-off as an alternative has obvious advantages for mitigating the capacity problems. Facility design and operation supportive of kiss-and-ride has been tentatively identified as important for encouraging that mode of access. In a comparative study of selected Metro-North and Long Island Rail Road commuter stations, site design, mode of access statistics, and neighborhood demographics were all examined. It was found that park-and-ride lots with larger, more accessible drop-off points and better enforcement of parking regulations tended to be associated with higher percentages of kiss-and-ride access. The only demographic marker found to be significant was percentages of females in the population, positively correlated with the kiss-and-ride mode of access and presumed by the researcher to simply indicate presence of multiple-person households (Schank, 2002).

Several studies have used various forms of user preference surveys to investigate the relative importance of individual customer amenities and other desired attributes on park-and-ride facility usage. Safety and security amenities often top the list. However, two studies that probed deeper suggest that this information must be taken together with degree of satisfaction information. A Seattle-area study, using both user and non-user surveys, concluded that security will only be a determinant of traveler choice if there is some room for improvement. Thus, if a facility is already perceived to be without security problems — as was largely the case in greater Seattle — security improvements will not have appreciable demand impacts. Similarly, in Chicago, lot safety and a safe walk to the train were ranked along with "parking available" as being of uppermost importance. At the same time, users indicated on average that they were somewhat satisfied (4 on a 5-point scale) with these features. They were identified in the study as borderline in priority between need for improvements and need for maintenance of existing strengths (Hendricks and Outwater, 1998; Foote, 2000)

The Seattle-area study also indicated that other amenities at park-and-ride lots have some appeal to users, but do not determine whether the traveler will choose one lot over another. "Espresso/Dry Cleaning" businesses were ranked as having the most appeal, and car care was the second most desirable (Hendricks and Outwater, 1998). The Chicago study, which asked users to rate the importance and satisfaction of 11 features of park-and-ride lots, found that the highest-rated scores went to those types of amenities that eliminated shopping stops for respondents traveling home from work, or stops likely to be made most frequently (Foote, 2000). A third feature-ranking study from the early 1990s placed pay telephones and bus shelters next after security and lighting as important features for park-and-ride facilities (Ewing, 1997).

In another investigation of desired features, part of a survey of park-and-ride facility users throughout Delaware, survey respondents gave their higher rankings to all 13 characteristics involved in actual transportation use of the facility. In descending rank order, these were adequacy of parking, lighting, crossing safety, highway conditions, direct service, cameras, guards, fencing, quality of access, more buses, shelters, more destinations, and rail service. Lower rankings were given to all 10 ancillary features posited in the survey. Again in top-to-bottom rank order, these were shopping, restrooms, news/coffee, ATM/bank, gas, postal, food, drug store, dry cleaning and day care (Urbitran Associates and SG Associates, 1999).

In all of these ranking studies, the results can be influenced by the specific choices given to the respondents. For example, in the Chicago study "car wash," "oil change," and "muffler service" were listed separately and received varying scores, while in Seattle the feature was simply identified as "car care" and received a fairly high ranking. None of these studies were conducted recently enough to have included in survey respondent rankings the new development of car-sharing services. Interestingly, child care facilities consistently ranked poorly among potential features at park-and-ride lots.

Parking Pricing at Park-and-Ride Facilities

Park-and-ride facilities themselves may charge fees for parking, especially at facilities that experience strong demand, such as at commuter rail and heavy rail stations. Such parking is usually priced at a substantial discount to the prevailing CBD parking rates. For example, in 2002, most Washington, DC, Metrorail lots were charging about $2.00 per day versus downtown daily parking rates exceeding $10.00 per day. Table 3-20 lists park-and-ride parking fee ranges reported in the 2002 American Public Transportation Association (APTA) Transit Fare Summary.

Table 3-20 Park-and-Ride Parking Fee Ranges for 2002 Including Free Parking

		Commuter Rail (CRR)		HRT/Metro (Rapid Trn.)		Light Rail Trn. (LRT)		Motor Bus	
Locale	Agency	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
San Diego, Miami, Northern VA–DC, Toronto, Montreal	5 U.S. and Canada commuter rail agencies responding to survey	free	free	—	—	—	—	—	—
San Jose - S.F., CA	Peninsula Corridor JPB	$1.50	$1.50	—	—	—	—	—	—
Boston, MA	MA Bay Transp. Auth.	1.00	3.00	$2.00	$4.00	$2.00	$2.50	$1.00	*$4.00
Baltimore, MD–DC	Mass Transit Adm. MD	free	6.00	—	—	—	—	—	—
Newark, NJ - NYC	NJ Transit Corporation	free	12.00	—	—	free	2.00	free	3.50
New York, NY	MTA Metro-North RR	free	5.00	—	—	—	—	—	—
Philadelphia, PA	SEPTA	free	0.50	1.00	1.00	—	—	—	—
Vancouver, BC	Translink	0.75	1.00	—	—	—	—	—	—
Los Angeles, CA	L.A. County MTA	—	—	free	free	free	free	free	free
S.F.- Oakland, CA	S.F. Bay Area RTD	—	—	free	0.25	—	—	—	—
Miami, FL	Miami-Dade Transit	—	—	3.00	3.00	—	—	—	—
Atlanta, GA	Metro Atlanta RTA	—	—	free	7.00	—	—	free	*7.00
Chicago, IL	Chicago Transit Auth.	—	—	1.00	10.75	—	—	*1.00	*10.75
Baltimore, MD	MD Transit Admin.	—	—	free	free	free	free	free	free
Lindenwold, NJ	Port Auth. Trn. Corp.	—	—	free	1.00	—	—	—	—
Cleveland, OH	Greater Cleve. RTA	—	—	free	free	free	free	free	free
Toronto, ON	Toronto Transit Comm.	—	—	free	6.00	free	*6.00	free	*6.00
Montreal, QC	Montreal Transit Corp.	—	—	free	free	—	—	free	free
U.S. and Canada	9 LRT/bus agencies responding to survey	—	—	—	—	free	free	free	free
U.S. and Canada	25 additional bus agencies responding	—	—	—	—	—	—	free	free

Notes: Five responding agencies (3 commuter rail and 2 motor bus) have been omitted for reasons of likely duplication, or suspect or confusing data.

An asterisk (*) indicates a parking fee thought to apply at facilities shared with HRT/Metro, where the primary park-and-ride function is presumably to serve the HRT/Metro.

Canadian parking fees are presumed to be in Canadian dollars.

Sources: American Public Transportation Association (2002), with interpretations/notes by Handbook authors.

The picture that emerges from Table 3-20 and other data is one of predominantly free park-and-ride parking, but with a majority of commuter rail and HRT/Metro systems levying a fee for parking at some of their facilities. The instances of both commuter rail and HRT/Metro systems charging for parking are all in the Boston, New York, Philadelphia, Washington, Chicago and San Francisco metropolitan areas, all featuring among the most dense central cities of the United States. Under these conditions, it does not appear that park-and-ride parking fees significantly deter rail system use. Atlanta, Miami and Toronto also report charging for HRT/Metro parking, although in Atlanta today the charges are primarily for overnight parking by riders going out of Hartsfield International Airport. Setting aside instances of LRT and bus lines serving an HRT/Metro station with pay parking, only transit agencies in Boston and the sector of New Jersey across from Manhattan report having LRT and bus park-and-ride facilities that charge for parking (American Public Transportation Association, 2002; Pratt and Copple, 1981; Shelton, 2001; Washington Metropolitan Area Transit Authority, 2002a). For further interpretation of user response to park-and-ride parking fees, refer back to "Underlying Traveler Response Factors" — "User Costs and Willingness to Pay."

Parking charges may be used to shift excess demand to existing facilities with available capacity. In 1995, for example, the Southworth Ferry park-and-ride lot was the most over-used such lot in the Puget Sound region, some 20 percent over capacity. In response, in 1997, free shuttles were offered to three nearby lots and a parking fee was introduced at the Southworth Ferry lot. This led to a 37 percent decrease in utilization of the Southworth lot. By 1999, Southworth lot utilization was back up to 94 percent, despite the fee. The lot was expanded in 2001, but the number of occupied spaces did not rise, dropping the utilization to 57 percent (Puget Sound Regional Council, 2002).

A trial optimization of park-and-ride fees was put in place as an early 1960s demonstration project on the Boston MTA's HRT lines (today part of the MBTA system). Daily parking rates were selectively reduced from 35¢ to 10¢ at 8 out of 15 parking lots along the three rapid transit lines. Parking loads were shifted from overutilized to previously underutilized lots, and parking along these lines increased by 48 percent in total. The study concluded that a $165,000 net gain in annual parking and farebox revenue was produced (Mass Transportation Commission et al., 1964). For more context on the overall endeavor this demonstration was part of, see the case study "Mass Transportation Demonstration Projects in Massachusetts" in Chapter 9, "Transit Scheduling and Frequency."

Some systems offer more than one pricing scheme at individual facilities. Free parking for carpools and vanpools may be offered to encourage ridesharing and to maximize available capacity. Discounts may be offered for monthly parking programs, or premiums may be charged for added convenience.

The Washington Metrorail HRT system offers monthly parking permits at many of its stations, and for an extra fee offers a "guaranteed parking space." Implemented in 1998, this reserved parking service proved popular — several stations have wait lists — and was expanded by 2002 to all 33 stations with all-day parking. For an extra $20 per month over the approximately $45 monthly parking fee, participants receive a permit tag that enables them to park in designated spaces that are reserved until 10:00 AM. Should a participant find all of these spaces full, they may use overflow spaces in their station's short-term parking area. The result is that for a premium price, users are guaranteed ability to use transit without parking uncertainties (Metropolitan Washington Council of Governments, 1996; Washington Metropolitan Area Transit Authority, 2002c).

The BART HRT system in the San Francisco Bay Area offers a similar program but in a quite different parking environment. Whereas Washington Metrorail park-and-ride facilities often fill early in the day, despite parking fees covering practically all Metrorail-operated long-term parking spaces, the mostly free park-and-ride lots along BART are rarely filled. BART's recently introduced reserved parking program charges a monthly fee of $63. The maximum parking reserved at any station is 25 percent. At the end of the first quarter of 2003, 3,500 of 9,700 permits had been sold, and 6 of the 27 stations involved had run out of permits (Urban Transportation Monitor, 2003a).

Time to Establish Use

Similar to the response to new transit services, demand for new parking facilities develops over a period of time after inauguration as familiarity increases and individual travel accommodations are adjusted. Promotion activities and high visibility help reduce the period over which this demand develops. The 1999 opening of a supplemental park-and-ride lot in Bridgeport, Connecticut, provides an example. Over a 4-month introductory period, as a steady stream of publicity including direct mailings, newspaper advertisements, billboards and lot visibility acquainted potential users with the facility, usage more than tripled. Short-term growth was essentially straight-line, from about 100 parked cars at the end of the first week to roughly 340 cars at the end of the 15th week (Levinson and Weant, 2000). Another example of sharp growth in usage accompanying substantial publicity is presented in the case study, "A Park-and-Ride Lot Implementation in Metropolitan Portland, Oregon."

Systemwide growth in parking demand, as contrasted to the individual facility perspective, adds in system expansion effects. Experience in Denver, Houston, Seattle, and Washington, DC, has shown that overall park-and-ride demand can continue to expand in the long term as transit services, stops and stations, and new parking capacity are added, and as suburbs grow. Table 3-21 displays this growth in park-and-ride/pool use systemwide, as distinct from individual facility usage growth, for the four urban areas.

One set of guidelines points out that older facilities may demonstrate a reduction in demand if not adequately maintained (Spillar, 1997).

Impacts on Traffic Volumes and Vehicle Miles of Travel

A variety of factors will influence the impact of park-and-ride facilities on traffic volumes and vehicle miles of travel (VMT). These include the prior mode of park-and-ride lot users, the distance of the facility from the downtown or major activity center, the access trip length and mode, and the competitiveness of the park-and-ride mode of travel in the specific transportation and geographic context involved. Park-and-ride facilities will have a positive impact on managing traffic congestion and reducing VMT to the extent that lower-occupancy vehicle trips, especially long distance trips, are removed from the system. These benefits can be substantial since park-and-ride is generally most effective where traffic and parking congestion are worst.

These positive impacts may be counter-balanced to some degree, however, if significant numbers of travelers attracted to park-and-ride were already transit users and previously rode feeder transit or walked to gain access to the long-distance transit mode. This effect, which would tend to manifest itself as increased traffic in the urban fringe, may be exacerbated if diversion to the parking facility introduces indirectness of travel or induces the making of additional auto trips (Pratt and Copple, 1981; Victoria Transport Policy Institute, 2003).

Table 3-21 Systemwide Growth in Park-and-Ride Use over Time

	1973	1980	1985	1990	1995	1998
Commuter Rail						
MARC–Baltimore/Washington [a]	n/a	1,225 [b]	1,296 [c]	3,289 [c]	5,150	n/a
VRE–Washington/Northern VA	—	—	—	—	2,411	n/a
Heavy Rail						
Metrorail–Washington, DC	—	6,514	8,461 [c]	23,956 [c]	34,195	n/a
LRT						
Denver	—	—	—	— [d]	988 [d]	1,634
Express Bus						
Houston with HOV	—	4,070	10,230 [e]	12,626	11,608 [e]	13,781
Seattle [f]	n/a	5,629	9,866	10,309	11,195	13,543
Denver [f]	n/a	n/a	n/a	4,934 [d]	6,679 [d]	8,199
Washington, DC [g]	2,914	4,926	5,487 [c]	13,015 [c]	17,502	n/a
Park-and-Pool						
Houston with HOV	—	—	84 [e]	126	162 [e]	184

Notes: n/a - Information not available; — - Information not applicable.

[a] Data for 1982 is for entire system. Data for 1983 is for Washington region "WMATA Compact" area only. Data for 1989 and 1995 is for an expanding study area. See Table 3-24 for a constant-area tabulation.

[b] Information from 1982.

[c] Information from 1983 and 1989.

[d] Information from 1994 and 1996.

[e] Information from 1986 and 1996.

[f] May include some express buses operating on HOV lanes.

[g] Includes express buses operating on HOV lanes as well as ridesharing and some local bus services. Data for 1973 is for "WMATA Compact" area; data for subsequent years is for an expanding study area. See Table 3-24 for a constant-area tabulation.

Sources: Metropolitan Washington Council of Governments (1990 and 1996), Municipality of Metropolitan Seattle (1998), Pratt (1987), Regional Transit District (1999), Texas Transportation Institute (1998).

Much of the before-and-after study information on park-and-ride facility traffic volume and VMT impacts is dated, but not likely to be invalidated by the passage of time. Some of the available findings must be subsumed from projects with heavy but not exclusive utilization by park-and-ride patrons. Two such projects are the San Bernardino Transitway and the Philadelphia-Lindenwold High Speed Line, where park-and-ride lots are a major system component, and the majority of transit riders utilize the auto-transit mixed-mode of travel. Surveys in the initial years of operation showed 72 percent of San Bernardino Transitway bus riders and 83 percent of Lindenwold Line HRT riders to be utilizing some form of auto access (Crain & Associates, 1978; Ellis, Burnett and Rassam, 1971).

Extensive surveys were conducted during the initial operating phases of the San Bernardino Transitway. The results were used to estimate savings in VMT and average daily auto trips generated, based on mode changes from driving to using the bus. For the bus-only operation (1976), daily savings of 100,000 VMT were estimated. For the mixed-mode carpool and bus operation (1978), the estimated daily savings were 146,000 VMT. Corresponding reductions in daily auto trips generated were 2,500 in 1976 and 4,100 in 1978 (Crain & Associates, 1978). It may be inferred that none of the savings in auto trip generation were attributable to park-and-ride activity, because for that, auto was still used for access. While the VMT savings figures pertain to the transitway/HOV lane overall and not just the park-and-ride element, they provide one indication of the potential impacts of these types of projects.

The opening of the Philadelphia-Lindenwold High Speed Line and park-and-ride facilities was associated with a 3 percent reduction in traffic volumes on the parallel Benjamin Franklin Bridge. Nevertheless, about half the initial ridership was drawn from existing bus or commuter rail services. Slower but direct trips to Philadelphia via bus and train were replaced with lateral drives to High Speed Line park-and-ride lots. Circa 1970, 83 percent of the systemwide ridership arrived by auto: 57 percent as auto drivers, 6 percent as auto passengers, and 20 percent being dropped off. The estimated VMT savings attributed to the net effect of opening the line and its park-and-ride lots ranged from an estimate of 66,000 daily work trip VMT (16,500,000 work trip VMT annually assuming 250 annual work days) to an estimate of 28,000,000 VMT annually for all travel purposes (Boyce, 1975; Ellis, Burnett and Rassam, 1971).

A survey of 150 park-and-ride facilities in Connecticut, Michigan, Missouri, and California with a median size of 40 spaces indicated each space to be contributing VMT savings that varied according to the distance of the lot from the primary destination. A formula developed on the basis of the survey exhibited the relationship presented in Table 3-22 between annual VMT savings per parking space and distance from destination (Flora, Stimpson and Wroble, 1980).

A 1986 study estimated that the far-flung State Highway Administration park-and-ride and park-and-pool lot system in Maryland removed 43 million VMT from the state roadway system in a year. On average, each user saved 55.4 vehicle miles per day, an outcome related to the outlying nature of the lots (Maryland Department of Transportation, 1998/90). In 1995, the Connecticut Department of Transportation estimated that some 12,300 commuters used

Table 3-22 Relationship of VMT Reduction per Park-and-Ride Space to Distance to Primary Destination

Distance to Primary Destination	Annual VMT Reduction per Space
10 miles	2,800 VMT
20 miles	4,300 VMT
30 miles	5,700 VMT
40 miles	7,200 VMT

Source: Flora, Stimpson and Wroble (1980).

park-and-ride/pool lots in the state on a daily basis, taking approximately 6,800 vehicles off main roadways daily. Survey data indicated the commuter lots generated shared ride trips at an average occupancy of 3.0 persons per vehicle, significantly higher than the state average vehicle-occupancy level (Connecticut Department of Transportation, 1996).

Impacts on Energy, Air Quality, and Other Environmental Factors

As covered above, park-and-ride lots work to reduce VMT — in most circumstances — by intercepting drive alone commuters and allowing them to change to a high-occupancy commute mode. Automotive energy consumption and pollution are closely related to VMT, and reductions in VMT generally help reduce energy consumption and lead to positive impacts on air quality. However, two aspects of automotive pollution complicate park-and-ride lot air quality impacts. First, automotive internal combustion engine emissions are particularly bad during the first few minutes of automobile operation when the engine is cold. Known as start or “cold start” emissions, this extra pollution is generated during the first several miles of travel. Second, evaporative emissions, also referred to as “hot soak” emissions, may continue to be released after the automobile is turned off but while the engine is still hot.

For a ten-mile automobile trip, with circa 1990 emissions control technology, approximately 84 percent of hydrocarbon (HC) emissions and 54 percent of nitrogen oxide (Nox) emissions result from the cold start and hot evaporative soak. Since park-and-ride facilities tend not to eliminate these types of emissions, levels of pollutants emitted for short trips to park-and-ride lots can be only marginally less than those of ordinary medium-length auto trips direct to the destination (Barry and Associates, 1991). It follows that park-and-ride lots could introduce negative impacts in cases where they inspire patrons to drive to the facility when they might otherwise use transit for the entire trip, or in certain instances where they cause motorists to drive out of the way to divert to the park-and-ride facility. There is an additional problem, also, in that park-and-ride lots may create emissions hot spots, causing localized degradation of air quality.

With these issues, it can be understood why there has been a lack of unanimity on the air quality benefits attainable from park-and-ride facilities, and why negative impacts have on occasion been found. In general, though, well conceived park-and-ride facilities appear to help reduce energy consumption through VMT reductions and to produce at least a modest positive impact on air quality. Further, by removing automobile trips from congested CBDs, or other major activity centers, park-and-ride lots help reduce cold starts, hot soaks and associated automobile emissions in these densely populated areas. Finally, it should be noted that as new no-emission and low-emission technologies are introduced, pollutant emissions may become more closely related to VMT incurred and less influenced by vehicle activation and parking.

Following are some example analyses of energy and air quality effects accruing from actual implementation of park-and-ride facilities or of transportation improvements encompassing major park-and-ride components. These evaluations are illustrative only in a general sense, not only because the first listed computations were made for all users of the transportation improvements, not just park-and-ride patrons, but also because there have been substantial changes in automotive fuel consumption and emissions controls in the intervening years.

The analyses conducted after the opening of the San Bernardino Transitway and the Philadelphia-Lindenwold High Speed Line, with their heavy reliance on auto access as described in the previous subsection, also examined the energy and air quality impacts of these overall systems. The San Bernardino Transitway was estimated to have saved 7 to 10 percent in energy consumption, while cutting air pollution emissions by 10 to 20 percent. These estimates pertain specifically to travel during peak periods in the peak-direction by trip makers shifting to the Transitway (Crain & Associates, 1978).

Two independent energy evaluations of the Lindenwold Line produced partially conflicting results. One concluded that the total rapid transit and park-and-ride operation provided an average weekday peak period energy savings equivalent to approximately 800 gallons of gasoline. The other calculated that there was a 600 gallon equivalent net energy loss for one-way weekday home-to-work travel. At issue here was not only indirectness and automobile energy consumption of the combined auto-HRT travel mode, but also the higher energy consumption per passenger of the High Speed Line relative to slower prior transit modes (Boyce, 1975; Curry, 1976).

An analysis of six park-and-ride lots in the Dallas-Fort Worth area estimated both the direct savings in gasoline consumption per year and the energy cost of parking lot construction. The lot at Garland, with 627 spaces and 18 miles from the CBD, generated 1.13 one-way person trips per space and was estimated to save 200,000 gallons of gas annually. This was enough to pay back in one year the energy consumed in construction. Four other lots resulted in direct savings of between 700 and 38,000 gallons on an annual basis, for a total of some 52,000 gallons. For the two lots involving new construction (the other two were shared-use), the construction energy payback period was estimated at 3.2 to 6.6 years. These four lots averaged 329 spaces in size and 8 miles from the CBD, and the two newly constructed lots generated 1.40 to 1.54 one-way person trips per space. The Los Colinas lot, with 170 spaces and a 12-mile travel distance to the CBD, was estimated to have resulted in a direct energy loss of some 3,800 additional gallons of gasoline on an annual basis. Obviously there was no payback of the energy used for lot construction. It generated 0.44 one-way person trips per space (Cooper and Weil, 1980).

In the course of evaluating cost-effectiveness of Seattle metropolitan area park-and-ride lots, pollutant emissions were evaluated for circa 1985 park-and-ride activity in the north and southeast corridors. The overall study is introduced in the next subsection. The pollutant emissions savings were estimated to be very small in a regional context, but positive for three out of four pollutants. The fractional reductions in total King County air pollutants that provision of park-and-ride facilities was estimated to provide were 0.09 percent in carbon monoxide, 0.12 percent in hydrocarbons, and 0.16 percent in nitrogen oxide. Total suspended particles were estimated to have been increased by 0.08 percent (Rutherford and Wellander, 1986).

With respect to other environmental factors, reduction of demand for arterial highway capacity and downtown parking have obviously positive environmental implications. On the other hand, extensive park-and-ride facilities at transit stations tend to conflict with creating Transit Oriented Development. There is also concern that park-and-ride facilities may encourage urban sprawl by lowering the cost and stress of long distance commutes (Victoria Transport Policy Institute, 2003).

Bus System Cost and Service and Other Economic Effects

Park-and-ride systems allow transit operators to provide effective line-haul services where residential densities are otherwise insufficient to support adequate local passenger pickup service or feeder routes. One analysis of residential densities required to support express bus service indicates that housing density must be roughly 5 times greater if collection of passengers within walking distance of their homes is to be provided instead of relying on park-and-ride (Pushkarev and Zupan, 1982). For further background on this assessment, see Chapter 15, "Land Use and Site Design," under "Related Information and Impacts" — "Transit Service Feasibility Guidelines" — "Density Thresholds for Transit Service."

Local Passenger Pickup Versus Park-and-Ride

There are both cost and service trade-offs to be considered in the decision of whether to provide local passenger pickup or rely entirely on park-and-ride. Transit service reached via a park-and-ride facility is not generally as attractive to the average user as truly equivalent service brought within close walking distance. This aspect was discussed earlier, in the "Underlying Traveler Response Factors" section, under "Overall Effects on Transit Mode Share" — "The Park-and-Ride Mode Change Penalty." The key offset in the service trade-off is that the service area for a transit station or stop with a park-and-ride facility is on the order of 400 times greater than the service area based on walk access alone (Ewing, 1997).

From the cost trade-offs perspective, the capital and operating costs of park-and-ride lots must be compared to the operating cost of collector or feeder transit services. Figure 3-4 illustrates the nature of cost thresholds at which construction of park-and-ride lots becomes more economical than provision of feeder service. Although the cost information used to develop the thresholds representation in the figure is from the mid-1970s, the nature of the overall relationship remains valid (Levinson et al., 1973).

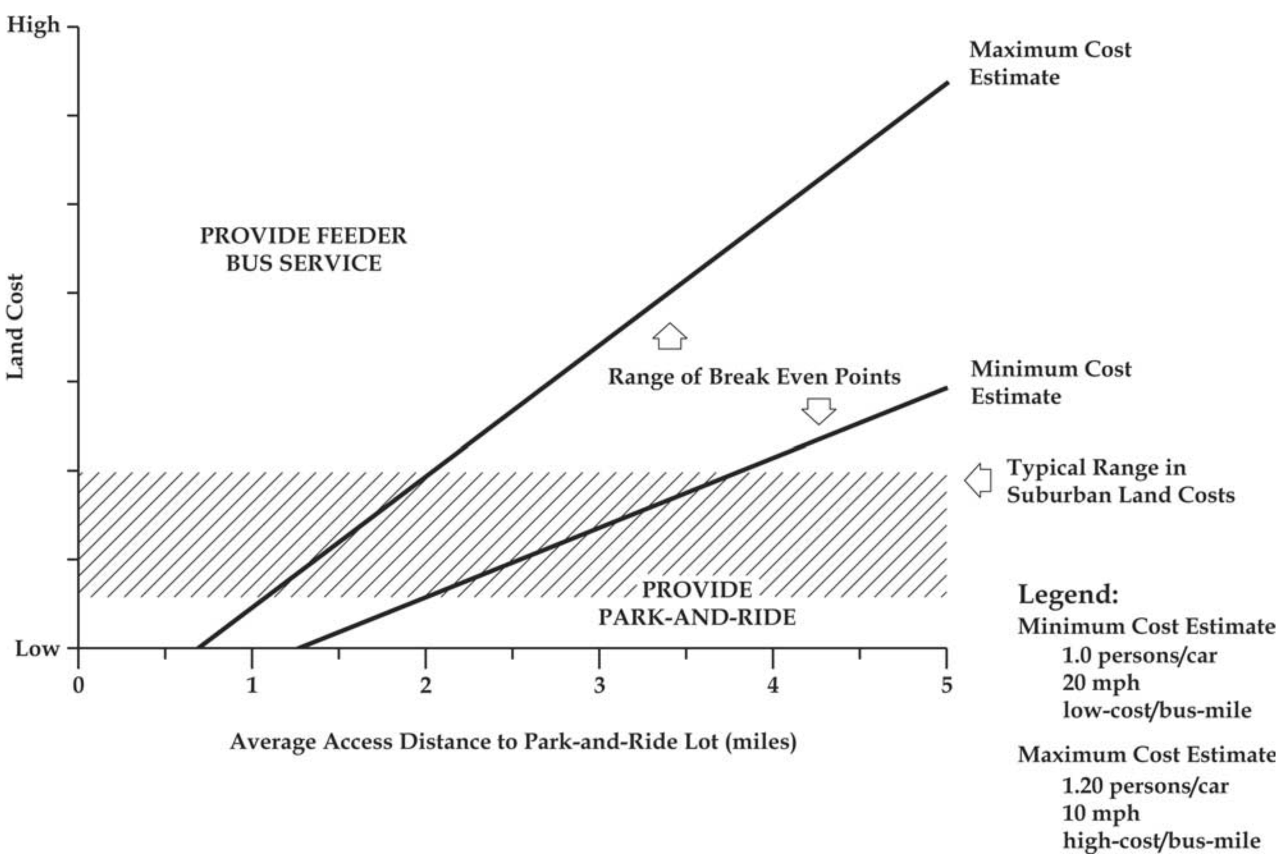
Park-and-Ride Cost-Benefit Findings

From the perspective of regional costs and benefits, the capital cost of park-and-ride/pool facilities will almost always be less, because of lower land costs, than the comparable cost of building parking in city centers (Victoria Transport Policy Institute, 2003). The middle to upper income characteristics of most surveyed park-and-ride lot users suggest that direct benefits accrue mainly to those groups and not much to lower income populations. Indirect benefits should accrue to all groups, however, to the extent that traffic is reduced and trunk line transit service is maintained or enhanced to handle park-and-ride patrons. Providing park-and-ride facilities in lieu of local outlying area service may hurt transit dependent persons, however, particularly if lower-income jobs are left unreachable by transit.

A 1985 study conducted by the Maryland State Highway Administration examined the costs and benefits associated with 45 park-and-ride/pool lots in the state, comparing capital cost expenses with the estimated gasoline and automobile maintenance costs saved by the carpooling focused on the lots. At the time of the study, most lots had a rural focus. Three different cost-benefit methodologies were used in this assessment, all assuming a 1983-85 construction cost of $1,779 per space. Two were rate of return analyses, and these indicated annual rates of return of 26 to 32 percent over 20 years. The third approach examined the value of future benefits accruing to users of new lots over the same period. The results from this analysis identified that every dollar spent on park-and-pool lots would yield an estimated $2.68 in benefits over 20 years (Maryland State Highway Administration, 1985).

A contemporary analysis of park-and-ride in metropolitan Seattle utilized methodologies designed to explore cost-effectiveness and cost-benefit on a somewhat broader scale. Its evaluation took into account not only the user and public agencies responsible for transportation, but also the community at large.

Figure 3-4 Economic comparison of feeder service versus construction of park-and-ride lots



Source: Levinson et al. (1973).

The study started with a survey of users of the 26 permanent lots existing circa 1985. A 39 percent survey return rate was achieved. The north and southeast corridors were chosen as being together representative of the overall system, and a detailed examination was conducted of before-and-after travel by the park-and-ride lot users in those corridors. Taken into account were time costs in-and-out-of-vehicle; public costs including roadway provision and maintenance, congestion impacts, related services such as planning and police, and environmental costs; automobile ownership and operating costs; provision of park-and-ride parking and fees for destination parking; and non-farebox transit provision costs plus fare.

The results indicated that VMT, traffic volumes, accidents, vehicle emissions, and energy consumption were all reduced by the Seattle area park-and-ride system. A negative impact was found on user person-miles of travel and travel time. The average trip using the park-and-ride system was estimated to be 11.6 percent less expensive than the average cost of the corresponding pre-existing trip. A sensitivity analysis of assumptions made produced 24 alternative sets of calculations, half of which did not include highway capital costs. The average park-and-ride trip was estimated to incur less cost in 15 of these 24 computations, while in 3 of the computations the cost of the park-and-ride trip equaled that of the prior mode trip. When two extreme case sets of assumptions were applied, the assumptions least favorable to park-and-ride indicated the park-and-ride trip to be 7.8 percent more expensive ($9.16 versus $8.50), while the most favorable assumptions indicated the park-and-ride trip was 25.6 percent less expensive ($9.17 versus $12.33) (Rutherford and Wellander, 1986).

In addition to information about economic effects on transit and park-and-ride agencies, some data is available on the influence of shopping center shared-use park-and-ride lots on retail business activity in the center. Surveys of users of three park-and-ride lots located at shopping centers in Montgomery County, Maryland, explored this question. Between 25 and 44 percent of the survey respondents indicated they shopped at the center the previous day. Average daily shopping expenditures ranged from $19 to $53. Of those surveyed, 68 percent reported using the lots five days a week. Most parked and rode the bus, while some used the lots to form carpools (Smith, 1983).

Indicators of Success

Park-and-ride is a travel option focused mainly on work purpose trips oriented to the downtown areas of cities, predominantly major cities. From the synthesis and analysis of this chapter, most particularly the “Access Travel Distance and Facility Location,” “Travel Time and Transit Level of Service,” and “User Costs and Willingness to Pay” discussions in the “Underlying Traveler Response Factors” section, the following key indicators of likely park-and-ride success may be drawn. Although lack of one or more of these indicators should not be taken as a certain predictor of failure, the more indicators that are present, the better the performance of a park-and-ride facility is likely to be.

- Facility operation in conjunction with direct transit service to a major workplace attraction, preferably the CBD.
- Availability of express transit service or transit service with priority.
- Provision of frequent transit service, preferably at 15-minute or closer intervals during the peak period (less critical for commuter rail services).

- Location in corridors with highway congestion, preferably with facility siting in advance of the congestion.
- Facility siting that affords quick and easy highway access, preferably within 1/2 mile or so of the direct auto travel route and with good visibility.
- Facility siting closer to midway between the urban fringe and the CBD than to either extreme.
- Existence of significant parking costs and/or scarcity of parking in the CBD or other major attraction served.
- Parking in the facility that is free or substantially discounted relative to prevailing CBD parking rates.
- Absence of unmitigated security problems, real or perceived.

Park-and-pool tends to serve a more diverse array of workplace destinations than park-and-ride. Facility location tends more toward the urban fringe and presence of transit service is, of course, not a requisite. Commuter trip distance is especially important to successful park-and-pool, with destinations over 15 miles or so of the facility being of primary interest.

In June of 2003, the Urban Transportation Monitor conducted a self-administered survey of transit agencies designed to obtain information on what each individual agency selected as its most successful park-and-ride lot based on the number of cars parked. A total of 110 agencies were contacted and 24 responded. An abridged tabulation of the characteristics submitted describing these 24 "most successful" park-and-ride lots is provided in Table 3-23 (Rathbone, 2003; Urban Transportation Monitor, 2003b). Among many items of interest in this tabulation is the strong association of small scale park-and-ride lot usage with urban areas small to medium in size.

ADDITIONAL RESOURCES

The report, *Park-and-Ride Facilities—Guidelines for Planning, Design, and Operation*, published by the Federal Highway Administration, presents a compilation of available information on park-and-ride lots and usage (Bowler et al., 1986). *NCHRP Synthesis 213*, "Effective Use of Park-and-Ride Facilities," provides an overview of park-and-ride, including information on conceptual issues, facility location factors, demand estimation procedures, design considerations, administration and operation, and supporting elements (Turnbull, 1995). The on-line *TDM Encyclopedia* places park-and-ride in an overall Travel Demand Management context while providing a concise summary of impacts and issues, with references for more information, that is updated periodically (Victoria Transport Policy Institute, 2003).

CASE STUDIES

Park-and-Ride/Park-and-Pool in the Washington, DC, Metropolitan Area

Situation. The Metropolitan Washington region encompasses the District of Columbia, Northern Virginia, and south-central Maryland. The area grew from 3 million population to almost 5 million between 1970 and 2000. Traffic congestion is a major problem for the region. Travel is oriented toward the District and to major suburban employment and activity centers.

Actions. A multimodal approach has been taken to address transportation in the Washington, DC, region. New and expanded highways, HOV lanes, the Metrorail system, commuter rail, bus services, and vanpools/carpools are all part of the mix. Park-and-ride and park-and-pool facilities are a major systems component. The first major park-and-ride lot was opened in 1955 at the Carter Barron Amphitheater north of the downtown area. Between 1969 and 1971, four park-and-ride lots were opened at suburban shopping centers with express bus service to downtown Washington, DC, as part of the Capital Flyer demonstration project. The Shirley Highway Express-Bus-on-Freeway demonstration from 1971 to 1974 included the development of three park-and-ride lots associated with the HOV lane and expanded express bus services. Over time, park-and-ride/pool lots oriented toward express buses and vanpool/carpool formation were opened in additional suburban areas of Virginia and Maryland. By 1977, there were 26 such official lots and by 1995 — over a much broader area — there were 165, not counting informal facilities.

Table 3-23 Characteristics of the "Most Successful" Park-and-Ride (P&R) Lot at Each of 24 Transit Agencies

			Distance (miles) from			Transit Service					
Urban Area	System	Facility	CBD	Urban Edge	High-way	Mode [a]	Frequen-cy [b]	Park-and-Ride Lot Amenities [c]	Lot Capa-city – Spaces	Week-day Occu-pancy	Other Corridor P&R Parking [d]
Austin, TX	Capital Metro	Northwest	25	7	0.5	Freeway bus	10	S, L, K	135	135+	250
Columbus, GA	METRA	River Center	0 [e]	15-25	5-7	Arterial bus	45	C, L, G	685	475±	0
Corpus Christi, TX	Corpus Christi RTA	Calallen	14	1	0.2	Freeway bus	One trip	C	100	12	0
Dallas, TX	DART	Mockingbird	3	25	0.3	LRT, art. bus	5	S, L, K, B	750	750	3,000
Dayton, OH	Greater Dayton RTA	South Hub	12	2	0.1	Arterial bus, freeway bus	10-20	S, L, G, R, K, B	150	75	0
Hampton, VA	Hampton Roads Transit	Silverleaf	15	0	0.5	Freeway HOV lane bus	15	S, L, R, K, B	225	150	0
Houston, TX	METRO	Northwest	19	n/a	0.3	Freeway HOV lane bus	4-5	S, L, G, K, B	2,631	2,034	2,625
Miami, FL	Miami-Dade, Tri-Rail	Golden Glades	12	4	0.1	CRR, fwy. HOV lane & art. bus	5	S, L, G, K	n/a	750	No
Milwaukee, WI	MCTS	College Ave.	8	0	0	Freeway bus	15	S, L, K, B	651	352	204
Tacoma, WA	Pierce Transit Sound Transit	Tacoma Dome	<1 [f]	15	0.3	CRR, fwy. HOV bus, other bus	<3	S, C, L, G, R, K, B	2,400	1,600	5,000
Nashville, TN	MTA	Bellevue	14	0	0	Art. & fwy. bus	20	S, L, B	65	25	30
Oakland, CA	BARTD	Hercules	25	8	0.1	Fwy. HOV lane bus, fwy. bus	15	S, L, B	276	476±	100
Orlando, FL	Expressway Authority	Beeline at Narcossee	10	2	0	(None – lot is park-and-pool)	Not ap-plicable	L	15	22	0
Philadelphia, PA	SEPTA	Cornwells Heights	14	6	0.2	CRR	15	S, L, G, R	1,600	725	922
Pittsburgh, PA	Port Auth. of Allegheny Co	South Hills Village	11	15	3	LRT	6	S, L, G, K, B	1,000	1,000	2,200

Table 3-23 Characteristics of the "Most Successful" Park-and-Ride (P&R) Lot at Each of 24 Transit Agencies (continued)

			Distance (miles) from			Transit Service					
Urban Area	System	Facility	CBD	Urban Edge	High-way	Mode [a]	Frequen-cy [b]	Park-and-Ride Lot Amenities [c]	Lot Capa-city – Spaces	Week-day Occu-pancy	Other Corridor P&R Parking [d]
San Diego, CA	M. T. D. B.	Old Town Transit Ctr.	5	30+	<1	CRR, LRT, art. lane & fwy. bus	10	S, L, G, R, B	550	550	200
Salt Lake City, UT	Utah Transit Authority	Sandy Civic Center	15	10-50	1	LRT, freeway bus	LRT 5-10 bus 15	S, L, K, B	1,186	693	2,840
Seattle, WA	King County Metro Transit	Federal Way	22	12	0	Fwy. HOV bus, art. & fwy. bus	5	S, L, G, B	894	929	2,570
Vancouver, WA	C-TRAN	Fisher's Landing	9	2-3	0	Freeway bus	15	S, L, R, K, B	600	540	0
Ottawa, Ontario	OC Transpo	Eagleson	14	14	1	Busway bus on arterial bus lane	5	S, L, G, B	807	880	3,245
Calgary, Alberta	Calgary Transit	Brentwood	4	6	0	LRT	5	S, L, K, B	1,254	1,254	530
Montreal, Quebec	Agence Met. de Transport	Brossard-Panama	10	0	0.3	Fwy. HOV, art. lane & art. bus	8	S, L, K, B	1,181	1,181	2,000
Winnipeg, Manitoba	Winnipeg Transit	Kildonan Pl. Shop. Ctr.	5	7	1	Bus on art. bus lane, art. bus	7	S, L, G, K, B	50	50	n/a
Wellington, New Zealand	W. Regional Council	Waterloo Int. Lower Hutt	10	0	2	CRR, arterial & freeway bus	10	S, L, R, K, B	600	600	500

Notes: [a] CRR = commuter rail, LRT = Light Rail Transit. [b] Peak period "frequency of transit" serving park-and-ride lot *in minutes*.

[c] S = shelter, C = covered parking, L = lighting, G = security guard, R = Restrooms, K = kiss-and-ride spaces, B = bicycle racks.

[d] Total number of cars parked at other park-and-ride lots in the same corridor ("0" = no other lots in the corridor).

[e] This peripheral parking facility (see Chapter 18, "Parking Management and Supply" — "Response by Type of Strategy" — "Peripheral Parking Around Central Business Districts") is the only one of the 24 "lots" reported to have a parking fee ($1.00).

[f] Although peripheral parking in part, this facility also serves the 30-mile Tacoma to Seattle commuter rail and bus corridor.

Source: Adapted and condensed from "This Week's Survey Results" tabulation, Urban Transportation Monitor (2003b).

The first park-and-ride lot associated with the Washington Metrorail system opened in 1976, at the Rhode Island Avenue station. Park-and-ride has continued to be developed as part of Metrorail expansion, with 39 facilities in operation in 1995. Most are surface lots, but large multi-story parking garages are located at several stations. Parking fees of $1 to $5 a day are charged at facilities oriented toward Metrorail, most but not all of which are operated by the Washington Metropolitan Area Transit Authority (WMATA). In 1998, WMATA started a *Guaranteed Parking* program, which provides a reserved space for an extra fee, described under "Related Information and Impacts" — "Parking Pricing at Park-and-Ride Facilities."

Park-and-ride facilities are also associated with the two commuter rail services in the region. In 1995, 26 lots were in operation along Maryland's MARC Penn, Brunswick, and Camden Lines. Virginia Rail Express (VRE) initiated service between Fredericksburg and Manassas, Virginia, and Washington Union Station in 1992. By 1995, there were 13 lots in operation along the two VRE lines. Parking fees were imposed for non-residents or for all users at many of the VRE lots (mostly removed since 1995).

Analysis. Periodic inventories of the official park-and-ride/pool facilities in the region have been conducted since the first survey was completed by WMATA in 1973. Updates were conducted by the Metropolitan Washington Council of Governments (MWCOG) in 1977, 1980, 1983, 1989, and 1995. As of 2003, the 1995 inventory is the latest regional survey of facility usage. Information on parking supply and occupancy levels from these inventories, as well as the results from other related surveys and studies, are presented here. Except where noted, the analyses cover only formal facilities officially designated by an agency or governmental unit, not informal lots.

It is important to note also that the study area was expanded several times, to include additional counties in Maryland, Virginia, and ultimately West Virginia. In 1973, the study area was the "WMATA Compact" area (the District of Columbia, northern Virginia as far out as and including Fairfax County, and Montgomery and Prince George's Counties in Maryland). Between 1973 and 1977, Prince William County, Virginia, was added. Then a major expansion took place between 1983 and 1989, out toward a new MWCOG boundary, but still not including Loudoun County, Virginia. Between 1989 and 1995, Loudoun County was added in along with four farther-out Maryland and Virginia counties, extending even into the outer Baltimore commutershed. These expansions affect both the commuter rail and bus/carpool park-and-ride statistics. The discussion and table that follow present 1989 and 1995 figures for both the 1977-1983 area ("WMATA Compact" area plus Prince William County, Virginia) and the further expanded areas.

Results. The numbers of park-and-ride/pool lots and available spaces, and utilization levels for Metrorail, commuter rail, and bus/rideshare facilities in the Washington, DC, region are summarized in Table 3-24. Not included are the results for 1973, when in 22 park-and-ride lots approximately 3,000 cars were counted parked in about 6,000 spaces, for roughly a 50 percent utilization rate. Since then through 1995, the number of park-and-ride/pool facilities in the expanding region has grown almost eleven fold, the number of spaces has grown by thirteen times, and the count of vehicles parked is up almost twenty fold. During the 1977-1995 period, some 30 lots (24 bus/rideshare, 3 commuter rail, and 3 Metrorail) were discontinued, replaced and added to by newer facilities. In terms of a constant sized study area, the "WMATA Compact" area plus Prince William County, the 1977-1995 annual growth rates have been 10 percent compounded for numbers of facilities, 12 percent compounded for numbers of spaces, and over 13 percent compounded annually for numbers of vehicles left in a park-and-ride/pool facility on the typical weekday. The greater growth in parking than in spaces has produced a climb in the overall average occupancy rate from 61 to 76 percent.

Table 3-24 Park-and-Ride/Pool Facility Supply and Utilization in the Washington, DC, Region

Mode/Year	Number of Facilities	Number of Spaces	Number of Parked Vehicles	Percent Utilization
Metrorail [a]				
1977	2	1,509	1,098	73%
1980	13	7,744	6,514	84%
1983	24	11,090	8,461	76%
1989	33	26,281	23,956	91%
1995	39	38,137	34,195	90%
Commuter Rail				
1977-80	n/a	n/a	n/a	n/a
1983 [a]	19	1,610	1,296	80%
1989 [a]	14 [b]	1,842	1,328	72%
1995 [a]	25	6,184	3,838	62%
1989 [c]	21	3,636	3,289	90%
1995 [c]	39	9,823	7,561	77%
Bus/Carpool				
1977 [a]	24	6,650	3,857	58%
1980 [a]	30	8,471	4,926	58%
1983 [a]	43	10,885	5,487	50%
1989 [a]	56	12,955	7,190	55%
1995 [a]	81	18,104	9,617	53%
1989 [c]	98	23,281	13,015	56%
1995 [c]	165	31,075	17,502	56%
Total				
1977 [a, d]	26	8,159	4,955	61%
1980 [a, d]	43	16,215	11,440	71%
1983 [a]	86	23,585	15,244	65%
1989 [a]	103	41,078	32,474	79%
1995 [a]	145	62,425	47,650	76%
1989 [c]	152	53,198	40,260	76%
1995 [c]	241	79,035	59,258	75%

Notes: [a] "WMATA Compact" area ("The 10-Mile Square" plus Fairfax County, VA, Montgomery County, MD, and Prince George's County, MD) and Prince William County, VA.

[b] Three lots shifted in jurisdiction from MARC commuter rail to Metrorail.

[c] Expanded Washington Metropolitan Area (shaded rows). Note that Loudoun County, VA, plus 4 farther-out Maryland and Virginia counties are included in 1995 only.

[d] Totals do not include commuter rail.

There were, in 1995, 66 percent more facilities in the expanded region than in the constant sized 1977-1983 study area, along with 27 percent more park-and-ride/pool spaces and 24 percent more parked vehicles. Of the 59,258 parked vehicles in 1995, 34,195 were oriented to Metrorail (58 percent), 7,561 were at commuter rail stations (13 percent), and 17,502 were at express bus or rideshare lots (30 percent). MWCOG estimates, based on an assumption of 1.1 persons per vehicle, that some 65,200 commuters use official park-and-ride facilities on any given day. Utilization levels differ by mode. They are highest for Metrorail and next highest for commuter rail. Even within modes, utilization varies widely by facility.

The growth in number of Metrorail park-and-ride facilities, spaces, and use has been steadily upward since the system's 1976 opening — as shown in Table 3-24. By 1995, Metrorail operations and parking had expanded to the extent that 39 park-and-ride facilities were located at or near 31 of 74 Metrorail stations, accounting for 38,137 spaces. Although the overall 1995 utilization level was 90 percent, 29 facilities were at capacity, usually by 8:30 AM. Five of the seven WMATA-operated facilities with available capacity were relatively new in 1995. The parking fees charged at all but one facility do not seem to have much deterred heavy use, given the pent-up demand.

The provision of park-and-ride facilities for commuter rail and their use reflect major improvements to Maryland services starting in the 1970s, and initiation of the Virginia Railway Express (VRE) system in 1992. In 1995, the 26 MARC lots in Maryland and West Virginia accounted for some 5,922 parking spaces and 5,150 parked vehicles, for an overall occupancy level of 87 percent. Fourteen of these lots were over capacity, however, while five were less than 50 percent full. The greater demand, in terms of both absolute numbers and percent utilization, is in the outer counties. VRE had 13 lots, with 3,901 spaces, and an overall occupancy of 62 percent in 1995. One lot was over capacity, while six were at or below 50 percent. Parking fees of $1.00 to $1.25, since removed, were charged at eight lots.

Overall utilization levels at facilities associated with express bus services and ridesharing have remained relatively constant over the 1977-1995 time period, averaging between 50 and 58 percent for the region. There is a great variation in use among these lots, however, with some over capacity and some less than 25 percent occupied. For the most part, the more heavily utilized lots appear to be those with good levels of bus service and/or linkage with the HOV facilities in the region.

Besides providing locations for commuters to easily access express bus services, the various park-and-ride/pool lots also serve as convenient places for the formation of vanpools and carpools. A 1989 survey of vanpool operators conducted by MWCOG found that 98 percent of the 1,100 vanpools in the region form at meeting places other than home.

In addition to the formal park-and-ride/pool facilities, commuters in the Shirley Highway HOV corridor form informal or "instant" carpools at a number of retail/commercial parking lots. Commuters park in these lots and wait in customary pickup areas for rides to different destinations. It appears that the presence of transit service is important to the success of the phenomenon, both in case a ride is not found for the inbound trip in the morning, and the same for the return trip in the evening. MWCOG estimates that there are some 2,600 instant carpoolers in the Shirley Highway corridor on a daily basis.

More… The MWCOG studies of park-and-ride and park-and-pool facility usage in the Washington, DC, region note that many facilities are full beyond capacity, while some are virtually empty. The study authors observe that a uniform regional development policy supported by accurate forecasting procedures would be helpful. The studies also raise concerns about the feasibility of developing affordable park-and-ride capacity sufficient to satisfy projected Metrorail parking demand, and conclude that improvements to transit accessibility should encompass a variety of modal options including feeder bus services, walking and bicycling.

Sources. Metropolitan Washington Council of Governments, "Washington Regional Park-and-Ride 1989 Inventory and Analysis." Washington, DC (1990). • Metropolitan Washington Council of Governments, "Washington Regional Park-and-Ride 1995 Inventory and Analysis." Washington, DC (1996).

HOV Lane Park-and-Ride/Pool Facilities in the Houston Area

Situation. The Houston metropolitan area has a population of approximately 3 million people. The area is characterized by low density development typical of most southwestern cities. In response to significant traffic congestion on the freeway system, limited available right-of-way, and air quality concerns, a system of HOV lanes, extensive park-and-ride and park-and-pool lots, and transit services is in operation. These facilities provide preferential treatment to buses, vanpools, and carpools.

Actions. The park-and-ride/pool facilities represent a significant part of the multifaceted approach being taken in the area to manage traffic congestion and improve mobility. These lots are associated with the approximately 64 operational miles of a planned 110 mile system of exclusive HOV lanes in operation in five freeway corridors, and an HOV lane under construction on a sixth freeway. A total of 25 park-and-ride lots and 3 park-and-pool lots are located in these six corridors. The larger park-and-ride lots have direct access to the HOV lanes and many have passenger amenities. Fifteen of the lots contain spaces for between just under 900 to 2,246 automobiles. The Kuykendahl facility on I-45N is the largest, with the 2,246 parking spaces and a two level transit station. The number of parking spaces at lots in each corridor range from slightly over 3,000 to almost 7,500.

Analysis. Information from the ongoing monitoring of the park-and-ride and park-and-pool lots in Houston is presented in this case study. The number of lots, spaces, and parked vehicles is examined from 1980 to 1998. Most of these facilities are located in corridors with HOV lanes, but lots are also found along non-HOV freeways and in other parts of the region. The results of surveys of park-and-ride lot users are also examined.

Results. Table 3-25 illustrates the growth in spaces available at park-and-ride facilities in Houston and in their use over time. The data allow usage to be examined in context with parking capacity and HOV lane openings (indicated with an asterisk). Note, for example, the sharp jump in Katy and Northwest Freeway park-and-ride lot occupancies following the introduction of HOV lanes on those particular facilities. In 1980, there were 10 park-and-ride lots with 6,414 spaces and in 1998 there were 25 lots with 28,507 spaces. Parking totals have more than tripled over this 18-year period, from 4,070 in 1980 to 13,781 in 1998. The 3 park-and-pool lots along the Katy Freeway, which lack direct access to the HOV lane, are less well utilized. Moreover, their usage has grown only marginally, from 84 daily parked cars in 1986 to 184 in 1998. In 1998, the overall occupancy levels at the individual facilities ranged from about 16 percent at the park-and-pool lots to 100 percent at well used park-and-ride lots.

Corridor average utilization ranged from 34 percent in the Southwest to 56 percent in the Gulf corridor.

Table 3-25 Houston HOV Lane Park-and-Ride/Pool Facility Supply and Utilization

HOV Lane	Year									
	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998
North (I-45N)										
Park-and-Ride Lots	3*	3	4	5	5	5	5	5	5	5
Spaces	2,341	3,341	4,621	7,416	7,416	7,416	7,806	7,386	7,386	7,386
Occupancy	1,700	2,874	3,738	4,569	4,734	4,301	4,008	3,740	3,447	3,643
Percent Occupancy	73%	86%	81%	61%	64%	58%	51%	51%	47%	49%
Katy (I-10W)										
Park-and-Ride Lots	1	2	2*	3	3	3	3	3	3	3
Spaces	1,269	2,769	2,769	4,145	4,145	4,145	4,145	4,082	4,082	4,525
Occupancy	59	418	601	1,145	1,702	2,090	2,161	2,127	2,035	2,764
Percent Occupancy	5%	15%	22%	28%	41%	50%	52%	52%	50%	61%
Park-and-Pool Lots	—	—	—	3	3	3	3	3	3	3
Spaces	—	—	—	1,169	1,169	1,169	1,169	1,169	1,169	1,169
Occupancy	—	—	—	84	184	126	131	133	162	184
Percent Occupancy				7%	16%	11%	11%	11%	14%	16%
Total Spaces	1,269	2,769	2,769	5,314	5,314	5,314	5,314	5,251	5,251	5,694
Total Occupancy	59	418	601	1,229	1,886	2,216	2,292	2,260	2,197	2,948
Total Percent Occupancy	5%	15%	22%	23%	35%	42%	43%	43%	42%	52%
Northwest (US 290)										
Park-and-Ride Lots	—	—	1	1	2*	3	3	3	3	3
Spaces	—	—	1,222	1,222	2,487	3,407	3,407	3,437	3,594	3,852
Occupancy	—	—	265	416	625	1,477	1,652	1,710	1,666	2,069
Percent Occupancy	—	—	22%	34%	25%	43%	48%	48%	46%	54%
Gulf (I-45S)										
Park-and-Ride Lots	1	2	2	2	2*	2	2	2	3	3
Spaces	550	2,265	2,265	2,265	2,265	2,265	2,265	2,164	3,018	3,018
Occupancy	440	824	1,077	1,257	1,225	1,380	1,339	1,273	1,429	1,694
Percent Occupancy	80%	36%	48%	55%	54%	61%	58%	59%	47%	56%
Southwest (US 59)										
Park-and-Ride Lots	4	5	5	5	5	5	5	7*	8	8
Spaces	2,054	2,679	2,679	2,679	2,679	3,779	3,989	6,887	7,308	7,308
Occupancy	1,527	1,661	1,715	1,857	1,814	2,114	1,703	1,841	2,016	2,481
Percent Occupancy	74%	62%	64%	69%	67%	56%	43%	27%	28%	34%
Eastex (US 59N) (Non-HOV Freeway)										
Park-and-Ride Lots	1	1	2	2	2	2	3	3	3	3
Spaces	200	940	1,870	1,870	1,870	1,870	2,418	2,418	2,418	2,418
Occupancy	344	546	722	986	1,110	1,264	1,472	1,115	1,015	1,130
Percent Occupancy	172%	58%	39%	52%	59%	67%	61%	46%	42%	47%

Table 3-25 Houston HOV Lane Park-and-Ride/Pool Facility Supply and Utilization (continued)

HOV Lane	Year									
	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998
TOTALS										
Park-and-Ride Lots	10	13	16	18	19	20	21	23	25	25
Spaces	6,414	11,994	15,426	19,397	20,862	22,882	24,030	26,374	27,806	28,507
Occupancy	4,070	6,233	8,118	10,230	11,210	12,626	12,335	11,806	11,608	13,781
Percent Occupancy	63%	52%	53%	52%	54%	55%	51%	45%	42%	48%
Park-and-Pool Lots	—	—	—	3	3	3	3	3	3	3
Spaces	—	—	—	1,169	1,169	1,169	1,169	1,169	1,169	1,169
Occupancy				84	184	126	131	133	162	184
Percent Occupancy	—	—	—	7%	16%	11%	11%	11%	14%	16%
Total Park-and-Ride/Park-and-Pool Lots	10	13	16	21	22	23	24	26	28	28
Spaces	6,414	11,994	15,426	20,766	22,031	24,051	25,199	27,543	28,975	29,676
Occupancy	4,070	6,233	8,118	10,314	11,394	12,752	12,466	11,939	11,770	13,965
Percent Occupancy	63%	52%	53%	50%	52%	53%	49%	43%	41%	47%

Note: In the "Park-and-Ride Lots" tabulations for individual freeways, an asterisk (*) indicates — for each freeway with an HOV lane — the first year of first phase HOV operation.

Sources: Stockton et al. (1997), Texas Transportation Institute (1998).

The well used lots tend to be those with high frequency bus service and direct access to the HOV lanes. For example, peak hour buses operate out of the Kuykendahl facility at 5 minute intervals. The less well used lots are those in corridors with newer HOV lanes (Southwest), those where the lanes are still being extended (Gulf), and the three park-and-pool lots without direct connections to the Katy HOV lane.

More… The Houston park-and-pool lots and HOV lanes have worked together to influence commuters to change from driving alone to taking a high-occupancy mode. Surveys indicate that between 38 and 46 percent of park-and-ride bus passengers formerly drove alone. Surveys conducted of park-and-ride lots users in the early 1980s, when all facilities then in place were relatively new, indicated that almost half previously drove alone.

The HOV lanes appear to be important factors in the decision to change modes. For example, in surveys conducted in 1988, 1989, and 1990, between 54 and 76 percent of the bus riders using the Houston lanes responded that the opening of the HOV lanes was very important in their decision to ride a bus. Further, between 22 and 39 percent of the respondents in those surveys indicated that they would not be riding the bus if the HOV lane had not been opened. For more extensive decision of the Houston HOV lanes see Chapter 2, "HOV Facilities," including the "Houston HOV System" case study.

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Park-and-Ride and Park-and-Pool Facilities in King County, Washington

Situation. The Puget Sound region in the Pacific Northwest has experienced significant growth over the past 30 years. The city of Seattle and King County represent the focal point for much of this growth. In 1995, the population of the county was approximately 1.6 million. Traffic congestion is a major concern in the region, and a number of approaches have been taken to address these problems.

Actions. The development of an extensive system of park-and-ride lots, along with bus services and HOV facilities, represents an important element of the overall transportation system enhancement in the area. The first park-and-ride lot in Seattle was opened in 1970 by Seattle Transit. An extensive system of permanent and leased lots has been developed since then through the joint efforts of the Municipality of Metropolitan Seattle, now King County METRO, and the Washington State Department of Transportation (WSDOT). Table 3-26 details the growth in permanent and leased lots in King County from a total of 22 lots in 1980 to 126 in 1998. The capacity of the permanent lots ranges from 46 parking spaces to 894 spaces. Church parking lots comprise most of the leased facilities, with a few located at shopping centers and other activity generators. Many but not all of the lots serve corridors featuring HOV lanes or other priority treatments.

Analysis. Information from the ongoing monitoring of the park-and-ride facilities in King County is presented in this case study. The results of surveys of lot use and studies conducted by other groups are also examined.

Results. Table 3-26, in addition to the numbers of park-and-ride lots and parking spaces in King County, includes 1980 to 1998 utilization levels. The number of permanent lots increased from 14 to 50 and the number of leased lots grew from 8 to 76 over this period, accounting for the total increase from 22 to 126 lots. The number of available parking spaces at all lots increased from 6,328 in 1980 to 17,886 in 1998. King County park-and-ride lot usage levels more than doubled over the 18-year period, increasing from 5,629 to 13,543.

The major increases in King County lots and spaces occurred during the 1980s. Utilization levels at the permanent facilities have been higher over the years than at the leased lots. The overall occupancy rates at the permanent facilities have ranged between 71 percent and 89 percent, with some individual lots at capacity. Occupancy levels at the leased lots have, since 1990, averaged around 45 percent overall.

More… The highest rates of growth in park-and-ride spaces are now found in the surrounding counties rather than in King County itself. Table 3-27 illustrates this with 1995 to 2001 percentage growth statistics for major facilities in King and surrounding counties of central Puget Sound. Increases in capacity reduced outlying county utilization rates during the period.

Table 3-26 King County Park-and-Ride Capacity and Utilization, 1980-1998

Year	1980	1985	1990	1995	1998		1980	1985	1990	1995	1998
North District						**South District**					
Permanent Park-and-Ride Lots	3	14	10	12	12		6	9	18	17	20[a]
Spaces	1,110	4,682	2,890	3,630	3,591		2,683	3,982	5,407	5,713	5,956
Occupancy	1,110	3,677	2,099	2,632	2,745		2,073	2,654	3,852	3,895	4,862
Percent Occupancy	100%	78%	73%	73%	76%		77%	67%	71%	68%	82%
Leased Park-and-Ride Lots	1	14	7	10	14		4	18	17	22	37
Spaces	73	459	234	312	524		396	737	525	836	1,580
Occupancy	77	241	150	141	280		288	313	218	385	692
Percent Occupancy	105%	52%	64%	45%	53%		73%	42%	42%	45%	44%
Subtotal Lots	4	28	17	22	26		10	27	35	39	57
Subtotal Spaces	1,183	5,141	3,124	3,942	4,115		3,079	4,719	5,932	6,549	7,536
Subtotal Occupancy	1,187	3,918	2,249	2,773	3,025		2,361	2,967	4,070	4,280	5,554
Percent Occupancy	101%	76%	72%	70%	74%		77%	63%	69%	65%	74%
East District						**Total All Districts**					
Permanent Park-and-Ride Lots	5	14	18	18	18		14	37	46	47	50
Spaces	1,897	4,002	5,157	5,301	5,330		5,690	12,666	13,454	14,644	14,877
Occupancy	1,895	2,711	3,776	3,920	4,577		5,078	9,042	9,727	10,447	12,184
Percent Occupancy	100%	68%	73%	74%	86%		89%	71%	73%	71%	82%
Leased Park-and-Ride Lots	3	15	13	18	25		8	47	37	50	76
Spaces	169	749	546	584	905		638	1,945	1,305	1,732	3,009
Occupancy	186	270	214	211	387		551	824	582	785	1,359
Percent Occupancy	110%	36%	39%	36%	43%		86%	42%	45%	45%	45%
Subtotal/Total Lots	8	29	31	36	43		22	84	83	97	126
Subtotal/Total Spaces	2,066	4,751	5,703	5,885	6,235		6,328	14,611	14,759	16,865	17,886
Subtotal/Total Occupancy	2,081	2,981	3,990	4,131	4,964		5,629	9,866	10,309	11,195	13,543
Percent Occupancy	101%	62%	70%	70%	80%		89%	67%	69%	66%	76%

Notes: [a] One lot closed for two years.

Source: Municipality of Metropolitan Seattle (1998).

Table 3-27 Central Puget Sound Park-and-Ride Facility Supply and Utilization Rates Expressed in Percentage Changes for Major Facilities, 1995-2001

Area	Capacity Change	Utilization Rate Change
Northwest King County	14.2%	15.1%
East King County	-5.7	21.1
South King County	5.8	3.5
Snohomish Co. (north of King Co.)	43.4	-1.2
Pierce County (south of King Co.)	271.7	-19.4
Kitsap County (west of King Co.)	19.1	-52.7
Central Puget Sound Region Overall	25.6%	2.8%

Note: The 2001 park-and-ride lot capacities in Northwest and East King County were affected by temporary lot closures.

Source: Puget Sound Regional Council (2002).

Sources: Rutherford, G. S., and Wellander, C. A., "Cost-Effectiveness of Park-and-Ride Lots in the Seattle Metropolitan Area." *Transportation Research Record 1081* (1986). • Municipality of Metropolitan Seattle, "4th Quarter Park-and-Ride Utilization Reports." Seattle, WA (1998). • Puget Sound Regional Council, "Regional View." Newsletter. Seattle, WA (April, 2002).

A Park-and-Ride Lot Implementation in Metropolitan Portland, Oregon

Situation. Tri-Met Route 96 is an express bus commuter service into downtown Portland, Oregon, that in 1988 was operating with four small park-and-ride lots along the local pickup portion of the route. Local operation extended from outlying Wilsonville in through the suburban community of Tualatin, after which point Route 96 entered the I-5 freeway for its 20 minute non-stop trip into Portland, running in mixed traffic. The innermost park-and-ride lot was an 80 space facility in the city of Tualatin.

Actions. Tri-Met opened a new 204 space park-and-ride lot served by Route 96 on September 19, 1988. Located at the point where Route 96 entered the I-5 freeway for its express run into downtown Portland, the lot with its covered waiting area is intended to serve residents of the adjacent suburban community of Tualatin. It in effect replaced the 80 space park-and-ride lot in the center of Tualatin. Also, on September 6, three inbound and two outbound trips were added to the Route 96 schedule.

Both the new park-and-ride lot itself and Route 96 were given extensive promotion. The bus route had not previously been promoted as an express service, and this feature was now emphasized. Promotions included large informational signs placed at the new lot a month in advance; notices posted at the old lot; posters promoting the Route 96 service sent to all downtown Portland employers of 50 or more employees; on-site promotions of reverse ridership at a Tualatin business park; letters to registrants in the Tri-Met carpool database; a direct-mail packet containing a schedule, map, tickets for 5 free rides starting on Route 96, and a book purchase discount for taking all 5 free rides sent on October 14th to Tualatin and Wilsonville area residents and persons sending in a newspaper coupon; plus an assortment of newspaper publicity, pathfinder signs, civic ceremonies, inquiry responses and related activities.

Analysis. Counts were made from the week after lot opening through mid-January of the number of cars in the new park-and-ride lot. The number of Route 96 passengers boarding at the lot and the total passengers on board leaving the lot were counted periodically from lot opening through January 26, 1989. Coupon/ticket redemptions were tallied, and surveys were conducted of Route 96 passengers and of persons who received the direct mail promotion.

Results. Use of the new lot increased steadily from when it opened on September 19, 1998, until it reached capacity in mid-January 1999. While there was no survey of lot users per se, it was clear that usage went well beyond the number of parkers displaced from the old lot two-fifths the size. Informally, Tri-Met learned that several groups started using the new lot as a carpool staging area. Inbound 6:20 to 8:00 AM ridership on Tri-Met Route 96 increased by 279 percent, from 126 to 352 riders, between September 5, 1988, and late January 1989, taking an average of counts on January 24 and 26. After a steep climb from 173 to 251 riders in the first 8 days the lot was open, growth was fairly steady into January. Outbound, the reverse ridership was not much affected, starting at about 50 riders and reverting to more or less the same after peaking at 68 at the end of November.

Based on the boarding and bus load counts between the first-day count at the new lot and late January, it may be arithmetically deduced that some 85 percent of the Route 96 inbound morning gross ridership increase during that period (179 riders) was traceable to persons boarding at the new park-and-ride lots, leaving 15 percent attributable solely to the frequency increase and/or promotion. Survey results indicated that of new passengers, 46 percent drove to the new lot, 13 percent drove to another lot or bus stop, 14 percent were dropped off by auto (a total of 73 percent by auto access), 16 percent walked to a bus stop, and 11 percent transferred from bus or LRT. Since practically all of the transfer passengers represented reverse ridership, this suggests an 82 percent auto mode of access for new inbound riders, indicating rough compatibility between count and survey assessments. It would appear that something on the order of 1.2 additional Route 96 riders (2.4 daily bus boardings) per new parking space were associated with the new parking and its promotion.

More… Over 90 percent of surveyed Route 96 riders were going to work, with another 5 percent headed for school. Median income of all bus riders responding to the direct mail survey was $35,000 while income of new riders alone was slightly less. Sources of information about the new park-and-ride lot and the Route 96 express service for on-board survey respondents were (multiple responses allowed): Driving by the park-and-ride lot, 71 percent of all riders/77 percent of new riders; friend/co-worker, 28/35 percent; packet in mail, 25/28 percent; sign at old lot, 18/3 percent; ad in local paper, 16/13 percent; “your bus driver,” 13/4 percent; personalized letter from Tri-Met, 11/10 percent; poster at work, 3/3 percent; a Tri-Met representative at work, 1/2 percent; other, 13/12 percent. Among recipients of the direct mail packet who responded to the direct mail survey, almost one in five personally used the free tickets provided. Among free ticket users, riding frequency increased. Before/after promotion commute mode shifts reported by free ticket users were: drive alone, 30/20 percent; carpool, 19/15 percent; bus, 48/62 percent; and other, 3/3 percent. Recipients not using the free tickets showed no significant changes in frequency or commute mode.

Source. Ambruso, C., "Tualatin Park-and-Ride Lot Program Evaluation." *Transportation Research Record 1297* (1991). • Arithmetic deductions and related conclusions by Handbook authors.

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ASCE	American Society of Civil Engineers
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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
U.S.DOT	United States Department of Transportation