CHAPTER 18

TCRP

REPORT 95

TRANSIT COOPERATIVE
RESEARCH PROGRAM

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Parking Management and Supply

Traveler Response to Transportation System Changes

TRANSPORTATION RESEARCH BOARD
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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 95

Traveler Response to Transportation System Changes

Chapter 18—Parking Management and Supply

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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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TCRP PROJECT B-12A PANEL
Field of Service Configuration

FOREWORD

By Stephan A. Parker
Staff Officer
Transportation
Research Board

The location, supply, and pricing of parking influences development opportunities, property values, and urban form. Parking plays a key role in land use accessibility and the economy of major centers. Parking availability is of significant importance to travelers making travel decisions. It affects such diverse travel decisions as mode choice, trip destination choice, and trip frequency.

This "Parking Management and Supply" chapter presents information on how travelers respond to differences in the supply and availability of vehicle parking, including changes that might occur as a result of shifting land-use patterns, changes in regulatory policy, or attempts to "manage" the supply of parking. Information on "normal" baseline parking characteristics is also provided. The effects of parking pricing are, however, covered in Chapter 13, "Parking Pricing and Fees." Parking in support of transit service and carpooling is the subject of Chapter 3, "Park-and-Ride/Park-and-Pool."

TCRP Report 95: Chapter 18, Parking Management and Supply will be of interest to transit, transportation, and land use planning practitioners; educators and researchers; and professionals across a broad spectrum of transportation and planning agencies, MPOs, and local, state, and federal government agencies.

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

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

The Second Edition of the handbook, *Traveler Response to Transportation System Changes,* was published by USDOT in July 1981; and it has been a valuable tool for transportation professionals, providing documentation of results from different types of transportation actions. This Third Edition of the *Handbook* covers 18 topic areas, including essentially all of the nine topic areas in the 1981 edition, modified slightly in scope, plus nine new topic areas. Each topic is published as a chapter of *TCRP Report 95*. To access the chapters, select "TCRP, All Projects, B-12" from the TCRP website: http://www4.national-academies.org/trb/crp.nsf.

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

REPORT ORGANIZATION

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

Upon completion of the *Report 95* series, the final Chapter 1 publication will include a CD-ROM of all 19 chapters. The complete outline of chapters is provided below.

Handbook Outline Showing Publication and Source-Data-Cutoff Dates

General Sections and Topic Area Chapters (TCRP Report 95 Nomenclature)	U.S. DOT Publication First Edition	U.S. DOT Publication Second Edition	TCRP Report 95 Source Data Cutoff Date	TCRP Report 95 Estimated Publication Date
Ch. 1 – Introduction (with Appendices A, B)	1977	1981	2003[a]	2000/03/04[a]
Multimodal/Intermodal Facilities				
Ch. 2 – HOV Facilities	1977	1981	1999	2000/04[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" (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 18 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.; SG Associates, Inc.; 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. Lead Handbook chapter authors and co-authors, in addition to Mr. Pratt, are John E. (Jay) Evans, IV, initially of Parsons Brinckerhoff and now of Jay Evans Consulting LLC; Dr. Turnbull; Frank Spielberg of SG Associates, Inc.; 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, 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 and now of URS Corporation; 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, and Bill Davidson of Parsons Brinckerhoff Quade & Douglas, Inc.; 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, and Stephen Bozik of Parsons Brinckerhoff; others too numerous to name but fully appreciated; and lastly the warmly remembered late Susan Spielberg of SG Associates.

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. 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, J. Richard Kuzmyak is lead author for this volume: Chapter 18, “Parking Management and Supply.” Contributing authors for Chapter 18 are Dr. Rachel Weinberger, Richard H. Pratt, and 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 Review Group members who assisted are not listed here in the interests of brevity, their contribution is truly valued. Those who have undertaken reviews of Chapter 18 are William Allen and Peter Valk. In addition, Stephen Iwata and Richard Walker stepped in to provide needed chapter reviews.

Finally, sincere thanks are due to the many practitioners and researchers who were contacted for information and unstintingly supplied both that and all manner of statistics, data compilations and reports. Though not feasible to list here, many appear in the “References” section entries of this and other chapters. Special mention should go to Keith Lawton and his colleagues at Metro (Portland, OR) and the City of Portland, who provided the Principal Investigator with a full day briefing and extensive followup information exchange pertaining to several topics and this chapter in particular.

CHAPTER 18—PARKING MANAGEMENT AND SUPPLY

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18 — Parking Management and Supply

OVERVIEW AND SUMMARY

This "Parking Management and Supply" chapter presents information on how travelers respond to differences in the supply and availability of vehicle parking, including changes that might occur as a result of shifting land use patterns, alterations of regulatory policy, or attempts to "manage" the supply of parking. Information on "normal" baseline parking characteristics is also provided. The effects of parking pricing are, however, covered in Chapter 13, "Parking Pricing and Fees." Parking in support of transit service and carpooling is the subject of Chapter 3, "Park-and-Ride/Pool."

In this Overview and Summary section, the following is found:

- "Objectives of Parking Supply Management" offers an overview of the importance of parking supply and availability, and the objectives served by their management.

- "Types of Parking Management Strategies" classifies the mechanisms that govern or can be used to manage the supply of parking.

- "Analytical Considerations" highlights the research limitations that should be recognized when using the traveler response data in this chapter.

- "Traveler Response Summary" encapsulates the key travel demand findings related to parking supply management. The Overview and Summary sections should be read as background for both the "Traveler Response Summary" and the chapter as a whole.

The sections following the Overview and Summary are as follows:

- "Response by Type of Strategy" provides detail on the results of each specific parking supply mechanism, with travel demand effects quantified where possible in terms of modal choice, vehicle trip rate differentials, and changes in parking use behavior.

- "Underlying Traveler Response Factors" offers discussion of behavioral mechanism interactions with parking location, modal alternatives, trip purpose, and income, and of interrelationships of parking supply with parking pricing and with land development.

- "Related Information and Impacts" examines baseline parking characteristics, mode and destination shifts, cost effectiveness, and environmental issues and outcomes.

- "Case Studies" presents four illustrative examples of parking supply management applications.

Effects of parking supply availability and management are often hard to separate from those associated with parking fees and pricing. In addition, parking supply management is frequently implemented in circumstances where other factors are changing or being changed. Remote parking along transit services may be part of parking management strategy. Thus, there is overlap between this chapter and several others. It is particularly important to also consult Chapter 13, "Parking Pricing and Fees," Chapter 19, "Employer and Institutional TDM Strategies," and Chapter 3, "Park-and-Ride/Pool." Effects of parking supply management may be important in relation to traveler response to multimodal strategies (Chapters 2 and 3), transit strategies (most importantly Chapters 4, 7, 8, 9, 10, and 12), and land use alternatives (Chapter 15).

Objectives of Parking Supply Management

The location, supply, and pricing of parking influences development opportunities, property values, and urban form. It plays a key role in land use accessibility and the economy of major centers. Parking availability is of significant importance to travelers making travel decisions. It affects such diverse travel decisions as mode choice, trip destination choice, and trip frequency.

Parking is a major urban land use. Availability of parking (parking supply) usually depends in large measure on intensity of development and cost of land. It may be governed by building codes or ordinances, and it may be controlled to achieve some strategic economic or policy purpose. The adjustment of parking supply outside the normal processes of the private marketplace to achieve strategic objectives is often referred to as *parking management*. The objectives that parking management may be intended to serve are varied, complex, and potentially contradictory.

Management of parking supply is a balancing act: Too much parking, particularly if provided in surface lots, uses valuable land resources and often results in widely-spaced and disconnected development patterns. Too little parking — or poorly designed or located parking — can result in parking spillover to adjacent areas, lead travelers to choose alternate destinations, and/or inhibit development.

Historically, municipal parking codes have stipulated a *minimum* number of spaces per unit of development, calculated to ensure sufficient on-site parking supply for accommodation of the site's needs. This approach was adopted in the interests of minimizing walking distances, enhancing property competitiveness, and preventing spillover of parking to adjacent facilities or local streets and neighborhoods. Now parking requirements are sometimes being framed in terms of *maximum* allowable parking ratios, as a strategy to encourage more intensified use of land, enhance transit use, and diminish use of private vehicles. Similarly, the owners or lessees of work sites or activity centers may establish measures to manage their own parking supply, either to respond to regulatory pressures such traffic mitigation ordinances or environment requirements, or to address internal needs associated with access route traffic congestion or costly and space consuming employee parking growth.

Transportation departments may restrict on-street parking in commercial areas or along heavily-used arterials for purposes of increasing roadway capacity, especially during heavy-use periods. In some instances on-street parking supply management may also include the objective of influencing mode choice. Local jurisdictions may adopt measures to restrict on-street parking by non-residents in residential neighborhoods, for the purpose of limiting adverse neighborhood impacts of parking by commuters, shoppers, students, and others.

Communities may elect to provide off-street parking at the fringe, or *periphery*, of a central business district (CBD) or activity center, with the aim of intercepting private vehicle trips before they enter a congested downtown street network. Similar objectives may lead to establishment of further-out change-of-mode parking, covered in Chapter 3, "Park-and-Ride/Pool." Fringe parking facilities may be managed with the objective of inducing modal shifts, either by enhancing their use by carpools or vanpools, or by using them for spillover single occupant vehicle (SOV) parking while providing closer-in or on-site carpool and vanpool parking.

Parking supply management may also entail the placing of restrictions on the availability, access to, or use of parking during certain times of the day or days of the week or year, or to certain users. Examples include no parking on game days near a stadium or university, with objectives of enhancing traffic flow and maintaining order; or the familiar standby of placing time limits on parking duration. On- or off-street parking duration time limits effectively reserve space for short-term parkers such as shoppers, in contrast to commuters, ensuring turnover of parking for commercial purposes. Residential permit parking may apply only within certain hours of the day or week, to keep inconvenience in balance with parking control needs.

There are other, hybrid methods of restricting parking supply or access associated with the objective of serving short-term parking and discouraging long-term parking, or the reverse. These include allowing free parking for the first half hour and then charging after that (to discourage long-term parking), or conversely, instituting a high price for short-term parking with lower prices thereafter (to discourage short-term use). These latter two strategies, while parking *supply* management strategies in a certain sense, cross over into the realm of parking *pricing* strategies, dealt with exclusively in Chapter 13, "Parking Pricing and Fees."

Types of Parking Supply Management Strategies

The categories of parking supply management strategies discussed in this chapter (or companion chapters as noted) include the following:

Minimum or Maximum Parking Requirements. Local building codes or zoning ordinances generally control the amount of parking that must or may be provided at a site by the site developer or owner. Typically, parking requirements are specified as a ratio of the number of parking spaces required/allowed per square foot, per dwelling unit, or per some other measure of intensity of use, taking into account the type of use proposed for the site. Parking codes traditionally stipulate a *minimum* number of spaces required, or may be framed in terms of *maximums*.

Employer/Institutional Parking Management. Owners or occupants of work sites or activity centers may elect to manage their own parking supply, adjusting parking space totals and utilizing targeted allocation of on- and off-site parking, preferential parking for high occupancy vehicles (HOVs), or price incentives or disincentives to allocate supply.

On-Street Residential Neighborhood Parking Management. Local jurisdictions may adopt measures to restrict parking by non-residents. These restrictions may involve permitting, various parking duration limits, and active enforcement and penalties.

On-Street Commercial Area Parking Management. Communities may impose parking restrictions to prohibit on-street parking or limit its duration. Typically this strategy involves either time of day/day of week restrictions (communicated through signs) or metering.

Peripheral Parking. Parking may be provided at the fringe, or "periphery," of a CBD or activity center, as an alternative to having more parking within the center. Such facilities are either located within a reasonable walk of the core area, or provided with shuttle service. They represent an option for private vehicle users willing to trade off a reduced cost for parking against foregone convenience of parking on-site. Peripheral parking facilities may be provided by local governments or by private interests, but usually are initiated by or consistent with a policy or planning requirement.

Park-and-Ride. Urban regions may develop "remote" park-and-ride or park-and-pool parking at outlying locations, generally along express transit lines. Such parking, normally provided by transit agencies, transfers parking supply and shifts demand away from city centers, while supporting transit riding from low-density areas. This parking management approach is covered in Chapter 3, "Park-and-Ride/Pool."

Analytical Considerations

Evidence of travel impacts resulting from parking supply management is drawn from the following types of sources:

- Case studies in which a detailed examination is made of changes in the parking supply and corresponding management policies in a given location, and the "before and after" travel characteristics associated with them.

- "With and without" studies that compare sites (mainly work sites) that are similar in all respects but their supply/availability of parking.

- Modeling studies in which travel survey or selected empirical data are synthesized and analyzed in travel demand forecasting models to simulate changes in behavior that might occur if parking conditions (price or supply) were changed.

Available sources notwithstanding, there is relatively little satisfactory information on the effects of parking supply — and changes thereof — on travel behavior. Many intervening and confounding factors make it difficult to isolate and quantify underlying relationships. These factors include pricing, availability of nearby on-street or competitively priced off-street parking space, availability of satisfactory public transportation alternatives, and presence of Travel Demand Management (TDM) programs of employers and site owners. They also include land use characteristics of the area that lessen dependency on personal vehicles, such as employment and population density, and integrated land uses.

Available studies tend to link aggregate point-in-time parking space ratios with modal shares without adequately accounting for other key context variables, particularly the factors listed above. No studies were encountered that recorded travel demand in adequate proximity to both before and after a parking supply adjustment or usage policy was implemented. Neither were any estimates of elasticity of demand for changes in parking supply or availability found that would be suitable for application in practice.

The intrinsic relationship between supply and pricing makes it is difficult to discern their individual effects. Parking supply is generally limited where land use is intense and costs of land are high. In such cases, it is common to see parking fees that also correlate with land values. Where the supply of parking is tight because of building codes or other regulations, it is also common to see parking fees, which in turn affect demand for parking and thus space availability. Intense land use is also typically accompanied by availability of convenient alternative transportation choices ranging from high quality public transit to the possibility of walking between nearby destinations, with land uses often mixed — offering a variety of services — and sidewalks generally available.

Another difficulty is the lack of a workable measure of parking deficiency as viewed from the perspective of the potential user. The quantity of parking activity that does not occur for lack of space generally can't be counted, but instead must be estimated, introducing another layer of analytical uncertainty. Potential models thus lack a robust dependent variable to describe deficiency outcomes, and data classifications are similarly hampered. Studies consequently tend to focus on observable phenomena such as parking price or walking distance to/from the trip destination, suggesting by default that parking supply is a contributing but not especially causal factor.

Cases are presented in this chapter that do attempt to discern direct linkage and degree of importance of parking supply limitations and management with respect to changes in travel demand and behavior. These relationships tend to be less well quantified and less robust or reliable than is the case with transportation strategies better developed in available research. What seems better established is the relationship between a restricted supply of parking and the ability to maintain or introduce companion strategies with their own effect on travel demand. This is particularly the case with parking pricing, where limited parking supply provides an important basis (or incentive) for parking fees. Conversely, plentiful parking is found associated with fewer parking restrictions, fees, or other travel polices, presumably because of the existing parking investment and variety of parking options for the user.

Chapter 1, "Introduction," highlights additional evaluation and measurement issues to be alert to in any synthesis. Under "Use of the Handbook," see the four subsections beginning with "Degree of Confidence Issues" and continuing through "Concept of Elasticity."

Traveler Response Summary

The relationship between parking supply and demand is captive to the dominant role of parking pricing. When supply is scarce, either because of market economics or regulation of parking supply, parking fees are frequently in place and often high. This raises the question of whether it was parking cost alone that influenced travel demand, or whether it was a constrained supply of parking that caused the parking to be priced, which then influenced demand in some combination with difficulty of finding a convenient space. Supply and pricing factors are obviously highly interrelated.

The governing factor in parking supply is most commonly the building or zoning code requirements of local governments, although developer and lending agency concerns about development marketability play a major role. Historically, building permits have been conditioned on *minimum* parking ratios designed to assure sufficient on-site parking supply. In primarily suburban office and business park situations, this approach has resulted in parking ratios typically in the range of three to four spaces per 1,000 square feet, often equivalent to one space for every employee. Research indicates that these space requirements exceed typical utilization, with peak occupancy rate averages from five studies ranging from 1.2 to 2.8 parked vehicles per 1,000 square feet, with an average of 2.2 and a median of 2.4. This demand represents some 50 to 80 percent of supply in the four studies with supply data.

Downtown parking "lids" and/or *maximum* parking ratios have been used in a few cities. In Oregon, Portland's maximum ratios and a 20-year "lid" — combined with controls on surface lots — appear to have reduced the overall downtown parking ratio from approximately 3.4 long term parking spaces for every 1,000 square feet of office/commercial space in 1973 to 1.5 per 1,000 in 1990. With excess parking thus squeezed from the system, the "lid" component of the plan was, in 1995, removed in favor of more flexible control mechanisms. The parking policy, major transit enhancements and some TDM measures are credited with increasing downtown transit mode share from 20 to 25 percent in the early 1970s to a downtown commuter transit share of 30 to 35 percent in the 1980s and 1990s, or about 40 percent in peak commute times. Aside from mode share, user and usage characteristics for downtown Portland parking spaces appear fairly typical.

San Francisco's parking policy, with no core area parking *minimum* and a 7 percent limitation on floor area devoted to parking, is another variation. In 1983, core area worker mode share was 60 percent transit, with only 17 percent driving alone. Seattle, with upper and lower limits on parking ratios, maintains a 40 percent downtown commuter transit mode share. Comparable transit shares in downtowns with low or no minimums but no maximums are 25 percent in Los Angeles, 28 percent in Denver, and 20 percent in Hartford.

Examination of the relationship between parking availability and transit use in eight Canadian downtowns found a fairly strong statistical link. An elasticity of -0.77 was obtained from regression analysis of the study's data.[1] However, the underlying equation does not account for the effects of pricing, quality of transit service, downtown employment, or other key determinants, so the elasticity is probably inflated and useful only for illustrative purposes. A separate analysis of 1997 parking survey data from 17 U.S. cities likewise shows a strong connection between parking supply ratios in downtown areas and commuter mode choice. However, the analysis also shows a much stronger first order relationship between parking fees and mode choice.

Ample parking supply makes it hard to introduce effective commute management programs, since it is difficult to price or otherwise restrict the use of parking that employees know to be available. A 1994 study of 49 employer TDM programs showed a high correlation between scarcity of parking and the existence of market or near-market rate parking fees. Sites with restricted parking supply and/or priced parking had significantly lower employee vehicle trip rates than sites without such restrictions, irrespective of central city or suburban location.

Results of site-specific TDM efforts are instructive. When pressured by a city requirement to supply less parking at individual sites, landowners and tenants in downtown suburban Bellevue, Washington, found creative ways to meet employee travel needs. US WEST built only 408 spaces to serve 1,100 employees, and with a combination of pricing and space allocation, realized an employee SOV share of only 26 percent. CH_2M Hill dealt with the

[1] An elasticity of -0.77 indicates a 0.77 percent increase (decrease) in ridership in response to each 1 percent decrease (increase) in the ratio of parking spaces per unit of development, calculated in infinitesimally small increments (see "Concept of Elasticity" in Chapter 1, "Introduction," and Appendix A, "Elasticity Discussion and Formulae"). Extreme caution should be employed in using this particular elasticity, because of the numerous explanatory variables not controlled for.

problem of a declining parking ratio built into its tenant lease by introducing a fee/subsidy arrangement coupled with priority HOV parking that resulted in an SOV share of 54 percent. The City of Bellevue implemented space rationing and pricing at its City Hall location that produced an SOV share of 52 percent. By comparison, SOV commute rates at other suburban employment sites in the Bellevue/Seattle region exceeded 80 percent.

Management of on-street parking, including residential parking permit programs, time restricted and metered street parking, and active enforcement can be a key to making other parking or commute management initiatives successful. The ultimate effectiveness of parking management will be diluted if auto users can easily find nearby inexpensive or free on-street parking available for sufficient lengths of time, and the overflow parking will be a nuisance. In Portland, Oregon, parking controls have been expanded into the downtown periphery in part because commuters were occupying on-street spaces in the fringe and walking or taking transit the rest of the way. In San Francisco, correlation analysis of transportation characteristics at six medical institutions showed on-street parking limits to be second only to commuter parking cost in dampening employee SOV usage.

Residential permit parking programs that impose a time limit on parking for those without permits do seem to free up curb space for residents, in perception if not always in reality. A variety of associated tactics have been experimented with. Demonstration results in Eugene, Oregon, and Hermosa Beach and Santa Cruz, California, suggest that allowing purchase of non-resident permits results in only minor use of the offer, accounting for about 50 users per day in three Eugene permit areas (total) and 30 per summertime day on average in the oceanside Hermosa Beach program. Whether or not availability of the option keeps down complaints was not reported. The permit programs did not significantly affect choice of travel mode; the primary response by non-residents was a change in parking behavior as expressed in location or duration.

Peripheral parking adjacent to downtowns provides parking for between 1,000 and 5,000 autos in a number of instances and lesser amounts in others. High downtown parking cost is the primary reason for users to choose peripheral lots. Site developers have shown little interest in developing fringe parking in exchange for reduction in on-site parking requirements. Several publicly developed installations have failed because they did not offer total user cost savings sufficient to overcome travel time disadvantages. Where lots are within one mile of the CBD, a substantial portion of users normally walk to their destination, even if shuttle transit service is available. Facilities with HOV preference or price incentives have attracted 1,000 to over 2,000 HOVs where provided near the terminus of HOV lanes, but with extremely modest effects on vehicle trip reduction in the one instance analyzed. There are concerns that peripheral parking detracts from transit use on a passenger-mile basis and from the attractiveness of further out park-and-ride facilities.

The average downtown parker walks 525 feet to his or her destination in areas of 100,000 to 1,000,000 population and 725 feet in areas of over a million. Primary purposes for parking downtown in the larger cites are — in order of importance — work, personal business, and shopping. Present day purpose distributions in smaller cities are uncertain, and are unavailable for suburbs. Because length of stay varies with trip purpose, every 4 work purpose parkers result in roughly 3 parked cars at the time of peak parking demand, but of 4 average non-work purpose parkers, only one will tend to require space at peak occupancy. Downtown parking accumulation peaks between 11:00 AM and 3:00 PM. Parking demand for individual uses may peak at different times, however, allowing for “sharing” of parking space in city or suburb mixed use developments, in contrast to single land use sites.

RESPONSE BY TYPE OF STRATEGY

Maximum and Minimum Parking Requirements

The most common regulatory mechanism through which parking supply is controlled is zoning or building codes that specify minimum (or sometimes maximum) parking ratios. These ratios specify limits on the number of parking spaces that may be provided in relation to the type, location, and intensity of specific land uses. Residential parking requirements are typically linked to the number of dwelling units, while commercial or employment parking is based on the number of square feet, or other measures of activity. Historically, development codes have imposed minimum parking ratios on landowners or developers to ensure adequate site parking supportive of enhanced commerce and guarding against street or neighborhood parking spillover. However, more recently, some local jurisdictions have been imposing maximum parking ratios in order to limit on-site parking, intensify land use, and create an incentive for travel via alternative modes.

Minimum Parking Ratio Outcomes

A number of studies have examined the outcomes of having minimum parking ratio requirements. These evaluations focus primarily on workplaces in suburban areas, where employment and commerce have proliferated since the 1980s. They show that worksite parking supply typically exceeds the demand for parking, even with the vast majority of parking free to the user. Available evidence also suggests that excess workplace parking supply compromises ability to manage travel demand. This relationship is explored later in the section on "Employer/Institutional Parking Management" — "Workplace Parking Supply Management Overall."

Suburban office and business park parking ratios have been found to be typically in the range of 3 to 4 spaces per 1,000 square feet, often equivalent to one space for every employee (Willson, 1992). Peak occupancy rate averages from five studies range from 1.2 to 2.8 parked vehicles per 1,000 square feet of building space, with an overall average of 2.2 and a median of 2.4. Adjusting for building space not occupied, the lower end of the range becomes 1.4 per 1,000, with the corresponding top of the range not known. This demand represents around 50 to roughly 80 percent of supply in the four studies with supply data. The studies involved are described next, with more specificity as to the particular units of measure employed in each.

Southern California. One study in Southern California is based on a 1975 survey of zoning ordinances for 117 cities, plus a 1993 replication. The comparison surveys show an increase in minimum parking requirements from 3.6 to 3.8 spaces per 1,000 gross square feet (GSF).[2] For seven case locations analyzed, five in the city of Los Angeles, an average parking demand of 2.4 spaces per 1,000 square feet was found. In 1993, 98 percent of the jurisdictions included in the survey required more than the estimated demand for driver-paid parking, and 91 percent required more than the estimated demand for employer-paid parking (Shoup, 1994).

A study of five randomly selected Southern California sites that took building occupancy into account found peak parking demand to average 47 percent of spaces provided at observed

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[2] Parking requirements are a function of activity at a site, for which employment may be a surrogate. Floor space is used as a proxy measure in both zoning/building codes and in parking evaluations.

building occupancy, equating to an average of 52 percent of parking capacity at a theoretical 95 percent building occupancy. The corresponding rate of parking demand ranged from 2.0 to 2.3 vehicles per 1,000 occupied GSF, with the average nearly midway (Willson, 1992).

Puget Sound Area. Among other studies corroborating the finding that more parking is often available than actually required to meet demand is an evaluation of professional office and industrial site parking in King and South Snohomish Counties, Washington. The average zoning requirement at the 31 sites where it could be determined was 3.0 spaces per 1,000 GSF. The average rate of parking provided at the 33 sites for which site profiles were obtained was 3.15 spaces per 1,000 GSF. The average observed parking demand was for 2.54 spaces on average, indicating an overall demand just over 80 percent of supply (Kadesh and Peterson, 1994).

Nationwide Compilations. The Institute of Transportation Engineers (ITE) reports average parking utilization rates for single use development sites of 2.8 spaces per 1,000 GSF for general office buildings and 2.5 spaces per 1,000 GSF in business parks. In both cases, however, there is a wide range in reported parking rates. (For additional information see Table 18-29 and the accompanying discussion under "Related Information and Impacts" — "Characteristics of Parking Demand" — "Suburban Single-Use Parking").

An Urban Land Institute (ULI) pilot study of parking supply and demand at eight suburban business parks, primarily office or light industrial in character, found the lowest parking occupancy rates. The business parks were located in both the east and the west of the United States, and included a mixture of new and old, and small and large sites. The key statistics on parking supply ratios and utilization are shown in Table 18-1.

Table 18-1 Parking Supply and Utilization Rates at Eight Suburban Business Parks

Suburban Business Park Size, Age and Location [a]	Percent of Floor Area Occupied	Parking Supply (Spaces per 1,000 sq. ft. GLA)	Percent of Parking Spaces Utilized at Peak Hour	Peak Space Utilization per 1,000 sq. ft. Occupied GLA
Large, Old, East	96.0%	1.2	47.6%	0.6
Small, Old, East	96.3%	1.9	53.2%	1.0
Small, Old, West	82.6%	2.1	28.0%	0.7
New, Medium, West	86.7%	2.3	34.0%	0.9
Large, New, East	84.2%	2.5	60.6%	1.8
Large, Old, West	83.6%	3.1	43.6%	1.6
Large, New, West	88.4%	3.2	49.1%	1.8
Small, New, West	71.7%	5.8	56.1%	4.5
Weighted Averages [b]	86.9%	2.6	46.8%	1.4

Notes: [a] Sites listed in order of increasing parking supply per 1,000 square feet of gross leaseable area (GLA).

[b] Weighted averages recomputed by Handbook authors.

Source: Urban Land Institute (1986).

While no information was given on the actual parking code requirements for the sites studied by ULI, the amount of parking provided ranged from a low of 1.2 spaces per 1,000 square feet of gross leaseable area (GLA) to a high of 5.8 for a small new business park located in the west. The weighted average ratio for the sample was 2.6 spaces per 1,000 square feet.

Peak parking demand reached the space utilizations shown in the next to last column of Table 18-1, expressed as the percentage of spaces occupied in each business park as a whole, in the highest one hour of demand. Even at peak occupancy, the number of spaces occupied averaged only 47 percent, with the highest utilization rate being just over 60 percent, for a large new business park in the east. The final column of Table 18-1 gives the number of spaces used at peak occupancy per 1,000 square feet of occupied GLA, thereby factoring out the effect of empty floor space.

The study authors suggest that a parking ratio of 2.0 would be sufficient to take care of the overall needs of most business parks. However, they caution that reduced parking ratios should not be adopted without analyzing the specific character and needs of the development in question. The last listed business park illustrates this point. Were its parking ratio to be reduced below the 4.5 peak usage ratio, with no allowance for variability among tenant profiles or from one day to another, the business park would experience a capacity constraint at higher tenant occupancy and peak demand (Urban Land Institute, 1986). Similarly, while the ITE study average rates of 2.8 and 2.5 parking spaces utilized per 1,000 GSF may be compared to the surveys nationwide indicating parking supply mostly runs between 3 and 4 spaces per 1,000 GSF (Willson, 1992), the observed variability indicates a need to provide some leeway, at least where satisfactory overflow accommodations are not provided.

Maximum Parking Ratios and Minimum Ratio Reductions

The oversupply of parking that results from parking ratio minimums in many instances is leading some jurisdictions into setting *maximum* parking ratios for on-site parking at new buildings. Alternatively, lower *minimum* parking ratios may be offered to developers or landowners as a cost-saving opportunity to provide less on-site parking. Parking minimums may be relaxed in exchange for dedicated carpool stalls or in-lieu contributions to city parking funds, or in exchange for building the difference in parking at a remote location, alone or in a sharing arrangement with the local jurisdiction.

There are limitations to the latter approach, however. While seemingly offering a benefit to the developer or landowner by reducing their cost exposure for provision of required parking, many entrepreneurs do not favor constructing a building with below-average on-site parking for reasons of marketability of the building. Even if developers are willing, lending institutions may not go along (Valk, 1990). In an effort to encourage acceptance of reduced on-site parking ratios, jurisdictions may provide incentives such as floor area ratio[3] (FAR) density bonuses that allow more development on a given parcel of land, or relief from certain trip reduction or adequate public facilities ordinance (APFO) requirements. Selected examples follow.

Montgomery County, Maryland. Developers of projects constructed within the vicinity of Washington Metrorail stations in Montgomery County, Maryland, are offered FAR density

[3] The floor area ratio or FAR is a measure of development intensity equal to the gross leasable floor area (sum of all storeys) divided by the land area.

bonuses in exchange for building fewer on-site parking spaces. Concurrently, Montgomery County, as part of its APFO requirements, imposes traffic level of service thresholds on development in the more densely settled areas of the county. Building permits are granted only when it can be demonstrated that the new development will not cause a specified traffic level of service threshold to be exceeded by its traffic generation. Developers can improve chances for approval by submitting a plan for reducing vehicle travel to their site. Particularly favorable treatment is afforded applications that combine all three: 1) Metrorail station proximity, 2) strong curbs on the supply and use of on-site parking, and 3) a plan for traffic mitigation. The case study "NRC Site Parking Management — Montgomery County, Maryland" later in this chapter presents one example and the results obtained. Nuclear Regulatory Commission (NRC) vehicle trip generation at their North Bethesda site was held to 53.7 vehicle trips per 100 employees, 41.6 percent less that the average for other employers in the area (Comsis, 1988; Comsis and ITE, 1993; Comsis, 1996).

Bellevue, Washington. As part of its plan to control traffic in the face of rapid growth during the late-1980s and early 1990s, the City of Bellevue, Washington — an eastern suburb of Seattle — introduced changes to its development approval process that made parking management a key strategy. Developers/landowners wishing to construct a building in the Bellevue CBD were required to meet the following provisions: 1) to limit building setbacks from the street and sidewalk to no more than 100 feet, 2) to implement employee TDM programs to encourage use of travel alternatives, and 3) to restrict on-site parking ratios to 2.7 spaces per 1,000 square feet (2.4 per 1,000 on the basis of net usable space). Some notable examples of high non-SOV mode shares at individual sites resulted from this policy, including US WEST and CH_2M Hill, once the CBD and the new buildings began to fill in (Comsis and Katz, 1990). Results are tabulated in Table 18-33 in the "Related Information and Impacts" section under "Travel Choices After Parking Supply Modification" — "Mode Choices with Worksite Parking Management," and further details are provided in case studies cross-referenced in Table 18-33. Bellevue's experiences overall are discussed further below, under "Employer/Institutional Parking Management," and in Chapter 19, "Employer and Institutional TDM Strategies."

Atlanta. The City of Atlanta has, since 1981, used Special Public Interest Districts (SPIDs) to encourage high intensity commercial development around its Metropolitan Atlanta Rapid Transit Authority (MARTA) rail stations in the traditional downtown and the Midtown areas. The goals are to attract development to the vicinity of rapid transit stations, reduce parking supply in the vicinity, and increase transit use. Developers locating new office developments inside a SPID are relieved from both the normal minimum parking requirement of 2 stalls per 1,000 square feet of GLA and a building height restriction outside of SPIDs of 30 stories.

A study of the effectiveness of the SPID policy on development and transit use at MARTA's three Midtown stations was conducted based on 1980 and 1988 through 1994 data. The midtown SPIDs are approximately 3 to 5 blocks square, and cover about 40 percent of the land in the study area. On the positive side, the study revealed that the overall Midtown area had been a major growth center, gaining about 4.8 million square feet of new office space in the 1980s and early 1990s, with 61 percent of that growth occurring inside the SPIDs. FARs for new buildings inside the SPIDs averaged 3.61, 7 percent above those for other new Midtown buildings. Data for 1989-1990 indicate that the commute trip rail transit share is substantially higher for SPID employees, at 10.8 percent, than for non-SPID employees at 6.3 percent.

On the downside, while Midtown employment has increased by over 30 percent since 1980, Midtown station transit ridership has remained constant at about 5 million annual boardings.

This is strong indication of declining transit mode shares. What has apparently happened is that developers, while opting to locate buildings inside the SPID zones and often taking advantage of the freedom to construct higher buildings, have not responded to the parking requirement relief. They have instead built on-site parking at slightly higher ratios than required outside the SPIDs, 2.1 spaces per 1,000 square feet on average compared to the 2.0 non-SPID requirement. Moreover, a survey of buildings inside and outside of SPIDs reveals no difference in policies regarding parking fees charged to tenants, employee parking subsidies, or free customer parking. To compound matters, considerable vacant land is being used by its owners for surface parking to earn income. While SPID commercial space increased 19 percent, parking supply increased 22 percent. As a result, Midtown area parking space occupancy is only 74 percent at midday, even as parking operator competition has forced prices down, encouraging auto use (Nelson, Meyer and Ross, 1997).

The parking component of Atlanta's SPID policy is essentially a voluntary parking supply management program, dependent upon owner/developer response. The demonstrated lack of response apparently results from developer concern about competition for tenants with real or imagined employee and customer parking needs, possible desire for parking revenue, and lending institution requirements that parking ratios of new buildings be equivalent to competing buildings (Nelson, Meyer and Ross, 1997). This lack of owner/developer response gives employees and visitors nothing different from business as usual to respond to. The relationship between owner/developer and employee/visitor response is analogous to the relationship described in Chapter 19, "Employer and Institutional TDM Strategies," under "Underlying Traveler Response Factors" — "Employer Participation," where in voluntary TDM programs, employee response to TDM measures is first and foremost dependent on whether employers even elect to participate.

The Midtown Atlanta analysis concludes that without areawide parking supply management, policies like Atlanta's SPID program will have limited effects on transit ridership (the mode of specific interest to the study). It also concludes that the lack of management of surface parking severely undercuts potential for reducing parking supply and increasing transit use, at least in the near- and mid-term while development proceeds (Nelson, Meyer and Ross, 1997). These conclusions make the results of parking management in downtown Portland, Oregon, of special interest. As described in the next section and the case study "CBD Parking Supply Management in Portland, Oregon," Portland's program is areawide (the entire CBD), has expanded with the expansion of central area commercial activity, and includes control of surface parking.

Areawide Parking Supply Management

Central business district parking supply management is found in several large cities. Boston, New York City, Portland (Oregon), San Francisco, and Seattle have limited the expansion of downtown parking space. Table 18-2 compares the CBD parking policies for three of these cities (Portland, San Francisco, and Seattle) with three other cities that have addressed parking without maximum parking ratios (Los Angeles, Denver, and Hartford) – (Higgins, 1989). The accompanying discussion describes the key features for each city. Data and evaluations are as of the late 1980s, except for Portland, where information through 2000 is included in the summary and in the corresponding case study (but not in the table). Less than 1/2 of the CBD workers in the three cities with statutory limits on parking expansion drove alone to work, at least at peak times, while the corresponding SOV shares for the other three cities were in excess of 50 percent.

Table 18-2 Experiences of Six Cities with Managing Parking Ratios, Circa 1988

City	Downtown Employment (Population)	Parking Supply	CBD Parking Rates	CBD Parking Policy	CBD Traffic Mitigation	Key Findings
Portland, OR	90,000 (Portland 380,000) (SMSA 1.2 million)	41,000 spaces in CBD (5,000 on-street, metered)	$35-87/mo. $0.60-1.00/hr. off-street $0.50/hr. average on-street	Parking Lid of 43,914 spaces on downtown parking Maximum ratios (spaces per 1,000 sq. ft. of new development): 0.7 near best transit 1.0 elsewhere	Transit & carpool promotion Discount carpool parking Priority carpool parking	High CBD employee transit & carpool use : 43% Transit 17% Carpool [peak commute times] Developers providing *less* than maximum ratios
Seattle, WA	150,000 (Seattle 461,000) (SMSA 2 million)	72,000 spaces citywide [sic] (12,000 public, mostly on-street)	$90/mo. $6/day off-street $0.25-0.50/hr. on-street	Maximum ratio (spaces per 1,000 sq. ft.): 1.0 Minimum ratios: 0.54 good transit 0.75 moderate transit (20% of minimum must be carpool parking) Parking reductions for carpool space set asides	Mitigation required for all non-residential structures exceeding 10,000 sq. ft.: Bike parking required Coordinator required 700 discount carpool spaces provided by city	High transit use (45% for CBD commuters) Greatest successes in areas near transit Developer resistance to and little participation in carpool space set asides Various enforcement problems
San Francisco, CA	250,000 (C-3 zone) (San Francisco 740,000)	48,000 greater-CBD spaces off-street (75% + private)	$60-260/mo. Escalating hourly rates off-street (public) $0.50-1.50/hr. on-street	"Transit First" policy affects parking supply and price *No* code-required parking downtown Only 7% of building GFA can be parking Short-term parking gets highest priority	Transportation Management Plans (TMPs) required from developers TMPs generally require coordinator, transit and rideshare information, transit pass sales, other strategies	Satisfied that parking management has aided transit use and minimized auto use CBD worker mode share 60% transit, 16% rideshare, 17% drive alone No major change in peak traffic in 10 yrs. growth

Note: Population is that within the city limits of Central City unless otherwise indicated. SMSA = Standard Metropolitan Statistical Area.

Table 18-2 Experiences of Six Cities with Managing Parking Ratios, Circa 1988 (continued)

City	Downtown Employment (Population)	Parking Supply	CBD Parking Rates	CBD Parking Policy	CBD Traffic Mitigation	Key Findings
Los Angeles, CA	200,000 (SMSA 3.3 million)	127,000 spaces off-street (projected) (81,300 open to public, with 5,000 on-street)	up to $0.50/hr. off-street up to $1/hr. on-street	Minimum ratios (spaces per 1,000 sq. ft.): 2 to 3 citywide, reduced to 1.0 in CBD Developers in certain areas can provide up to 75% of parking at remote locations If project >100,000 sq. ft. in certain areas, *must* provide 25-40% of parking off-site	Employer trip reduction plans required under Regulation XV [Southern CA air quality mandate] Trip reduction plan average vehicle employee ridership (AVR) target of 1.75 persons/vehicle	Peripheral parking options not exercised by developers Many traffic mitigation plans not very good or effective CBD employee mode share 25% transit, 60% drive alone
Denver, CO	118,000 (Denver 491,000) (SMSA 1.6 million)	71,000 greater-CBD spaces, mostly private off-street (open to public)	$60-80/mo. $0.50/half hr. off-street, public $0.20-$1/hr. on-street	Minimum ratio (spaces per 1,000 sq. ft.) for office 2.0 citywide, except no CBD maximum or minimum Peripheral parking allowed as alternative Density bonuses for CBD parking *above* 70% of non-CBD ratio	Essentially none — note that parking requirements *not* set to encourage transit or ridesharing Price breaks for car and vanpools in certain city facilities	Some developers provide as little as 0.25 spaces per 1,000 sq. ft. in CBD Transit mode share 28% for core area employees; 13% for greater downtown Peripheral parking provided, but little used and hard to monitor
Hartford, CT	90,000	21,000 spaces, 12,700 open to public (2,700 public on-street)	$120-180/mo. garage $50-75/mo. surface lot $0.50/hr. on-street	CBD Minimum ratio (spaces per 1,000 sq. ft.) for office 1.0, new CBD office parking must be underground 30% reduction for demand management Peripheral parking allowed	TMPs required for CBD developments, additional requirements for projects impacting state hwys. Rideshare Company encourages transit and ridesharing	Parking ratio incentives and peripheral parking options not used City peripheral parking lot not well used SOV use to CBD 55% and increasing

Source: Compiled from Higgins (1989).

Portland. The city of Portland, Oregon, has for years used parking supply management as a major strategy to achieve transportation and development goals. Beginning in 1975, in response to failure to meet national EPA standards for CO emissions, the City set maximum parking ratios to limit the number of spaces provided at new downtown buildings, restricted surface parking, and imposed a "lid" capping the number of downtown parking spaces. The ratios were fairly tight: 0.7 spaces per 1,000 square feet for sites in proximity to the best transit service, and 1.0 elsewhere in the CBD. The lid of about 40,000 non-residential spaces included existing parking, approved but not yet built parking, and a remaining "reserve" from which parking for new development would be allocated. These policies are credited with helping bring peak transit use by downtown commuters to as high as 48 percent, dropping back to 43 percent in 1988 — coupled with a carpool rate of 17 percent (K.T. Analytics, 1995), and holding at about 40 percent in recent years. Over time the transit share for downtown Portland appears to have risen from 20 to 25 percent in the early 1970s to a 30 to 35 percent all-day share of CBD work-to-home and home-to-work trips in the 1980s and 90s.

Excess parking was squeezed from the system by 1990, concurrently with downtown growth from 70,000 to 90,000 employees. The downtown parking supply ratio of long-term spaces for every 1,000 square feet of office/commercial use appears to have been reduced from approximately 3.4 in 1973 to about 1.5 long term spaces per 1,000 by 1990. In 1995, the parking lid provisions were supplanted by a new, broader parking ratio approach framed by the Central City Transportation Management Plan. While the prior policies had accomplished their purpose, concerns had shifted to growth in regional vehicle miles of travel (VMT) and ozone precursors. An approach more supportive of further central area growth was sought. Parking management was also needed in areas adjacent to the CBD, where employment was increasing, and where CBD commuters were parking and walking or taking short transit trips into downtown. The new plan refined CBD parking regulations and prescribed 2.0 per 1,000 parking ratios for peripheral areas previously not included. It was accompanied by more restricted/metered on-street parking and other transportation demand management actions. One available indicator of continued pressure on SOV use is the inflation-adjusted 26 percent increase in monthly parking fees between 1987 and 1999. (See the case study "CBD Parking Supply Management in Portland, Oregon" for sources and for additional information.)

Seattle. Seattle, Washington, employs both minimums and maximums. The city put in place a maximum parking ratio of 1.0 spaces per 1,000 square feet citywide, with a procedure for variances. The required minimum is only 0.54 spaces per 1,000 square feet for office uses (for example) in areas near "good" transit service, and 0.75 in areas with "moderate" transit service. At least 20 percent of the minimum required spaces must be reserved for carpools. Reductions in the minimum parking requirement can be obtained by supplying carpool spaces above the minimum, by subsidizing carpool parking, by making contributions to the city parking fund, or by providing free transit passes. Few developers were reported to have taken advantage of the parking minimum reduction options, nor were commuters reported to be taking advantage of the reserved carpool spaces. In the case of city-provided discount carpool spaces, when the carpools first formed, 40 percent were reported to have been attracted from transit. (For more detail, see Table 13-21 in Chapter 13, "Parking Pricing and Fees," under "Underlying Traveler Response Factors" — "Travel Alternatives.") Despite these limitations, the city credits parking supply management with significantly helping to sustain a 45 percent rate of transit use among downtown commuters (Higgins, 1989).

San Francisco. San Francisco's "Transit First" policy influences both parking supply and price. The Downtown Plan aims at keeping parking supplies tight and emphasizes short-term parking over long-term. There are only 48,000 parking spaces for 250,000 employees, with 10,000 of them outside the official downtown. No parking is "required" by code in the downtown (C-3) area, and no more than 7 percent of a building's gross floor area (GFA) can be devoted to parking. Under the Downtown Plan, new buildings must have an approved parking plan. In some cases, only short-term parking is approved, while in others, a mixture of long-term, short-term, and carpool parking has been approved. City planners indicate that there has been no major increase in peak traffic over the past 10 years, despite considerable office growth. Local transit ridership is steady, with a 1983 survey of workers in the C-3 zone showing only 17 percent driving alone, with 60 percent on transit (Higgins, 1989).

Los Angeles. In Los Angeles, estimated 1990 parking included 81,300 CBD off-street spaces open to the public. City parking policies have been gradually changed to encourage more use of transit and ridesharing. Parking requirements are normally a minimum of 3 spaces per 1,000 square feet, but a lower requirement of only 1 space per 1,000 square feet applies to the downtown business district (treated as an "exception area"). The City waives any minimum requirement for property located adjacent to publicly-owned parking lots. The city also allows developers to provide up to 75 percent of required parking at remote locations, if they provide shuttle service between the lot and destination. Another parking policy allows parking to be reduced by up to 40 percent for special traffic mitigation programs (Higgins, 1989). Few developers have taken advantage of this program, an outcome that has been attributed to insistence by lenders on higher parking ratios (Valk, 1990). Within the area regulated by the Community Redevelopment Agency, developers of projects exceeding 100,000 square feet must provide no fewer than 25 percent and no more than 40 percent of code-required parking in peripheral locations. Shuttle service to these peripheral lots is required to operate at least every 10 minutes. About 60 percent of Los Angeles downtown employees drive alone to work; 25 percent take transit (Higgins, 1989).

Denver. There are 71,000 parking spaces in the greater downtown area of Denver, with 37,000 in the core area. Most are privately owned and operated, and open to the public. Denver does not use parking policy as an explicit means for reducing solo driving or increasing transit use, although price breaks for carpools are offered in certain city facilities. Requirements for office development in the city are 2 spaces per 1,000 square feet minimum except in the downtown, where there is no maximum or minimum. Parking pricing at Denver's publicly owned facilities tends to favor long-term parking. Concerned that developers were not providing enough parking downtown, where 0.5 spaces per 1,000 square feet is common, the city adopted a policy that actually rewards developers with an extra 500 square feet of development for each parking space provided beyond 70 percent of the non-downtown parking requirement. Another policy, which has proved difficult to monitor and enforce, allows for provision of peripheral parking to satisfy parking requirements. About 28 percent of commuters use transit to the core, while 13 percent use it to the greater downtown (Higgins, 1989).

Hartford. The city of Hartford, Connecticut, requires new parking in the downtown to be underground. The downtown parking code requirement is a minimum of 1 space per 1,000 square feet This requirement can be reduced by up to 30 percent in exchange for discounted carpool parking, transit subsidies, rideshare promotions, and shuttle service to and from intercept parking sites. The overall intent is to encourage development of off-site parking, and also to encourage transit use and ridesharing to mitigate traffic. Parking is relatively scarce in downtown Hartford, with only about 21,000 spaces for 90,000 employees. In 1988, 20 percent of employees took transit, 22 percent shared rides, and 55 percent drove alone to downtown employment sites. Because parking is scarce in downtown Hartford, developers have not taken advantage of the possibilities for parking reduction, and in fact, have tended to provide more than the minimum required parking (Higgins, 1989).

Parking Supply and Transit Use

A study of the interplay between downtown parking supply and transit use in eight Canadian and several U.S. cities sought to establish the importance of this relationship through regression analysis of such characteristics as CBD population, CBD employment, percent employed in the CBD, office space, total long-term parking and parking per employee in the CBD, total park-and-ride spaces and spaces per CBD employee, and AM peak-hour mode split. Statistics from the study for the Canadian cities are presented in Table 18-3. The authors acknowledge a number of other important factors that influence transit use, such as development densities, transportation systems, and amount and quality of transit service; however, these variables were not investigated (Morrall and Bolger, 1996).

Table 18-3 Relationship Between Downtown Parking Supply and Transit Use in Canadian Cities

City	CBD Share of Area Employment	CBD Office Space (1,000 ft^2)	Parking Spaces per 1,000 ft^2	Parking Spaces per CBD Employee	Park and Ride Spaces per CBD Employee	AM Peak Hour CBD Transit Share
Saskatoon	20.7%	3,600	3.5	0.79	—	14.6%
Edmonton	20.2%	15,133	2.1	0.51	0.029	32.0%
Calgary	23.4%	31,493	1.3	0.46	0.084	38.8%
Montreal	14.9%	87,996	1.0	0.38	0.270	48.7%
Winnipeg	26.1%	17,478	1.4	0.36	—	39.7%
Vancouver	16.3%	n/a	n/a	0.29	0.034	46.0%
Toronto	25.3%	61,570	1.5	0.29	0.122	64.1%
Ottawa	31.7%	21,024	1.1	0.28	0.008	48.8%

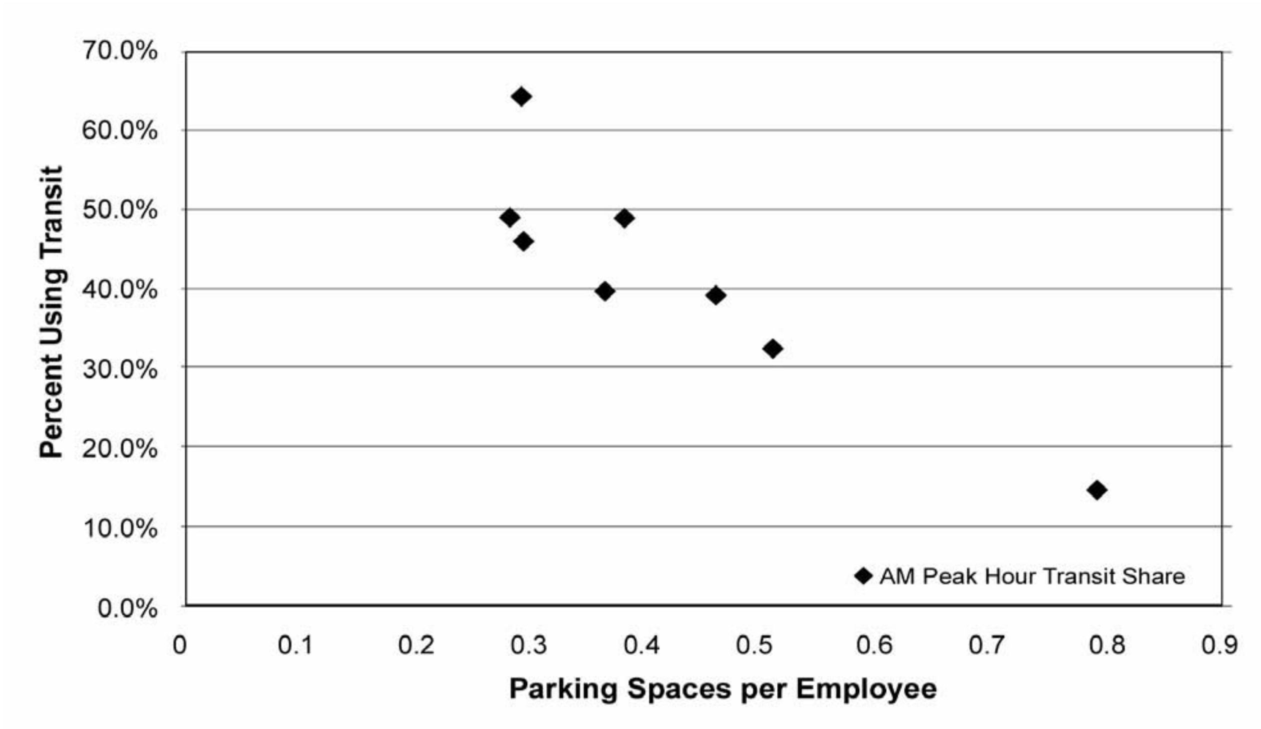
Note: Listed in order of decreasing ratios of long-term parking spaces per CBD employee.

Source: Morrall and Bolger (1996).

The study concluded that there was a strong, inverse relationship between the supply of downtown parking per employee and the AM peak-hour proportion of CBD commuters using transit. This relationship is fairly apparent when these data for the eight cities are plotted in Figure 18-1. The authors also noted that the larger the city, the smaller the ratio of long-term parking spaces per CBD employee. The transit mode share also was observed to increase with city size. No clear relationship was observed between city size and the ratio of park-and-ride spaces per CBD employee. The low rate of parking in Ottawa was attributed to the 1975 action of the Canadian government of discontinuing free parking for civil servants, which led to a higher modal split and a reduction in single-occupant vehicle use.

The non-linear regression analysis conducted on the Canadian city data resulted in an r^2 value of 0.92 for the equation explaining transit use to the CBD as a function of downtown parking supply per employee. When the authors attempted to include the U.S. cities in the equation, a much weaker relationship resulted, shown in an r^2 of 0.59 (Morrall and Bolger, 1996).

Figure 18-1 Relationship between downtown parking spaces per employee ratios and transit mode share for Canadian cities



Source: Plot of data presented in Morrall and Bolger (1996).

If one develops a linear regression equation describing the transit mode share for the eight Canadian cities in Figure 18-1 as a function of the ratio of parking spaces per employee, the equation that results is:

AM Peak CBD Percent Transit = 73.6 - 76.2 x (CBD spaces/CBD employee ratio)

This simplified equation, which has an r^2 of 0.82 and a coefficient with high statistical significance, leads to computation of a linear arc elasticity of change in transit mode share in relation to parking space ratio of -0.77. This implies that for every 1.0 percent increase in parking spaces per employee, transit mode share will decline by 0.77 percent (when calculated in infinitesimally small increments). Such an elasticity should be used with special caution, however, because the underlying equation does not take into account the previously noted non-parking variables. Another limitation of the model itself is that as the spaces per employee parking ratio nears 1 space per employee, the transit mode share becomes 0 and turns negative. The elasticity is mainly of interest as an illustrative indicator of the important role of parking supply in mode choice.

A linear regression equation model adding in the ratio of park-and-ride spaces per downtown employee was specified in the original study, also for the Canadian cities only. While the model's overall explanatory power is only marginally better (r^2 = 0.83) than the one-variable model presented above, the estimated parameters for both variables are statistically significant (Morrall and Bolger, 1996), and the constant is a little smaller. Implications are discussed further in Chapter 3, "Park-and-Ride/Pool," under "Underlying Traveler Response Factors" — "Overall Effects on Transit Mode Share" — "The Effect of Park-and-Ride Availability." The equation is:

$$\text{AM Peak CBD Percent Transit} = 68.2 - 81.0 \times (\text{CBD spaces/CBD employee ratio}) + 138.1 \times (\text{park-and-ride spaces/CBD employee ratio})$$

The analysis of Canadian cities also examined the amount of "bylawed" parking (equivalent to that required by zoning or building codes in the United States), relative to the amount of non-bylawed surface parking. The authors concluded that while the bylawed parking may result in a parking supply that is counterproductive when attempting to enhance transit use, the greatest negative impact is produced by the excess surface parking on vacant land (Morrall and Bolger, 1996). This conclusion is of particular interest in the context of Portland, Oregon's downtown parking supply management, which as discussed in the subsection above and corresponding case study, specifically includes strict limitations on such surface parking.

Employer/Institutional Parking Management

Parking may be managed by owners or occupants of work sites or activity centers on a smaller scale than is involved in area-wide programs. The most common example is site-specific employer-based programs designed to reduce SOV usage. Site-specific parking management may be accomplished under the umbrella of an area-wide program or it may be wholly independent.

Employers typically engage in employee commute management or assistance programs in response to traffic mitigation or air quality regulations, to address practical problems of maximizing use of existing space, such as to avoid expansion of parking in place — or business relocation — in the face of growth, or to otherwise control costs, while at the same time attracting and retaining employees. Site-specific parking management programs may involve providing preferential parking for high occupancy vehicles (HOVs), sometimes in conjunction with targeted allocation of on- and off-site parking, adjusting parking space totals, and/or using price incentives or disincentives to allocate supply.

Role of Pricing

With any parking supply management measure, employers may use pricing strategies to strengthen effectiveness. Along with supply management, employers may provide parking price discounts to carpools and vanpools, provide cash to employees in lieu of a parking space, or impose first-time or increased parking fees on single-occupant vehicle users. The existence of active parking pricing strategies is most often seen when parking at the site is constrained or limited relative to what might be demanded.

Parking pricing strategies are the subject of Chapter 13, "Parking Pricing and Fees." For workplace based programs, including approaches such as parking cash-out, see especially "Elimination of Employer Parking Subsidy" and "Employee SOV versus Rideshare Fee Differentials" under "Response by Type of Strategy," and also "Other Incentives, Options, and Associated Programs" — particularly Table 13-22 — under "Underlying Traveler

Response Factors," all in Chapter 13. In Chapter 19, "Employer and Institutional TDM Strategies," other types of workplace strategies are covered.

Preferential Parking for HOVs

Preferential parking for HOVs and other targeted allocation of parking spaces may involve providing:

- Preferentially located spaces for certain users, notably employees who use carpools or vanpools;

- Reserved, dedicated spaces for preferred users, while forcing other users to secure space on a first-come basis; and

- On-site or covered parking for preferred users, while other users are obliged to park off-site, or at a remote location, or in open lots.

Early examples of preferential parking generally applied the strategy in conjunction with carpool matching programs, and were evaluated during an era of two fuel shortages — the 1970s. Some companies obtained a doubling in the number of carpools. Before and after information was available for two. At the state government facility in Little Rock, Arkansas, the number of carpoolers rose from 400 to 1,100 in response to implementation of carpool parking priority *and* a requirement that all state-owned cars have at least three passengers if taken home at night. At Hallmark Cards in Kansas City, Missouri, where carpool matching and parking priority were combined, the number of 3-person carpools increased from 132 to 258.

In two documented cases, the resultant proportion of auto commuters in carpools exceeded 50 percent and/or produced an employee auto occupancy of about 2.0. Providing priority parking at the Pentagon in Arlington, Virginia, together with carpool matching, resulted in issuance of carpool permits covering 4,960 of the 10,000 parking spaces. The 2.0 auto occupancy was reported at the Government Employees Insurance Company headquarters in Bethesda, Maryland in response to an aggressive carpool matching program tied to the provision of guaranteed preferential parking spaces. Some 1,000 of 4,200 employees were issued 340 carpool parking permits (Pratt, Pedersen and Mather, 1977).

Reports of more recent programs indicate both successes (one at Nike in Beaverton, Oregon, and another at GEICO in Washington, DC) and ineffective programs. The lack of success Seattle had in encouraging developers to reserve carpool spaces, and the poor utilization of those provided, was reported above under "Maximum and Minimum Parking Requirements" — "Areawide Parking Supply Management" — "Seattle." Information from Silicon Valley suggests that Sunnyvale, California's requirement that certain developers designate close-in parking as HOV spaces likewise led to stalls utilized by few carpoolers (K.T. Analytics, 1995). Perhaps preferential HOV parking only works well in an environment of employer enthusiasm for SOV use reduction, expressed in companion programs and an organizational ethic, and perhaps this was lacking in the programs imposed as a building code or zoning requirement in Seattle and Sunnyvale.

As worksite TDM has evolved, preferential parking has often been used as a complementary rather than isolated strategy. This approach makes it difficult to estimate the effect of HOV preferential parking per se, but it likely contributes to a more substantial program impact overall. Example multifaceted programs are covered in the case studies "NRC Site Parking Management — Montgomery County, Maryland" in this chapter, and "City Hall Employee TDM — Bellevue, Washington," in Chapter 19, "Employer and Institutional TDM Strategies."

Workplace Parking Supply Management Overall

A difficulty in assessing most documented cases of employer parking management is that the parking supply issues or strategies are tied in with numerous other factors or strategies, including transit subsidies, guaranteed ride home, or other alternative mode incentives. While parking supply constraints appear to stand out as one of the primary factors in an effective transportation management program, no existing research has done a comprehensive analysis to isolate the effect of parking supply management alone.

A study of the "Cost-Effectiveness of Transportation Demand Management Strategies," performed under TCRP Project B-4, offers some insights. The characteristics and performance of 49 employer and institutional TDM programs were surveyed. The sample was national in scale and included TDM programs across a wide range of employer types, size, setting, regulatory environment, and program intensity (Comsis, 1994). The identity and characteristics of the sites investigated, along with vehicle trip rate outcomes and comparisons, are presented in the previously cited Table 13-22 of Chapter 13, "Parking Pricing and Fees."

Parking supply ratios, location/access to parking (garage, surface lot, on or off site), and the existence and schedule of parking fees were ascertained for each TDM program. Sites were grouped on the basis of parking supply, characterizing parking availability as "Ample," "Limited," or "Scarce." Similarly, groupings were made according to pricing conditions, using the categories "Free/None," "Nominal," and "Market." Not surprisingly, the existence and level of parking fees was found to be closely related to parking availability, as shown in Table 18-4. Only 2 of the 29 sites offering free parking were sites where the parking supply was scarce, while 8 of the 15 sites where parking supply was scarce were found to charge for parking at market rates.

Table 18-4 Parking Supply and Pricing Relationships at 49 Employer TDM Sites

Parking Supply Availability	Parking Pricing Conditions			All
	Free/None	Nominal	Market	
Ample	13	3	0	16
Limited	14	2	2	18
Scarce	2	5	8	15
All	29	10	10	49

Source: Developed from Comsis (1994).

To examine possible relationships between characteristics of the various employer TDM programs and changes in travel behavior, TCRP Project B-4 estimated the per-employee vehicle trip generation rate from modal split information obtained from the sites, and then compared this rate with the "ambient" trip rate for the adjacent area as determined from U.S. Census Transportation Planning Package (CTPP) data for 1990. The difference between the site vehicle trip rate and the CTPP-based ambient trip rate was used as an indicator of the respective TDM program's effectiveness in reducing vehicle use by employees (Comsis, 1994). Of course, many factors — both internal and external — influence a given site's vehicle trip rate. Use of an ambient trip rate as the comparison datum offers a degree of research control over external "context" factors, such as surrounding land use, density, transit service, and such other conditions as are shared with all other employers in the comparison area.

Table 18-5, in an effort to isolate the importance of parking availability relative to other individual TDM program strategy effects, groups the 49 sites in the TCRP Project B-4 sample by parking availability alone. The results, shown in the left side of the table, exhibit an obvious distinction in vehicle trip rates relative to parking supply. TDM effects range from vehicle trip rates averaging 7.1 percent below the CTPP-based ambient control rate for sites with "Ample" (unrestricted) parking, to results 28.6 percent below ambient rates where parking was "Scarce."

Table 18-5 Comparison of TDM Program Vehicle Trip Reductions Under Different Conditions of Parking Supply Availability and Parking Pricing Levels

Parking Availability	Number of Sites	Vehicle Trip Rate vs. Ambient [a]	Parking Pricing	Number of Sites	Vehicle Trip Rate vs. Ambient [a]
Ample	16	-7.1 %	Free	29	-8.4%
Limited	18	-11.2%	Nominal	10	-17.9%
Scarce	15	-28.6%	Market	10	-32.2%

Note: [a] The term "ambient," with reference to employee trip rate, denotes the trip rate for all workplaces — of the same general type — in the surrounding area.

Source: Developed from Comsis (1994).

Differences in trip rate according to pricing are shown in the right side of Table 18-5. Here the effects range from vehicle trip rates averaging 8.4 percent below ambient for TDM program sites with "Free" parking, to trip rates averaging 32.2 percent below ambient for those with "Market" rates for parking. Parking availability affects the trip rate directly, and also indirectly through pricing. The effects are nearly parallel, although they stand out slightly more when the data are arrayed by price.

An array of the TCRP B-4 results that permits assessment of the relative role of parking supply as a factor in *shaping* the given employer program, as well as in *affecting* the estimated vehicle trip generation result, is provided in Table 18-6. This table distributes the 49 sites into four broad program categories:

- "Support" type programs that stress employer encouragement and facilitation, but which offer no real physical or economic inducements.

- "Service" type programs, where the employer provides physical travel options for employees, such as vanpools, transit shuttles, etc.

- "Incentive and Disincentive" programs, where financial subsidies and/or parking charges are used to encourage use of alternative modes and discourage solo driving.

- "Service and Incentive" programs, which combine the financial and service features of the previous two categories.

Table 18-6 Relationship Between Parking Supply Availability, Nature of Overall Employer TDM Program, and Vehicle Trip Generation

Parking Supply Availability	Number of Sites by Type of TDM Program (and Associated Site Versus Ambient Vehicle Trip Rate)				
	Support	**Services**	**Incentives and Disincentives**	**Services and Incentives**	**All**
Ample	3 (+4.5%)	3 (-10.5%)	7 (-6.9%)	3 (-15.6%)	16 (-7.1%)
Limited	3 (-1.8%)	2 (-5.6%)	9 (-11.0%)	4 (-20.7%)	18 (-11.0%)
Scarce	0 (—)	0 (—)	11 (-26.7%)	4 (-34.0%)	15 (-28.6%)
All	6 (+1.4%)	5 (-8.5%)	27 (-16.3%)	11 (-24.1%)	49 (-15.1%)

Source: Developed from Comsis (1994).

The number of sites that fall in each of these program categories is shown in the table, along with the distribution when further stratified by the parking availability at the respective sites. The associated average TDM site versus ambient vehicle trip rate percentage differences are also shown (in parentheses) for each category and cross-classification.

The information in Table 18-6 indicates that sites with limited or scarce parking more often adopt more aggressive measures into their TDM programs. As shown, no sites in the sample with "Scarce" parking supply opted for only "Support" or "Services" programs. In contrast, the great majority of "Incentives and Disincentives" programs and programs with combined incentive and service features occurred at sites with "Scarce" or "Limited" parking supply.

The results also show that the "Support" type programs had minimal effects on vehicle trip rates (exhibiting rates actually *higher* than ambient on average), while clearly the most significant improvements over ambient rates were seen in the "Incentives and Disincentives" and combined programs. Correspondingly, it appears that where parking was ample the least mitigation of vehicle trips was obtained, while the estimated vehicle trip savings were greater where parking was "Limited" and, especially, "Scarce."

Employer Involvement in Parking Management

In 1995, a national survey of 603 U.S. employers was conducted to support a comprehensive analysis of employer practices with respect to employee transportation benefits (KPMG, 1995). The information compiled helps identify how widespread lack of supply management is in provision of employee parking. It also helps dimension the conditions of employer ownership that may significantly affect employer involvement with policy initiatives having the objective of minimizing employer parking (under parking cash-out or other methods) to discourage solo driving or influence land use management. The following are key findings (KPMG, 1995):

- In 1990, the Census Journey to Work survey showed 73 percent of commuters driving alone to work, 13 percent carpooling, and only 5 percent using transit.

- Bringing in the 1995 survey, it was estimated that commuters generated 90 million SOV and 7 million carpool vehicle trips per day, contributing to a demand for approximately 97 million employee parking spaces at worksites.

- Parking benefits (primarily free or subsidized parking) were found to be provided to employees by 80 percent of all employers, with the practice most pronounced among larger employers.

- The vast majority of employers who provide parking to employees either own the parking facility outright (60 percent), or receive the parking through their building lease (37 percent). Only 3 percent rent or lease parking spaces from their landlord or a third party. Only 1 percent reimburse employees who obtain parking on their own. This situation suggests that very few employers have an easy ability to shed parking benefits through strategies such as parking cash-out.

- The major source of parking provided to employees is surface lots owned by employers, the type of parking with the least land value. Parking facilities are deemed unlikely to have potential for alternative use.

- Employers provide an estimated 294 million spaces allocated to employee parking and an additional 39 million spaces for visitor parking.

- While transit service ranging from rudimentary to excellent is provided to 34 percent of employer locations, transit benefits were found to be provided by less than 1 percent of employers, at varying values perhaps typified by the $21 per month average subsidy on transit fare media resold. Similarly, vanpool/carpool benefits were provided by 3 percent of employers, with an average value of $20 per month for vanpoolers. These benefit levels may be compared with the 1995 $60 federal tax limit per employee.

- In the face of parking benefits to employers being limited under Section 132(f) of the tax code to $160 per month in 1995, 47 percent of employers who owned their parking weren't aware of the cap. The value of the parking for tax purposes was not known, or was put at $0 value, by 99.8 percent of survey respondents (who were not necessarily the same persons who filled out the tax returns). Some 53 percent placed $0 value on the parking.

Thus, while carefully managing the supply of parking at worksites appears to have strong impact on auto use by commuters, legal and economic factors may make it difficult to retrofit parking supply strategies on preexisting employer situations. The viability of controlling parking at new locations depends on how the requirement is perceived by the developer or land owner as affecting their competitiveness at the site in question versus other sites. These factors — explored further in the "Cost Effectiveness" section under "Related Information and Impacts" — serve to diminish the likelihood of *employer* participation in parking supply management. Without *employer* participation, there will be no *employee* response, i.e., no parking-related differential in auto use. *Employer* participation/*employee* response relationships are a subtopic of Chapter 19, "Employer and Institutional TDM Strategies."

On-Street Residential Neighborhood Parking Management

Insufficient on-site parking, substantial parking fees, and even on-site parking management each may cause overflow of parking vehicles in search of empty, cheap, free, or easier to access spaces. On-street parking in residential areas is often the most adversely impacted. Typically, on-street spillover effects occur either around the parker's ultimate destination, or at an intermediate change-of-mode location, such as near a commuter bus or rail station.

Neighborhood on-street parking management, a response to spillover concerns, typically takes the form of residential permit parking programs when less restrictive approaches prove inadequate. Permit programs are either absolute in application — no unpermitted vehicles may be parked in the area — or time limits are imposed for unpermitted vehicles. Typically parking for unpermitted vehicles will be allowed for at least one and at most four hours. Effectiveness of street parking or neighborhood permit parking programs depends heavily on the degree of enforcement.

Effects on Curb Parking Behavior

Two studies serve to illustrate effects of residential parking management programs on driver behavior. Both involved elements of pricing, and were located in mixed residential and commercial use environments.

Eugene, Oregon. A parking management demonstration in Eugene established three parking zones designed to combat high usage and low turnover of on-street parking spaces in the West University area, primarily a residential neighborhood. Residents holding permits could enjoy unlimited parking in their respective zone, while non-resident commuters, students, and others were restricted to 2-hour limits on free parking. In two of the three zones, non-residents were permitted to buy monthly or daily permits for unlimited parking, at a cost of $10.00 to $17.50 per month, or $1.50 per day.

Results of this program, covered more completely in Chapter 13, "Parking Pricing and Fees," under "Response by Type of Strategy" — "On Street Parking Pricing," were as shown in Table 13-7 in that chapter. In summary, the average number of cars parked at any given time was reduced by 22 to 50 percent in the three zones. Parking duration (length of stay) went down by 30 to 39 percent. Effects on turnover — the average number of cars served by a space in a day — were mixed, with overall average turnover remaining about the same.

While this program was reasonably successful in achieving its objectives of freeing up on-street parking for residents and short-term users, most of the change was accomplished through modifications in parking behavior. Some 95 percent of non-residents continued to drive alone to the area, rather than shifting mode. They either parked in private facilities, or managed their time parked to stay within the two-hour limit. Pricing through sale of permits to park seems to have played a very minor role, as detailed in Chapter 13, even though prior to the program there was a perceived on-street parking shortage of about 1,000 spaces (Dornan and Keith, 1988).

Hermosa Beach, California. A residential permit parking demonstration in Hermosa Beach provides results in the context of a recreational destination with over-saturated summertime parking. Hermosa Beach had a population of 18,000 at the time, with an area of 1.3 square miles. The program goal was to increase availability of on-street parking for residents living in a 3 to 4 block wide zone adjacent to the popular beach, and reduce traffic congestion in the residential neighborhoods involved. After three seasons of experimentation, the 1983 program features were (Rhyner, 1985):

- A $10.00 annual permit available to residents of the permit parking zone, allowing unlimited-time parking within the zone, including at the meters on streets within a block of the beach. One such permit per resident could be "transferable" for visitor use.

- For unpermitted vehicles, a 50¢/hour rate at the 1 to 2 hour meters (compared to 25¢ in the 1979 "before" condition), and a one-hour time limit in unmetered spaces of the permit parking zone.

- A unique $10.00 permit available to residents of the permit parking zone for parking on the street in front of their own driveway (only).

- A day use permit sold for $2.00 at City Hall and two special booths, good for all-day parking in unmetered spaces within the permit zone.

- Peripheral fringe parking, inland of the permit parking zone, served — along with the City as a whole — by free minibus service on a 30-minute headway on three loop routes (as compared to a 60-minute headway on two routes in the "before" condition), providing a consolidated 15-minute shuttle headway from much of the peripheral parking.

As reported for the Eugene demonstration, as well as for a companion project in Santa Cruz, California, little use was made of the non-resident permits, which in Hermosa Beach were one-day only. Average daily sales were 17 on 1983 in-season weekdays, and 59 on weekend days. Even after large banners were placed on approach roadways, nonresident awareness of the permit system and free bus service was low. Total free bus ridership averaged 66 on 1983 in-season weekdays, and 94 on weekend days. Most free bus riders were town residents; peripheral parking lot users tended to walk to the beach. While 7 percent of riders on loop buses and 32 percent on shuttle buses used an auto to reach the bus stop, only 3 percent on the loop buses and 6 percent on the shuttle bus said they would have driven all the way without the bus. The bus service worked well for those who used it, however (Rhyner, 1985). It might be argued that the alternatives provided by the free buses and the day use permit served as a safety valve for those disaccommodated by the permit parking.

Development of and experimentation during the demonstration indicated that charging a nominal fee to permit zone residents for the annual permit greatly reduced the number distributed over offering them free, and drove home the importance of making provisions for service vehicles, local business owners and employees, and other special user categories. The program was financially self-sufficient, in large measure due to revenue generated by citations, providing a $45,000 surplus in 1983. Residents perceived an improvement in conditions, although total weekend curb space occupancy remained at capacity, and the study concluded that effects were limited (Rhyner, 1985). Table 18-7 gives the before and after parking behavior of residents, which seems to reflect increased flexibility of choice.

Table 18-7 Permit Area Resident Parking Behavior in Hermosa Beach, California

Parking Use and Location	Before Permit Program (1979)	After Permit Program (1983)
Frequency of On-Street Parking		
All or most of the time	33.8%	39.4%
Sometimes	7.8	11.4
Occasionally	10.4	19.7
Never	48.1	29.6
Current Location of Car (Evening)		
Off-street	*61.2%*	*56.1%*
On-street in front of driveway	(illegal)	9.0
Parking meter curb space	3.3	6.3
Permit area unmetered curb space	28.8	18.1
Other curb space		2.1
On-street subtotal	*32.1%*	*35.5%*
Other	*6.7%*	*7.0%* [a]

Note: [a] Disposition of remaining 1.4% not indicated.

Source: Rhyner (1985).

Effects on TDM Program Effectiveness

Affording residents priority access to adjacent curb space is not the only outcome of neighborhood parking management. The importance to TDM program effectiveness of limited or managed on-street parking supply in residential areas has been strongly suggested in a study of factors affecting TDM programs at six medical institutions in San Francisco. Program characteristics are summarized in Table 18-8 (Dowling, Feltham and Wycko, 1991).

Each of the six medical institutions maintained their TDM programs both to manage their supplies of scarce on-site parking, and — at most of the sites — to comply with city-imposed conditions for facility expansion. For each site, the size of the daytime workforce, the supply and pricing of on-site parking, the availability of off-site street parking, the quality of transit service to the site, and the observed modal split of the institution's employees were ascertained as set forth in Table 18-8.

At all but one of the six sites, San Francisco General Hospital (SFGH), parking in the adjacent neighborhood was restricted by residential parking permit programs limiting parking by non-residents to two hours. Such a restriction would clearly discourage commuters seeking all-day parking. In addition, the scarce off-street parking offered at the hospitals was priced at fairly substantial rates at all but the SFGH site (although the parking space-to-employee ratio of 0.23 at SFGH was second smallest in the group).

Table 18-8 Parking and Transportation Characteristics at Six San Francisco Medical Institutions

Medical Institution	Davies	SFGH	St. Mary's	Kaiser	St. Francis	Mt. Zion
Licensed Beds	341	582	531	323	362	439
Daytime Employment	850	2,600	1,150	1,500	1,000	1,400
On-Site Parking Spaces	333	610	293	507	406	270
Remote Lot Spaces	0	0	200	475	0	0
Total Spaces	333	610	493	982	406	270
Total Spaces per Employee	0.39	0.23	0.43	0.65	0.41	0.19
On-Site Parking Charge						
Hourly	$1.75	Free	$1.00	$1.00	$3.00	$0.75
Daily	$20	Free	$7.50	$9.50	$13	$7.50
Monthly	$20	Free	None [a]	$62 [b]	$95	$90
Carpool Reserved Spaces						
Number	30	0	15	182	4	20
Percent	9.0%	0	3.0%	18.5%	1.0%	7.4%
Daily Charge	Free	Free	None [a]	Free	Free	Free
Off-Site Parking Characteristics						
Residential Parking Permits	Yes	No	Yes	Yes	Yes	Yes
On-Street Time Limits	2 hr.	None	2 hr.	2 hr.	2 hr.	2 hr.
Parking Meters	No	No	No	No	Yes	Yes
Transit Service						
Buses or Trains within 2 Blocks, per Hour	19	14	22	48	45	34
Employee Modal Shares:						
Drive Alone	55%	59%	54%	51%	51%	43%
Shared Ride	19%	10%	14%	20%	12%	19%
Public Transit	19%	25%	22%	24%	27%	26%
Other Modes	7%	6%	10%	5%	10%	12%
Percent Employees Drive Car	63%	63%	60%	59%	56%	51%
Average Auto Occupancy	1.18	1.09	1.14	1.20	1.13	1.22

Note: [a] All monthly parking for employees is off-site, with a charge of $40 ($15 for carpools).

[b] Off-site monthly charge of $35.

Source: Dowling, Feltham and Wycko (1991).

The modal shares for each institution were remarkably high in use of non-SOV modes, leaving drive-alone rates in the range of 43 to 59 percent. A correlation analysis was performed on the various factors thought to have a role in the low rates of employee vehicle use. A portion of the matrix from this analysis is reproduced in Table 18-9.

Table 18-9 Correlation Between Employee SOV Rates and Contributing Factors

	Monthly Parking Cost	On Street Parking Limit	Transit Veh./Hr.	Parking Spaces per Employee	Percent Drive Alone
Monthly Parking Cost	1.00	-0.74	0.76	0.04	-0.85
On Street Parking Limits	-0.74	1.00	-0.61	-0.37	0.71
Transit Vehicles per Hour	0.76	-0.61	1.00	0.59	-0.60
Parking Spaces per Employee	0.04	-0.37	0.59	1.00	0.10
Percent Drive Alone	-0.85	0.71	-0.60	0.10	1.00

Note: Correlation reflects the degree of relatedness between two variables where a correlation coefficient of 1.0 indicates that the two items are perfectly related, and 0.0 indicates no relationship. A negative ("-") coefficient means that the two quantities are inversely related.

Five of eleven explanatory factors examined are reproduced here.

Source: Dowling, Feltham and Wycko (1991).

These San Francisco medical institution analyses suggest the factor exhibiting the greatest influence on the drive alone rate at these sites is Monthly Parking Cost (correlation of -0.85). Second in importance is On-Street Parking Limits (0.71), followed by Transit Vehicles per Hour (-0.60). Surprisingly, the *on-site* parking ratio (Parking Spaces per Employee) does not show up as being important (correlation of 0.10) (Dowling, Feltham and Wycko, 1991). A possible clue as to why is offered by the poor correlation between Monthly Parking Cost and Parking Spaces per Employee (0.04), which in the context of the other correlation coefficients, may suggest anomalies in supply or designation of employee parking vis-à-vis other hospital parking. Monthly Parking Cost is clearly the best descriptor of on-site commuter parking constraints in this situation.

Drive alone shares for both before and after implementation of residential parking permits are available for two of the medical institutions, however the results are clouded by a renewal of commitment during the before/after time span to previously lapsed overall TDM activity. The combination of renewed TDM commitment and residential parking permit program implementation was associated with a decrease in drive alone shares from 63 to 55 percent for Davies, and 65 to 54 percent for St. Mary's. Over the same time span, the proportion of Davies employees parking along neighborhood streets dropped from 59 to 52 percent of those who drove (Dowling, Feltham and Wycko, 1991).

On-Street Commercial Area Parking Management

On-street parking, in urban areas of over 250,000 people, comprises about 10 percent of the CBD parking supply on average. The proportion tends to be higher in the least populated urbanized areas and smaller in the largest areas (ITE, 1992). Commercial area on-street parking management typically involves setting peak hour, daytime, or 24-hour parking restrictions; establishing parking time limits; and installing parking meters. The primary objectives traditionally have been to improve safety, reduce traffic congestion, facilitate parking turnover, and provide for passenger and goods loading.

Effective enforcement of curb parking is essential, especially where time limits are in place. In Boston, for example, 1972 field surveys found average parking durations of 70 minutes at meters with 30 minute limits, 90 minutes at 1 hour meters, and 135 minutes at 2 hour meters. The average parking duration at un-metered spaces was 210 minutes (Wilbur Smith, 1972). Curb parking is generally among the most convenient for the user in traditional business districts, and its reservation for short-term parking deserves high priority. Such use is generally not in conflict with employee parking management objectives.

On the other hand, one concern with employee oriented parking management programs, like cashing out employer-paid parking, is that employees may only partially respond, with unintended consequences. For example, employees may take a cash-out benefit and still drive, taking advantage of local on-street parking or other available commercial parking (Shoup, 1994). Impacts are not limited to residential on-street parking, covered in the previous subsection. Adoption of broader commercial parking management strategies, specifically involving curb parking, may be called for in such instances. Fulfillment of the role of partnership with off-street parking management is thus added to the list of on-street commercial parking management objectives.

Data for analyzing impacts of constraints or changes in the supply of on-street parking on travel behavior are particularly scarce. A 1997 survey of CBD parking information by The Urban Transportation Monitor assists in this regard (Urban Transportation Monitor, Oct. and Nov. 1997). The results of this survey are fully described in the "Underlying Traveler Response Factors" section under "Supply, Pricing, and Mode Share," and are set forth there in Table 18-12, accompanied by a correlation analysis.[4]

The data and the correlation analysis suggest the following relationships of specific interest to the subject of curb parking in the CBD:

- The most important curb parking relationship involving travel mode shares appears to be with parking cost to the user, rather than any measure of supply. SOV use is inversely proportional to on-street meter charges normalized to an effective 10-hour day in the respective parking stalls (r = -0.88; as rates go up, SOV share declines). The effect is nearly as strong as for off-street parking monthly rates, and somewhat stronger than the effect for off-street parking daily parking charges.

- The supply of on-street parking also shows a relationship with SOV use, although modest compared to price. SOV use increases with the number of on-street parking spaces per 1,000 CBD employees (r = 0.23). The effect is not as strong as for off-street parking supply (r = 0.40).

- Another modest relationship seen is a positive one between the maximum time limit reported for on-street parking and SOV use (r = 0.20). Where the maximum limit is less restrictive, SOV use is higher. This could logically be a causal relationship, or it may

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[4] Correlation coefficients — indicated in the text by the symbol "r" — are no more than measures of the strength of relationship between two variables, and should not be construed as elasticities. They range from 0 to 1 or -1. The closer to 1 or -1, the stronger the relationship, which is inverse if the "r" is negative. A correlation coefficient that is only half as large as another *does not mean* that the corresponding impact is only *half as important*; it simply means that the relationship seen is only about *half as strong*.

simply mean that longer time limits and SOV use are both more common in smaller cities with fewer incentives not to drive.

A review of this information with the objective of determining the relative importance of parking supply versus on-street parking price in influencing travel demand is inconclusive. While on-street parking supply seems to have a much weaker direct relationship with SOV use than on-street pricing, the role of parking supply in establishing parking prices in the first place must ultimately be factored into the evaluation. The apparent existence of an inverse relationship between on-street meter charges and the ratio of on-street spaces per 1,000 employees ($r = -0.23$) is suggestive of such a role. The relationship is less strong, however, and probably less meaningful, than the apparent role of total parking supply in influencing off-street parking prices. That role is explored further in "Underlying Traveler Response Factors" — "Supply, Pricing, and Mode Share" — "Relationships with Mode Share."

Peripheral Parking Around Central Business Districts

Some cities have developed or encouraged "peripheral parking" facilities adjacent to their central business districts (i.e., "fringe parking" on the CBD periphery). Such facilities are generally sufficiently removed from the downtown core proper that they can be inexpensively priced, yet close enough that their users can either walk to their final destination or take a short bus ride, often a shuttle. This siting contrasts with the fringe parking generally associated with either park-and-ride transit service or park-and-pool ridesharing activities, usually located some distance from the CBD. Such "remote" fringe parking is covered in Chapter 3, "Park-and-Ride/Pool."

A key goal of peripheral parking is intercepting commute trips headed to the CBD before they enter the downtown street grid and contribute to core area traffic congestion. Unlike park-and-ride or park-and-pool facilities, peripheral parking is typically not targeted mainly on inducing travelers to change their primary travel mode. However, in combination with preferential parking or fees, peripheral parking can sometimes be deployed to help form carpools or vanpools.

The decision to employ peripheral parking as part of an area's parking strategy may also be motivated by either a shortage of parking in the built-up core area itself, or conversely, by a desire to tighten the core area parking supply as part of a policy to manage land use, traffic, or travel demand. In areas with parking shortages, failure to provide adequate and fairly priced parking can be detrimental to businesses, potentially turning away customers to areas with fewer restrictions. In areas with a current or developing parking surplus, a policy of restricting on-site parking and replacing it with peripheral parking offers the potential for encouraging travel by transit and other modes for at least the final distance into the CBD.

Peripheral Parking Success and Failure Experiences

Peripheral parking is often provided by municipalities; however, employers and institutions sometimes do so. Success with both types of peripheral parking is mixed. Developer-provided peripheral parking has been constrained by owner, lender, and lessee desire to have parking close at hand, as well as by cost factors relative to other options and site availability. City facilities have achieved broader success, with some in operation from as early as the 1950s. Certain municipal projects encountered failure or disappointing results, however, most notably as a result of insufficient user cost savings to justify the loss in time or convenience relative to core area parking.

There are several examples of areas that have had difficulty encouraging developer implementation of peripheral parking systems (K.T. Analytics, 1995):

- Although parking is tightly limited in downtown San Francisco for new buildings, no developers had proposed to build or use peripheral facilities when reported on. This outcome was despite encouragement for developers — as one aspect of the restrictive parking policy — to supplement their supplies with peripheral or other fringe parking, connected by shuttle systems.

- Despite a city of Hartford policy allowing parking requirements for new developments to be reduced by up to 30 percent in exchange for shuttle service from off-site parking, paired with a requirement for putting new on-site parking underground, developers have preferred leasing nearby surface parking over use of peripheral parking.

- Claiming it was important to provide at least the minimum required parking on site to stay competitive, Orlando, Florida, developers — as of 1986 — had not taken advantage of a 1982 ordinance waiving up to 20 percent of required parking downtown in return for contributions to a transportation management trust fund. Contributions were set at 80 percent of avoidable construction cost.

There are also some comparative successes with developer and institutional peripheral parking programs, although the effectiveness of these examples may have ebbed with time:

- An off-site parking and shuttle operation was established in 1983 between the atrium of Crocker Court in Los Angeles and a parking lot 4 blocks away. Both the lot and Crocker Court are located within the CBD (hence not strictly a peripheral parking application). The lot has spaces for 1,000 vehicles, and on a typical workday is 85 percent occupied. Shuttles operate all day until 11:30 PM, with peak period headways of 3.5 minutes, and 80 percent of the lot users take the shuttle (Brophy & Associates et al., 1986).

- A free remote lot for employees of the San Jose Medical Center 2 blocks from the hospital attracts some use, but many employees continue to park on-street in adjacent residential neighborhoods. Similar systems are known to operate in other areas, such as the University of Pittsburgh Medical Center, where intense demand for parking by staff and visitors, often around the clock, severely taxes scarce parking (K.T. Analytics, 1995).

- The University of Maryland operates a successful peripheral lot and shuttle service, with 25 buses serving about 750,000 riders annually. Routes serve peripheral lots as well as residential areas and the regional transit system. Parking management combined with public transportation offerings is a common strategy for many universities, where auto use by staff and students severely taxes campus parking supplies, and where students are more easily influenced by the economics of parking fees and permits than commuters. MIT does not grant parking permits to students living within the service area of the regional transit system, and UCLA similarly considers proximity to transit in allocating permits (K.T. Analytics, 1995). (For related information see “Response by Type of Service and Strategy” — Service Changes with Fare Changes” — Service Changes with Unlimited Travel Pass Partnerships” in Chapter 10, “Bus Routing and Coverage.”)

A number of CBD peripheral parking systems were implemented in the 1970s and early 1980s, many as demonstration projects. A summary of various sites as of 1981 is provided in Table 18-10. Facilities were generally located within 1 mile of the CBD, with a few as far as 3 miles away. Most were served by shuttle transit with headways of less than 10 minutes. Parking and/or shuttle service was free in some locations, while fees were charged in others. The facilities generally had significant capacity, with space for more than 1,000 vehicles in many lots.

Table 18-10 Characteristics and Usage at Peripheral Fringe Lots as Examined in 1981

	Cincinnati, OH	**Cleveland, OH**	**Cleveland, OH**	**Washington, DC**	**Washington, DC**
Parking Volume/Capacity	1,400/1,400	2,200/2,500	1,450/1,450	615/625	220/290
Distance to CBD (miles)	0.6	1	1	3.2	3.1
Transit Headway (minutes)	6	5-10	5-10	4	4
Parking Fee	$0.25	$0.25	$0.25	free	free
Transit Fare (round trip)	$0.20	$0.50	$0.50	$0.50	$0.50
CBD Parking Cost	n/a	$2.00	$2.00	n/a	n/a
	Fort Worth, TX	**Albany, NY** (2 lots)	**Atlanta, GA** (2 lots)	**San Diego, CA**	**Pittsburgh, PA**
Parking Volume/Capacity	4,200/5,000	850/1,900	375/1,250	10/900	20/2,000
Distance to CBD (miles)	0.3	1-3	1	2	1
Transit Headway (minutes)	frequent (subway)	5-7	10	15	5-10
Parking Fee	free	$5/mo.	$0.50	free	n/a
Transit Fare (round trip)	free	included	free	$0.35	n/a
CBD Parking Cost	n/a	$15-40/mo.	$1.00	n/a	n/a

Note: Some of the facilities listed have been subsequently closed for various reasons including urban rail system introduction and expansion.

Source: Pratt and Copple (1981).

In several demonstration projects, a substantial number of peripheral parkers were found to choose walking for the final leg of their trip, rather than transit service. Although the expected short-haul transit ridership did not materialize in these cases, shifts in parking demand and traffic away from core areas was nevertheless achieved.

As shown in Table 18-10, utilization of peripheral facilities was generally good in a majority of the cities examined, but not in the Atlanta, San Diego, and Pittsburgh instances. In Atlanta, San Diego and also a case in Baltimore, failure was attributed to insufficient user cost savings over central parking to justify the time loss or inconvenience (Pratt and Copple, 1981; Brophy & Associates et al., 1986).

An example over time of the effect of insufficient user cost savings is provided by New Orleans, where in the mid-1970's a successful shuttle service was operated from parking at the Superdome to the CBD. Of 5,000 spaces available, 85 percent were occupied on a typical day. It was estimated that the facility shifted about 1,200 cars per day away from CBD parking. Daily parking was $1 at the lot compared to $3 to $4 in the CBD, while the shuttle bus ran on headways of 3.5 minutes and cost only 10¢. Eventually, high operating costs combined with the low Superdome parking and shuttle fees created a large deficit. When rates were increased, usage declined significantly (Brophy & Associates et al., 1986).

Peripheral Parking and Mode Shifts

Peripheral parking may also be managed with the objective of fostering ridesharing. Placing regular parking at the periphery of the CBD while reserving premium parking for carpools and vanpools closer in can be an attractive time savings for HOV users, although in practice this has rarely been done, and then only on a very limited basis. Alternatively, close-in parking can retain its natural rationing of spaces based on market pricing mechanisms, while peripheral parking can be priced and managed to attract HOV users. A good example of this latter type of usage may be seen in the Minneapolis I-394 distributor garages experience (Finstad, 1996), which is presented as the “Minneapolis Third Avenue Distributor Garages” case study toward the end of this chapter.

Another example of this type also comes from Minneapolis, in the period leading up to the construction of the I-394 distributor garages. Minnesota Rideshare introduced a carpool peripheral parking program in 1983, primarily as a traffic mitigation strategy during the reconstruction of Highway 12 into I-394. Six peripheral locations were offered — five offering free parking to registered carpools and vanpools, with discounted parking at the sixth, negotiated with a privately owned lot in a desirable location. Downtown access from the peripheral lots was facilitated by a Dime Zone bus service. By parking in the free lots, users could save $30 to $80 per month in parking costs relative to comparable locations, and between $100 to $200 relative to parking in the downtown core.

The network of lots and supply of spaces was changed in response to construction activity and other factors. As shown in Table 18-11, usage of the free lots tracked the amount of capacity provided, with steadily increasing utilization per space. The maximum number of registered pools was 1,356 in 1987. To qualify for registration, carpools had to have at least 2 members and had to carpool at least 3 days a week (Comsis and Katz, 1990).

Table 18-11 Capacity and Utilization of Minnesota Rideshare Carpool Free Peripheral Parking Lots

Year	Number Lots	Number Spaces	Number Users	Utilization Rate
1983	2	189	40	21.2%
1984	2	189	144	76.2%
1985	5	1,389	566	40.7%
1986	5	1,699	1,206	71.0%
1987	5	1,699	1,356	79.8%
1988	5	1,378	1,207	87.6%

Source: Comsis and Katz (1990).

While Minnesota Rideshare never performed a formal occupancy count at the free lots, a review of the permit registration data indicated that the 1,207 pools registered in December 1988 claimed 2,752 named riders, equivalent to an average auto occupancy of 2.28 persons per vehicle (when carpooling). To determine how much of the carpool formation and utilization was actually induced by the parking program, as opposed to pre-existing pools simply taking advantage of the free parking, a survey was conducted in January 1989 that queried the 2,752 registered riders about present and past travel behavior. Analysis of the 1,172 usable responses revealed the following (Comsis and Katz, 1990):

- Prior to becoming carpool users of the free lots, 35.4 percent drove alone, 21.2 percent rode the bus, 8.1 percent rode the bus from a park-and-ride lot, 31.1 percent were existing carpoolers, 1.5 percent were existing vanpoolers, and 2.7 percent used other means of transportation.

- The average number of reported occupants per vehicle for lot users was 2.57 persons. Since 4.74 days per week was the average frequency of carpooling, the effective daily occupancy was 2.43 persons.

- The estimated net vehicle trip reduction induced was 203 [round] trips, about 15 percent of the vehicle trips calculated to have been previously produced by the same commuters.

- Among persons switching to carpooling, 92.1 percent claimed that the free parking encouraged their decision.

- Reasons given for carpooling by *all* respondents were: money savings, 18 percent; convenience, 16 percent; time savings (ability to use a new HOV lane on Highway 12 during reconstruction), 13 percent; avoid stress, 11 percent; bus unavailable, 9 percent; changed job location, 7 percent; do not drive, 7 percent; and no car available, 7 percent.

- The average parking cost experienced before beginning to use the free carpool lots was $55.45 per month. The average monthly savings *per person* thus indicated was $22.82, or about $1.05 per day.

- The average age of carpools formed under the program was 21.5 months. The sponsor estimated the rate of attrition of pools out of the program to be about 10 percent.

As already noted, peripheral fringe parking is not universally seen as an effective way to induce desired mode changes, most particularly with regard to transit mode share. One review concludes that "the park and ride literature suggests that close-in lots may take away ridership from local transit service" (Higgins, 1989). The Canadian study discussed earlier under "Maximum and Minimum Parking Requirements" — "Parking Supply and Transit Use" concludes "[t]he single most important factor that has a negative effect on downtown transportation policies is the large amount of surface parking within and adjacent to downtown areas." Although that finding does not address peripheral parking per se, the authors go on to state: "Surface parking on the periphery of central business districts… accounts for more than one-third of all downtown parking in many Canadian cities. The effect… is counterproductive to achieving higher peak-hour mode splits to the downtown, and erodes the attractiveness of park and ride facilities, which are designed to keep unnecessary long-stay parking out of the downtown" (Morrall and Bolger, 1996). Clearly the potential for unwanted mode shifts is a factor in peripheral parking considerations.

UNDERLYING TRAVELER RESPONSE FACTORS

The impact of parking supply management strategies on travel behavior, and thus their effectiveness in achieving desired objectives, depends on a variety of determinants. These factors relate to the application setting and context, to known attributes of traveler choice behavior, and to the time frame involved.

Variables that affect application setting include location, land use type and intensity, existing parking supply levels, presence and amount of parking fees, and the number and quality of alternatives — including both other travel modes and other destinations. How these are incorporated in local transportation, land use, and parking programs and policies is critical. Characteristics of the traveler and the trip that are important to traveler choice behavior include income and trip purpose. Finally, response to parking supply management strategies, like other strategies, entails both short term and long term responses. Over time, travelers may make more fundamental alterations in their behavior to cope with the transportation system changes in the way most satisfactory to them.

Location and Modal Alternatives

There are two levels from which the roles of location in parking supply management impacts need to be viewed. One is at the regional level, as in *CBD* versus *suburban activity center* versus *dispersed development*. The other is at the local level within a CBD or other center, as in *prime location* versus *periphery*. Regional locational differences affect quality of alternatives to driving and parking. Local area siting differences affect the quality for the user of the parking option itself. Both affect space availability and land cost influences on parking supply, pricing, and parking management impetus.

Altering the parking supply is a more absolute strategy than pricing. In the abstract, at least, a space that is simply not provided cannot be made available by user election to pay a higher price. In reality that is not quite so, because tight parking supplies in free market situations normally lead to higher parking prices, which in themselves discourage some parkers, leaving space for those willing to pay the tab. In any case, the displaced parkers need other means of travel if they are to continue making the trip involved.

A frequent objective in managing parking supply is to influence the use of more efficient modes and reduce SOV travel. The degree to which this objective can be achieved depends on the number and quality of available transportation alternatives, including transit, ridesharing, walking, or bicycle.

Attractiveness of transit is a function not just of the frequency and cost of service. Also critical is the ease with which it can be used to access a parking supply management site, plus the ability of the user to function *at the site* without needing to rely on an automobile. Autoless mobility at the site is obviously important for bike or walk alternatives as well, but perhaps less so with ridesharing, as a vehicle may be at hand should it be needed. (Related effects of land use mix and site design on travel choices are covered in Chapter 15, "Land Use and Site Design.")

At a regional level, CBDs inherently have the best transit service and, because of the confluence of travel, the most opportunity for ridesharing. Densely developed downtown areas are also locales where new parking is typically difficult and expensive to provide, tipping the balance toward minimization of supply. These circumstances also may exist, though typically to a lesser degree, at certain non-downtown transit stations or stops. The combination of a downtown location and a major transit stop is generally optimal for parking supply management. In Chicago, for example, developers have been willing to take advantage of minimum parking requirement reductions for connections to underground transit stations, most of which are located in the central area (K.T. Analytics, 1995).

Although one might expect candidate locations for parking supply management to be limited outside of the densely developed downtown areas, suburban activity centers do provide their own set of opportunities. Parking supplies in these areas tend to exceed demand, posing challenges in the development of parking management strategies — either supply or pricing — which are meaningful. Once again, alternative means of travel are essential, whether transit or viable ridesharing programs, to allow mode shifts, maintain effective accessibility, and thus limit risk of adverse economic consequences. When Bellevue, Washington, implemented maximum parking ratios, the program provided for a reduction in both the minimum and maximum ratios by 0.3 spaces per 1,000 square feet of office space every 2 years. Faced with fewer improvements to transit service than anticipated, it was necessary for the city to defer implementation of those reductions (K.T. Analytics, 1995).

A concern in management of parking supplies in any setting, which gets into locational issues at the local level, is the travel behavior option of shifting one's parking location to other areas where it is less restricted. To avoid adverse outcomes, management of on-street parking is often needed in both the subject area and adjoining neighborhoods. Any parking management policy can only be expected to accomplish its full intent when the behavior of the population being "managed" can be contained to the area of application.

When the city of Portland, Oregon, lifted its parking lid downtown and substituted a more comprehensive supply management policy, a major component of the new plan was increased area coverage. This expansion served in part to address the unintended behavior of travelers to the downtown restricted parking area who were taking advantage of parking spaces in adjacent areas, and either walking or taking a short transit trip into the core area (City of Portland, 1995b; K.T. Analytics, 1995). Further insights into the highly sensitive tradeoffs of time and cost that underlie the phenomenon of parking location shifting are offered further on, under the heading "Income and Time/Cost Tradeoffs."

Trip Purpose and Trip Making

The nature of a trip also bears on traveler response to parking supply and parking management strategies, and strategy effectiveness and feasibility in turn. Parking behavior characteristics such as space turnover and duration are a function of trip purpose, and affect system efficiency and revenues. Acceptability to the user of alternative parking locations and walking distances also depends on the type of trip.

Discretionary trips — trips for purposes such as shopping, personal business, or social-recreation — can conceivably be made at another time, to another place, or not made at all. Because of these options, and because discretionary trips are paid for directly out of the traveler's pocket, they are likely to be more sensitive to parking availability and price than non-discretionary trips such as work or business trips. If restricting parking supply drives up the cost of parking or makes parking too difficult, shoppers may elect to make their purchases elsewhere, or may cut down on the time of their stay. (For more on parking for non-work purposes, see the discussion of San Francisco's Parking Tax in Chapter 13, "Parking Pricing and Fees," under "Response by Type of Strategy" — "Changes in Overall Parking Rates" and in the case study "A Parking Tax in the City of San Francisco").

Commuters, on the other hand, are less able to avoid the likely cost of restricted parking by traveling somewhere else or parking for shorter duration. They are, therefore, more likely to either choose a mode that is compatible with their income and budget over the long run, or to park in a more remote location where parking is available and affordable. The disutility of a lengthy walk to the work site, happening once at the start and once at the end of work, is at least spread over an 8- or 9-hour workday from the commuter's perspective.

In assessing these considerations, it is useful to think of travel to a localized area subject to parking restraints as falling into one of the following five categories (Lieberman, 1974), to which the phenomena of electing to park for longer or shorter time periods could well be added:

1. Constant Trips, which would be made to the area regardless of the actions taken, but which may shift from one travel mode to another.

2. Attracted Trips, shifting their destination from competing areas to the affected area in response to improved non-auto access including transit service betterments and pedestrian amenities.

3. Diverted Trips, redirecting their destination away from the affected area to competing areas as the result of having auto access made more difficult.

4. New Trips, which would not have been made under prior conditions, but would be generated by the affected area in response to non-auto travel improvements including pedestrian amenities.

5. Discontinued Trips, which would have been made under prior conditions, but which would be suppressed or foregone as the result of more difficult auto access.

The "Constant Trips" category would pertain primarily to the work commute and associated long-term parking, although "Constant" may be too absolute a term, as discussed under "Short- versus Long-Term Response." The other four categories would pertain more to discretionary travel, primarily non-work trips, and associated short-term parking. It may be especially difficult to counterbalance the negative economic effect of non-work diverted, discontinued, and foreshortened trips with attracted trips and new trips, arguing for treading lightly on or even enhancing short-term parking supply as part of parking management actions.

Supply, Pricing, and Mode Share

Role of Pricing

Many parking supply management strategies involve or abet parking pricing, and their effects are heavily intertwined. If parking is restricted for regulatory reasons, its scarcity supports pricing. If supply is restricted for market reasons, the capital cost is also greater and it is similarly likely to be priced. Privately capitalized public parking in densely-developed downtown areas generally is priced to maximize revenue to the owner. Publicly provided parking will tend to follow suit, to at least some degree, and prices are normally set sufficient to cover debt service requirements.

Private employer parking is typically offered as a benefit to employees, subsidized by the employer. However, when private, on-site parking supplies have been carefully restricted through parking codes and growth management policies, the cost to the employer is higher, making it more difficult to supply free or low cost parking to all employees. Under these conditions, employers are more likely to introduce parking cash-out and other TDM programs that have major incentive or disincentive features.

Attempting to gauge traveler response to parking supply changes or restrictions is frequently confounded by the correlative effect of pricing. Where supply is restricted, pricing is likely to be in place also. Statistical analyses will typically show a stronger direct relationship between travel behavior and price than between travel behavior and supply. However, the contributing role of parking supply in this chain of relationships cannot be overlooked.

Relationships with Mode Share

One source of information on relationships between traveler behavior and central business district parking supply and price is a 1997 survey by The Urban Transportation Monitor. This survey queried a number of city traffic engineers and parking directors on the supply, availability, and pricing of parking in the downtown areas of their cities. Questionnaires were returned from 17 of the 75 areas contacted. The cities responding represent a broad range of environments, from New York City with over one million workers in the CBD to Fontana, California, with 2,500 CBD workers (Urban Transportation Monitor, Oct. and Nov. 1997). The data provide a cross-sectional look at metropolitan area population and CBD employment, modal split of commuters to downtown jobs, CBD parking spaces per 1,000 employees, amount of off-street and on-street CBD parking, percentage of "free" off-street parking, average daily and monthly off-street parking fees, differentiation between city and privately owned parking facilities, on-street parking average meter rates, and maximum on-street parking time limits allowed. Selected data for the respective cities are reproduced in Table 18-12.

The self-administered nature of the survey from which Table 18-12 is derived introduces inevitable definitional inconsistencies for parameters such as extent of the CBD, used in calculating most values. Probably for this reason, some of the absolute values such as jobs in the CBD differ significantly from those in other sources. Relative values will also be affected, although less so. Despite these limitations, from this information it is possible to begin to look at the relationships between parking supply, parking cost, and travel behavior at a single point in time.

The cities in Table 18-12 are arranged in order of SOV share for commute trips, from lowest SOV share (New York City, 11 percent) to highest (Greenville, 99 percent), as shown. A simple correlation matrix was prepared from the data showing relationships among some 21 of the variables. Table 18-13 summarizes the correlation coefficients for transit, HOV, and SOV mode shares, and for monthly off-street parking rates, for selected factors. All variables, except metropolitan area population, pertain to the central city CBD.

Table 18-12 Urban Area, Modal Split, and Parking Characteristics for 17 U.S. CBDs

Name of City	New York, NY	Pittsburgh, PA	Philadelphia, PA	San Francisco, CA	Tempe, AZ	Madison, WI	Santa Barbara, CA	Phoenix, AZ
Metro Area Population	19,000,000	2,300,000	5,182,705	5,200,000	155,000	259,491	90,000	2,100,000
CBD Employment	1,020,424	140,000	287,869	198,000	7,700	28,850	27,900	25,000
Modal Split (Weekday Work Trips to CBD)								
SOV	11.0%	32.0%	36.0%	38.5%	70.0%	71.0%	71.6%	72.0%
Carpool	5.0%	20.0%	11.9%	11.5%	5.0%	13.0%	6.8%	8.0%
Transit	72.0%	45.0%	44.2%	38.5%	5.0%	5.0%	3.8%	20.0%
Bike, Walk, Other	12.0%	3.0%	7.9%	11.5%	20.0%	11.0%	17.8%	n/a
Total Off-Street Spaces in CBD	168,999	42,000	51,762	57,600	7,450	33,000	8,693	23,300
Number of Off-Street Spaces per 1,000 Employees	166	300	180	291	968	1,144	312	932
Pct. of Off-Street Parking Free	2%	0%	18%	0%	91%	0%	33%	0%
Number of Off-Street Spaces Owned by City	2,960	7,000	4,603	11,378	300	3,394	2,538	7,044
Pct. of Off-Street Parking Owned by City	2%	17%	9%	20%	4%	10%	29%	30%
Carpool Preferential Parking at City-Owned Facilities	No	No	No	Vanpool only	Yes	Yes	Yes	Yes
Average Monthly Parking Charges, City-Owned Parking	$288.25	n/a	$150.00	$250.00	n/a	$95.00	$40.00	$33.00
Avg. Daily Parking Charges, City-Owned Parking	$19.81	n/a	$7.16	$11.00	$5.00	$5.20	$9.00	$4.00
Average Monthly Parking Charges, Non-City Facilities	$188.00	n/a	$170.00	$250.00	$34.75	$95.00	$75.00	$55.00
Avg. Daily Parking Charges, Non-City Facilities	$13.46	n/a	$8.41	$9.00	$7.50	n/a	$11.00	$5.75
Minimum Parking Requirements for New Developments	1:4k	None	Not Specified	None	5:1k Ret. 4:1k Ofc. 2.9:1k Com'cial.	None Required; Needs	1:5k	None
Maximum Parking Limitations on New Developments	100 sp. Max. for Com'cial.	None	Not Specified	Max. 7% of floor area	No Restriction	Negotiated	n/a	n/a
Number of On-Street Parking Spaces in CBD	50,494	400	9,813	n/a	500	1,100	1,933	2,250
Number of On-Street Spaces per 1,000 Employees	49	3	34	n/a	65	38	69	90
On-Street Parking Spaces as a Percentage of Off-Street Spaces	30%	1%	19%	n/a	7%	3%	22%	10%
Total of Off/On-Street Spaces per 1,000 Employees	215	303	214	n/a	1,033	1,182	381	1,022
Street Meter Charge, *per hour*	$1.50	$2.00	$1.00	$1.50	$0.75	$0.75	n/a	$0.60
Street Meter Charge, 10 hours	$15.00	$20.00	$10.00	$15.00	$7.50	$7.50	n/a	$6.00
On-Street Max. Time (Hours)	1.0	10.0	3.0	1.0	1.33	2.0	1.5	8.0

Note 1: In "…Requirements…" descriptions, "~:~k" = parking spaces per (000) square feet of floor area.

Table 18-12 Urban Area, Modal Split, and Parking Characteristics for 17 U.S. CBDs (continued)

Name of City	Indian-apolis, IN	San Jose, CA	Santa Cruz, CA	San Anton-io, TX	Char-lotte, NC	Winston -Salem, NC	Bil-lings, MT	Fon-tana, CA	Green-ville, SC
Metro Area Population	1,462,000	850,000	55,000	1,115,600	500,000	171,000	90,000	108,000	60,000
CBD Employment	106,000	21,000	5,000	63,000	48,000	20,000	n/a	2,500	17,000
Modal Split (Weekday Work Trips to CBD)									
SOV	74.0%	74.3%	80.0%	80.0%	84.0%	90.0%	91.5%	92.0%	99.0%
Carpool	18.0%	18.0%	3.0%	15.0%	10.0%	1.5%	1.0%	2.0%	0.5%
Transit	6.0%	3.1%	10.0%	3.3%	6.0%	8.0%	7.5%	6.0%	0.5%
Bike, Walk, Other	2.0%	4.6%	2.0%	1.7%	n/a	0.5%	n/a	n/a	n/a
Total Off-Street Spaces in CBD	51,100	23,700	3,663	30,000	39,604	15,000	3,833	250	16,226
Number of Off-Street Spaces per 1,000 Employees	482	1,129	733	476	825	750	n/a	100	954
Pct. of Off-Street Parking Free	n/a	0%	40%	0%	n/a	10%	0%	100%	80%
Number of Off-Street Spaces Owned by City	0	1,165	1,976	7,600	0	6,375	2,179	250	5,366
Pct. of Off-Street Parking Owned by City	0%	5%	54%	25%	0%	42%	57%	100%	33%
Carpool Preferential Parking at City-Owned Facilities	None	No	Yes	No	Yes	Yes	No	Yes	No
Average Monthly Parking Charges, City-Owned Parking	n/a	$60.00	$23.00	$40.00	n/a	$47.00	$27.50	n/a	$40.00
Avg. Daily Parking Charges, City-Owned Parking	n/a	$12.00	$2.50	$6.00	n/a	$6.00	$3.00	n/a	$5.00
Average Monthly Parking Charges, Non-City Facilities	$68.00	n/a	n/a	$60.00	$60.00	$50.00	$26.75	n/a	$25.00
Avg. Daily Parking Charges, Non-City Facilities	$4.55	n/a	n/a	$5.00	$5.75	$5.38	$2.75	n/a	n/a
Minimum Parking Requirements for New Developments	None	n/a	1:400 sf. GLA	None	0.5:1k, + 0.25:1k over 200k; 500k; 800k	None	n/a	1 space per 200 sf.	None
Maximum Parking Limitations on New Developments	None	n/a	No Limit	None	None	n/a	n/a	None	None
Number of On-Street Parking Spaces in CBD	4,200	1,000	1,435	2,000	500	1,500	1,071	350	733
Number of On-Street Spaces per 1,000 Employees	40	48	287	32	10	75	n/a	140	43
On-Street Parking Spaces as a Percentage of Off-Street Spaces	8%	4%	39%	7%	1%	10%	28%	140%	5%
Total of Off/On-Street Spaces per 1,000 Employees	522	1,176	1,020	508	835	825	n/a	240	998
Street Meter Charge, *per hour*	$0.75	$0.75	$0.45	$0.30	$1.00	$0.30	$0.10	$0.00	$0.00
Street Meter Charge, 10 hours	$7.50	$7.50	$4.50	$3.00	$10.00	$3.00	$0.10	$0.00	$0.00
On-Street Max. Time (Hours)	2.0	2.0	12.0	10.0	2.0	10.0	10.0	2.0	2.0

Note 2: Self-administered survey data (see text for discussion of data limitations).

Source: Urban Transportation Monitor (Oct. 24 and Nov. 7, 1997); augmentation by Handbook authors.

Table 18-13 Selected Correlation Coefficients for Area Population, CBD Employment, Parking Supply, Parking Pricing, and Travel Mode Shares in 17 U.S. CBDs

Factor	Transit Share	HOV Share	SOV Share	Parking Rates
Metropolitan Area Population	0.87	0.01	-0.80	0.68 to 0.86
CBD Employment	0.85	0.00	-0.79	0.63 to 0.83
Total Spaces/1,000 Employees	-0.49	0.02	0.39	-0.42 to -0.45
Monthly Off-Street Parking Rates				
City-owned facilities	0.89	0.18	-0.92	
Non-city-owned facilities	0.82	0.31	-0.89	
Percent Off-Street Parking Free	-0.37	-0.55	0.40	
Percent Owned by City	-0.29	-0.60	0.49	

Note: Correlation reflects the degree of relatedness between two variables where a correlation coefficient of 1.0 indicates that the two items are perfectly related, and 0.0 indicates no relationship. A negative ("-") coefficient means that the two quantities are inversely related.

Key apparent relationships evident from the correlation coefficients — indicated in the text by the symbol "*r*" — include the following:

Transit Use. Transit's modal share increases with CBD employment (r = 0.85) and monthly parking rates (r = 0.82 to 0.89). It decreases with supply as measured by parking spaces per 1,000 employees (r = -0.49).

HOV Use. HOV modal share shows essentially no relationship to either CBD employment or to parking spaces per 1,000 employees (r = 0.00 to 0.02) but increases moderately with monthly parking costs (r = 0.18 to 0.31).

SOV Share. The SOV share decreases as CBD employment increases (r = -0.79) and as monthly parking rates increase (r = -0.89 to -0.92). It increases with the parking spaces per 1,000 employees (r = 0.39).

Other points of interest are that:

- Relationships with metropolitan area population are very similar to those with CBD employment.
- Relationships with percent off-street parking that is free are less strong than those for monthly parking fees, but operate in the same direction.
- Relationships with percent off-street parking that is city owned are similar to percent free (city-owned parking is often priced lower than non-city-owned parking).

The correlation analysis supports the existence of a relationship between scarcity of parking and parking prices, as shown in the last column of Table 18-13. Higher parking costs (and prices) often reflect higher land values and scarcity, as found in CBDs with large employment concentrations. The correlation between CBD employment and monthly parking charges proves to be substantial (r = 0.63 to 0.83). The relationship between parking availability (measured here as spaces per 1,000 employees) and monthly parking fees is also significant though not quite as strong (r = -0.42 to -0.45); the fewer the parking spaces per 1,000 employees, the higher the price of parking to the user.

Overall, the most important factor influencing modal choice appears to be parking price. The strongest relationships are with monthly off-street parking fees, with daily fees (not shown in Table 18-13) fairly close behind. Parking supply also has an important, although less visibly strong, effect. The role of parking supply in establishing parking prices needs to be factored into the evaluation. While the scarcity of parking apparently isn't the most directly compelling signal to travelers, the higher prices it seemingly induces produce the signal that most influences mode choice.

Mode Share Outcomes

Observations of actual mode share outcomes for workplace parking management and for a parking lot closure example are presented in the "Related Information and Impacts" section under "Travel Choices After Parking Supply Modification." Parking fees — shown to be closely related to parking supply — clearly play a significant role in mode choice decisions, the outcome of which has been better measured. Consult Chapter 13, "Parking Pricing and Fees," for material on the impact of parking fees on mode choice. In particular, see Tables 13-3, 13-11, 13-12, 13-13 and 13-21 for empirical mode shift or mode share comparison data covering at least the SOV, carpool, and transit modes.

Income and Time/Cost Tradeoffs

Because the value of a travelers' time increases with income, the effects of parking supply management will be somewhat dependent on income levels in the target population. Given a choice of parking for free and walking some distance to one's destination (or using an alternative mode of travel), versus paying a fee for parking at a convenient location, travelers can be expected to choose based on their ability to pay, the premium they place on convenience, and their corresponding value of time. In general, it would be logical that travelers with more modest incomes — for whom money is more scarce than time — would opt for lower priced, further away parking, or alternative modes, while higher income travelers would prefer to pay for the convenience of parking near by.

No income-stratified evaluations of traveler response to parking supply restrictions have been located. Chapter 13, "Parking Pricing and Fees," reports on model-based analyses of differential effects of parking pricing on mode choice, by income quintile. See "Income" under "Underlying Traveler Response Factors" in Chapter 13, including Table 13-18.

Travel demand and parking location modeling does, however, provide support for the general proposition that it is the closer-in (and more expensive) spaces that will be taken by those with a high sensitivity to time costs, and vice versa. For example, an analysis using Toronto data calculated a parking price point elasticity of -0.33 for parking in the block next to one's destination, with progressively *higher* price elasticities for blocks further removed from the desired destination. Furthermore, this indication of increasing sensitivity to price with greater distance from the destination was paired with decreasing parking elasticities with respect to time, i.e., decreasing sensitivity to time costs. Similarly, an analysis using Chicago data estimated that a 50 percent overall parking price increase would decrease the percentage of parking in the block next to the desired destination, not affect the percentage of parking one block removed, and increase the percentage of parking three blocks away. Both evaluations indicate a substantial tendency for change in parking location choice in the face of parking management actions (Feeney, 1989).

More recent disaggregate cross-sectional modeling focused on Toronto central area work trip mode choice has produced both parking price elasticities and parking walk time to destination elasticities in the vicinity of unity (-1), the line of demarcation between inelastic and elastic response. These particular results are neither stratified by income nor proximity of parking to desired destination (Miller, 1993). Nevertheless, these findings lend further support to the existence of a highly fluid trade-off between parking price and spatial separation between parking and desired destination, which could be easily tipped one way or the other by the traveler's income.[5]

Peripheral Parking Tradeoffs

Parking on the periphery of a CBD or activity center represents the extreme case of separation between parking location and desired destination, aside from remote park-and-ride or kiss-and-ride facilities. Use of such cheaper parking may entail walking or using transit/shuttle service in order to hold down costs yet still be able to drive.

The "Time/Cost Tradeoffs" discussion above, identifying higher sensitivity to price with greater removal from the desired destination, leads to the inference that users of peripheral parking should be especially sensitive to cost. It has been noted that users of peripheral lots do not have the opportunity to avoid congestion on routes leading to the CBD or to significantly decrease vehicle operating costs, leaving downtown parking saturation and cost as the primary inducements to park in peripheral lots (Deen, 1965; Ellis, Burnett and Rassam, 1971). Many if not most peripheral parking failures have been attributed to insufficient user cost savings over core area parking to justify the extra time or inconvenience incurred.

Although some peripheral lots have been successful in charging a nominal parking fee, the level of the parking charge has affected usage. Increasing the fee from 25¢ to 50¢ in Cleveland (in the 1960s) after peripheral parking had been in use for several months reduced the volume of autos parked at one lot from 2,200 to 1,500, an implied arc elasticity of -0.55. Usage declined from 365 to 310 in Atlanta, when after a similar time period the combined transit and parking charge increased from 50¢ to 75¢, representing an elasticity of -0.40 (Ellis, Burnett and Rassam, 1971). Compared to the not well established but generally accepted parking price elasticity of -0.3 for areawide downtown parking price changes in general, these peripheral parker sensitivities to cost are higher, but still within the "inelastic" range. (See Chapter 13, "Parking Pricing and Fees," under "Response by Type of Strategy" — "Changes in Overall Parking Rates" — "Areawide Tax or Surcharge" for discussion of areawide parking price elasticities.)

[5] At the same time, the sharply different parking price elasticity magnitudes produced by this investigation (compared to other findings) underscore the difficulty of drawing generalized conclusions from the values of parking elasticities, which may differ as much as anything because of definitional inconsistencies, differences in model structure, and possible data limitations and other methodological problems.

An illustration of the combined effect of time and cost savings in comparison to time loss and lesser savings is provided by a peripheral lot and shuttle service operated in Albany, New York, as a benefit to state employees. The operation was primarily in response to a long waiting list for parking spaces at state facilities. The $5.00 per month combined peripheral parking and shuttle cost compared to an average $14.00 monthly transit cost from the suburbs to downtown. An analysis by residential zone was performed comparing park/shuttle users, as a percentage of total employees, with the difference in travel characteristics between the park/shuttle and auto driver modes. Table 18-14 compares results from zones with a 20 percent or greater park/shuttle mode share to results from zones with less than a 2 percent park/shuttle mode share (Keck and Liou, 1976).

Table 18-14 Comparison of Albany, New York, Trip Characteristics for High and Low Peripheral Lot Park/Shuttle Mode Shares

Difference in Trip Characteristics with Peripheral Park/Shuttle Use	Zones with 20% or More Park/Shuttle Mode Share	Zones with 2% or Less Park/Shuttle Mode Share
Average Time Saving (loss) per Trip [a]	7 minutes	(4 minutes)
Average Cost Saving per Day [b]	$0.75 – 0.80	$0.25 – 0.30
Average Increase in Travel Distance	0.4 miles	2.7 miles
Average Park/Shuttle Mode Share	30%	1%

Notes: [a] Includes all walking and waiting time (not factored).

[b] Includes all out of pocket auto operating costs.

Source: Keck and Liou (1976).

Peripheral lot users in Cleveland were surveyed as to their perception of the cost and travel time differences between park/shuttle and their next best alternative. (The survey allowed respondents to report that their time or cost was the same either way.) Only 41 percent of those who would otherwise have traveled by auto and 28 percent of those who would otherwise have used transit perceived that they spent *either* more time *or* money using the peripheral lot. Among those who did perceive expenditure of more time or money, most who would otherwise have driven all the way were sacrificing time to save money (90 percent), while a majority of those who would otherwise have taken transit for the entire journey were accepting extra cost to save time (68 percent) (Ellis, Burnett and Rassam, 1971).

Short- Versus Long-Term Response

Practically all quantitative studies of parking management effects focus on travel impacts like mode shifts and changes in parking behavior; responses that can be made in the reasonably short term. Yet, when left with unsatisfactory choices and given time to adapt, travelers — or the entities they are traveling to and from — can be expected to consider more fundamental changes in their circumstances that would provide preferred travel conditions. In other words, commuters — or their employers — may shift their place of employment, and shoppers — or the businesses that seek their patronage — may seek alternative locations where parking is not overly restricted or priced.

Of course, businesses and households generally would not change location based entirely on issues related to parking supply. Workers will obviously choose jobs that provide them with the best opportunity, and employers will tend to locate where they have access to the pool of employees, services, contacts, and consumers they need. Similarly, shoppers may opt for the convenience of a shopping mall with abundant free parking for certain needs, but for special purchases, may well seek out stores not so easy to access. Similar examples may be drawn for other types of travel. Much depends on what factors are being balanced in the particular decision and how important driving and parking is to that decision.

The success of a parking supply management policy over the long run depends on three primary factors:

1. The inherent attractiveness and uniqueness (or "draw") of the place where parking is being managed.

2. The availability of quality travel alternatives, or more fundamentally, the extent to which accessibility is enhanced or impeded.

3. The ease with which travelers and the business community affected by the parking policy can evade it by moving or conducting the activity somewhere else.

Although no known empirical studies have quantified long term shifts in behavior in relation to parking supply management policies, a 1994 Dutch study offers some insights on parking management impacts through a model simulation. The analytic tool used was the "Teacher Friendly Transportation Program" (TFTP), developed at Delft University, the Netherlands, in 1991 as an education tool, and subsequently modified to address transportation and land use issues. The model calculates trip distribution and mode choice simultaneously, using feedback from land use. "Elastic" constraints in the model allow for modification of trip end totals to reflect change in land use patterns in response to accessibility changes (Hamerslag, Fricker and Van Beek, 1994).

The TFTP model was used to study the potential results of a parking and land use policy, known as the "ABC" location policy, introduced by the Dutch Ministries of Land Use and Transportation. The policy attempts to control the location of new employment in relation to the quality of public transportation. Businesses that generate large concentrations of work trips by individuals would be located in areas of good public transit service (A or B locations), while more industrially oriented activities would be located closer the road network (C locations) to facilitate goods movement. The A and B locations are areas with either "high-quality" or "good" transit service, respectively, while the C locations are easily reached by highway but are not well-served by transit. Maximum parking space ratios for these areas are set by national government targets: "A" locations in the city or designated urban districts are allowed 10 spaces per 100 employees; "A" locations elsewhere, 20 per 100; "B" locations in the city or designated urban districts, 20 per 100; and "B" locations elsewhere, 40 per 100. Parking supply is unrestricted in "C" areas.

Since implementation of the ABC policy is ultimately at the discretion of lower jurisdictions, the study authors were concerned with the question of whether patchwork implementation of these policies — or differences in enforcement — would work to increase the attractiveness and use of public transit, or whether imperfect implementation and/or enforcement would push urban activity away from the A or B locations to less restricted areas, and work to the detriment of transit use.

Two spatial scenarios were simulated, one "fixed" where the spatial distribution of land use would not change under the influence of the ABC policy, and one "elastic" where it would change. Additionally, analyses were framed where parking enforcement would either be restrictive or lax, characterized as small overflow or large overflow of parking into adjacent zones (Hamerslag, Fricker and Van Beek, 1994). (A real-world example of parking overflow would be the problem Portland, Oregon, was having with commuters beginning to park in areas adjacent to the CBD, where parking supply was not as tightly managed. This was viewed in Portland as defeating the intent of the policy to shift more trips onto transit (K.T. Analytics, 1995), and was one of the justifications for extension of the parking management concept to a broader area of the city.)

The results of the Dutch analyses are presented in Tables 18-15 and 18-16. The study authors did not speculate as to what might cause one or the other of the two spatial scenarios. Interpreting the scenarios in the context of U.S. law and practice, it seems reasonable to represent the unchanging land use distribution as a short term scenario, and the changing distribution as a possible long term outcome. The tables are so labeled.

Table 18-15 Modeled Short-Term Effects of the Netherlands' "ABC" Parking Policy

	Modes Selected with Alternative Parking Overflow Assumptions				
Mode	**Base**	**Large Overflow**	**% Change**	**Restricted Overflow**	**% Change**
Auto Driver	240,015	239,882	-0.06%	221,533	-7.70%
Auto Passenger	24,477	24,463	-0.06%	22,618	-7.59%
Public Transit	24,203	24,379	0.73%	29,818	23.20%
Walk	77,802	77,759	-0.06%	81,864	5.22%
Bicycle	118,635	118,799	0.14%	129,880	9.48%

Notes: Interpretation of the "fixed" land use scenario as "Short-Term" is offered by the Handbook Authors.

Trip totals were fixed. The sums are not exactly the same due to rounding within the model.

Source: Hamerslag, Fricker and Van Beek (1994).

In the scenario taken to equate to the short-term, the analysis assumes that land use distributions remain fixed and that the only travel behavior responses are to shift mode or park in an adjacent jurisdiction. If parking enforcement is lax (large overflow), then the policy would only have a marginal effect in shifting travel mode, with transit mode share increasing by less than one percent and no other shares changing measurably. If parking enforcement is strict, then there is small overflow to adjacent zones, and predicted mode shifts are much more dramatic; estimated transit use increases by 23 percent, bike by 9 percent, and walk by 5 percent, as shown in Table 18-15.

In Table 18-16, which represents the analysis taken by the Handbook authors to equate to long-term conditions, land use patterns have been allowed to "respond" to the parking policy. Under the lax parking enforcement (large overflow) assumption, employment is predicted to shift away from zones with parking restrictions, but in moderation given the opportunity to "get around" the parking restrictions. While overall auto use declines, unfortunately so does transit ridership, contrary to the objectives of the "ABC" location policy. The parking restrictions lead to a decentralization of employment centers, which, in the Netherlands, would favor greater use of walking and bicycles, but makes public transit less practical to provide or use. Under the strict parking enforcement (restricted overflow) assumption, essentially all growth takes place within zones without restrictions; those not well served by transit. Auto use drops by 2 percent, because of non-motorized travel made feasible by shorter trips associated with decentralization, but transit ridership is decimated.

Table 18-16 Modeled Long-Term Effects of the Netherlands' "ABC" Parking Policy

	Modes Selected with Alternative Parking Overflow Assumptions				
Mode	**Base**	**Large Overflow**	**% Change**	**Restricted Overflow**	**% Change**
Auto Driver	240,015	237,686	-0.97%	235,414	-1.92%
Auto Passenger	24,477	24,265	-0.87%	24,116	-1.47%
Public Transit	24,203	22,610	-6.58%	13,810	-42.94%
Walk	77,802	80,525	3.50%	87,120	11.98%
Bicycle	118,635	120,358	1.45%	121,954	2.80%

Note: Interpretation of the "elastic" land use scenario as "Long-Term" is offered by the Handbook Authors.

Trip totals were fixed. The sums are not exactly the same due to rounding within the model.

Source: Hamerslag, Fricker and Van Beek (1994).

If strong land use controls prevent development shifts in response to restrictive parking, then the estimates in Table 18-15 would pertain, even though labeled "short term." The study concludes that strong parking policy and strong land use controls are both necessary to lead to higher transit ridership (Hamerslag, Fricker and Van Beek, 1994). If land use distribution is presumed to be inherently fluid in the long-term, as has been done in the interpretation added here, then the study results portend worrisome unintended consequences, particularly in an environment where greater distances overall make walking and bicycling less likely than in the Netherlands.

The quite different modal distribution characteristics of the Netherlands relative to North America, the completely synthetic nature of the modeling, and the imposition of "short-term" and "long term" characterizations onto the scenarios by the Handbook authors, all argue for using substantial caution in accepting the absolute shifts calculated in this "ABC" Parking Policy research. The findings serve a useful function, however, in highlighting the types of unintended consequences that might take place in response to incomplete or poorly executed policies, and providing some indication of the direction changes in travel choices might conceivably take. They suggest that strict parking controls may need to be suitably balanced with land use control (Portland, Oregon, has its urban growth boundary; San Francisco, its peninsular geographics) to avoid major risk of shifting investment to other locations.

RELATED INFORMATION AND IMPACTS

Characteristics of Parking Demand

The basic characteristics of parking demand, such as trip purpose, parking duration, daily turnover per space, vehicle accumulation, and walking distances incurred, provide important inputs to assessing and developing parking management actions. Full reports are devoted to this subject and associated parking facility design and operation issues. A summary of demand characteristics is provided here.

Central Business District Parking

A seminal presentation of CBD parking characteristics is that of Highway Research Board (HRB) *Special Report 125* (*SR 125*). The HRB Committee on Parking compiled and integrated results of CBD parking studies from 111 U.S. cities, stratified into seven population size ranges. The studies involved day-long, hour-by-hour interviews of parkers at the curb along each block and using each off-street parking facility (Committee on Parking, 1971). Given the never-since duplicated comprehensiveness of this analysis, key findings are reproduced here despite the 1960-68 age of the data.

As potentially instructive as are the relationships displayed, such as clear progression in certain characteristics from small to large urbanized areas, the information from *SR 125* must be utilized with substantial caution. CBD parking characteristics have been affected, in the intervening years, by major shifts in certain types of business, especially retail, away from CBDs to suburban shopping centers, strips, malls, and edge cities. The effect is likely to be strongest on trip purpose distributions and on the parking characteristics averages most directly affected by the trip purpose mix.

The concern is arguably greatest in the case of smaller cities. The *SR 125* small city data are thought to reflect patterns of commercial activity no longer prevalent on the American scene, except in instances where a high level of downtown retail activity has been preserved or restored. Even there, it should be understood that the *SR 125* parking data were most likely obtained on 1960s weekdays selected as being typical, i.e., those weekdays with essentially no evening retail store hours. Reflecting this concern, *SR 125* data for the three smallest city ranges (10,000-25,000, 25,000-50,000, and 50,000-100,000) have been consolidated into one 10,000-100,000 range in the tables provided here, as indicated in table footnotes.

Where consistency of data categories allows, more recent study results from individual cities have been spliced in to facilitate comparison and to provide context for the sparse newer findings. Of particular interest are the data for Portland, Oregon, which has had particularly tight control of CBD parking since 1975. The Portland experience was examined earlier in this chapter under "Response By Type Of Strategy" — "Maximum and Minimum Parking Requirements" — "Maximum Parking Ratios and Minimum Ratio Reductions," and is described further in the case study "CBD Parking Supply Management in Portland, Oregon."

Trip Purpose. A major determinant of parking characteristics is trip purpose. The duration of the parking associated with the trip is related to its purpose, and the duration in turn affects the choice of facility and the walking distance acceptable to the parker (Committee on Parking, 1971). Table 18-17 presents information on the distribution of travel purposes among CBD parkers. It is the older information in this particular table to which the cautions advised above most strongly pertain.

Table 18-17 Trip Purpose Distributions in Percentages of All Parkers Using All Types of CBD Parking

City [a]	Urbanized Area Population [b]	Study Year(s) [c]	Work	Shop-ping	Personal Business	Other	Other Incl. Pers. Bus.
Population Group	10,000-100,000 [d]	1960-68	20%	30%	30%	20%	50%
Population Group	100,000-250,000	1960-68	26	21	34	19	53
Charlotte, NC	*351,000*	*1987*	*72*	*3*	*n/a*	*n/a*	*25*
Population Group	250,000-500,000	1960-68	30	19	33	18	51
Jacksonville, FL	*598,000*	*1981*	*41*	*7*	*38* [e]	*14*	*52*
Winston-Salem, NC	*830,000*	*1980*	*35*	*15*	*n/a*	*n/a*	*50* [f]
Population Group	500,000-1,000,000	1960-68	47	13	25	15	40
Milwaukee, WI	*1,207,000*	*1972*	*59*	*5*	*n/a*	*n/a*	*36*
Cleveland, OH	*1,752,000*	*1978*	*40*	*10*	*n/a*	*n/a*	*40 (sic)*
Baltimore, MD	*1,755,000*	*1989*	*39*	*11*	*n/a*	*n/a*	*50*
Boston, MA	*2,679,000*	*1972*	*36*	*15*	*23*	*26*	*49*
Population Group	Over 1,000,000	1960-68	41	10	30	19	49

Notes: [a] Data summarized by population group was compiled by the HRB Committee on Parking from studies made between 1960 and 1968 in 111 U.S. cities. Data for individual areas, shown in italics, are more recent. Urbanized area data in Weant and Levinson from the 1960-68 period are assumed to be duplicative and are thus not individually shown here.

[b] Based on 1960 Census in the case of population group ranges; 1980 Census in the case of individual urbanized areas.

[c] Relationships shown by the older data may reflect conditions prior to shifts in retail and services to suburban locations.

[d] The 1960s data for city population groups 10,000-25,000, 25,000-50,000 and 50,000-100,000 (arguably the must susceptible to shifts over time) have been combined by simple averaging of HRB Committee on Parking findings across the three groups in question.

[e] Nature of business (personal or otherwise) not specified.

[f] Identified as "on business." Note that population includes Greensboro and High Point.

Sources: Committee on Parking (1971), Weant and Levinson (1990), Wilbur Smith (1974), ITE (1992).

It is not known to what extent smaller cities any longer exhibit the higher prevalence of shopping clearly reflected in the *SR 125* data. The newest observations hint that the reverse condition may now hold, but the data is far too thin for any certainty. The very high work purpose percentage for Charlotte is probably not representative given that city's particularly strong retention and attraction of CBD office uses paired with no retention of major CBD retail. The limited comparisons available do suggest that changes over time in larger cities may be more muted and of less concern in drawing inferences from the *SR 125* and other older data.

A detailed breakdown of CBD parking characteristics in downtown Boston is provided in Table 18-18. The table indicates that while 36 percent of the parkers were making work purpose trips, these workers accounted for 63 percent of the peak parking accumulation.

Table 18-18 Boston CBD Parking Characteristics Including Trip Purpose Distributions for All Parkers and for Parkers at Peak Accumulation

Parameter	Purpose	Work Manager	Work Employee	Personal Business	Sales	Service	Recreational	Shopping	Other	Total
All Parkers										
Number		3,535	25,732	18,799	3,874	4,203	2,512	12,694	10,576	81,925
Percent		4.3%	31.5%	22.9%	4.7%	5.1%	3.1%	15.5%	12.9%	100.0%
Maximum Accumulation (12:00 PM)										
Number		2,658	20,188	3,935	1,246	994	540	3,012	3,547	36,120
Percent		7.3%	55.9%	10.9%	3.4%	2.8%	1.5%	8.3%	9.9%	100.0%
Average Duration (Minutes)		330	359	126	134	129	138	117	192	280
Percent Arriving by 9:30 AM		66.2%	74.2%	15.1%	19.7%	18.5%	10.5%	0.5%	28.7%	45.5%
Average Auto Occupancy		1.31	1.34	1.43	1.20	1.31	2.04	1.67	1.45	1.42
Average Walking Distance (Feet)		823	993	844	773	717	964	800	1,174	895

Source: Wilbur Smith and Associates Field Surveys, 1972, as presented in Wilbur Smith (1974).

The distribution of parker trip purposes in the Portland, Oregon, CBD during the period of peak parking accumulation, 11:00 AM to 1:00 PM (TDA Inc., 1988), is shown in Table 18-19. Of peak parkers, 64 percent were making home-based work trips, a figure generally consistent with the 63 percent value summed from Table 18-18 for Boston "managers" and "other employees."

Table 18-19 Trip Purpose Distribution and Average Auto Occupancies of CBD Parkers at Peak Accumulation in Portland, Oregon

Trip Purpose	Percentage at Peak Accumulation	Auto Occupancy
Home Based Work (HBW)	64%	1.22
Home Based Other (HBO)	11%	1.38
Home Based Entertainment	1%	1.9
Home Based Shopping	2%	1.5
Home Based School	4%	1.2
Home Based Personal Business	3%	1.4
Non-Home Based (NHB)	25%	1.30
All Trip Purposes	100%	1.26

Notes: The HBO percentage has been allocated to HBO subcategories, by the Handbook authors, proportional to unadjusted breakouts in source document backup tabulations.

HBO subcategory auto occupancies have been calculated by deriving and applying an HBO adjusted/unadjusted occupancy factor to auto occupancy breakouts in backup tabulations.

Source: TDA Inc. (1988), with additional subcategory calculations by the Handbook authors.

The Portland, Oregon, trip purpose shares in Table 18-19 cannot be compared directly with the information in Table 18-17, since the Portland data are for parkers at peak accumulation only, while Table 18-17 pertains to all individual parkers during the all-day survey period, typically 9 or more hours. A further complication is that the non-home-based (NHB) percentage for Portland would have to be allocated to other purposes for direct comparison. However, an approximation utilizing conversion factors presented later in Table 18-26 suggests that the 1988 split between work purpose and non-work parking for Portland is little different than for the corresponding city size category in 1960-68, despite the quarter-century time separation and Portland's parking controls. This consistency may reflect Portland's successful pursuit of their goal to retain and revitalize a major downtown retail presence.

Comparison between the 1988 Portland and 1972 Boston data in Tables 18-19 and 18-18, respectively, is less problematical, yet there are still trip purpose definitional differences to contend with. Correction might make the work purpose percentages not quite as close as they appear, but they are nevertheless similar. Note that the Portland and Boston trip purpose data in these tables are accompanied by average auto occupancies.

Parking Duration. Table 18-20 presents averages of length of time parked (parking duration) for all trips and for individual trip purposes. Here the shorter duration of non-work trips can be clearly seen. Table 18-21 classifies parking activity by ranges of duration and gives percentage distributions of these ranges.

Table 18-20 Length of Time Parked (Hours) in CBD Spaces Averaged by Trip Purpose

City [a]	Urbanized Area Population [b]	Study Year(s)	Work	Shop-ping	Personal Business	Average All Trips
Population Group	10,000-100,000 [c]	1960-68	3.5 hours	0.6 hours	0.6 hours	1.2 hours
Population Group	100,000-250,000	1960-68	4.3	1.3	0.9	2.1
Charlotte, NC	*351,000*	*1987*	*n/a*	*n/a*	*n/a*	*6.7*
Population Group	250,000-500,000	1960-68	5.0	1.3	1.0	2.7
Jacksonville, FL	*598,000*	*1981*	*n/a*	*n/a*	*n/a*	*3.6*
Population Group	500,000-1,000,000	1960-68	5.9	1.5	1.7	3.0
Portland, OR	*1,050,000*	*1988*	— [d]	— [d]	— [d]	*6.2*
Cleveland, OH	*1,752,000*	*1978*	*n/a*	*n/a*	*n/a*	*4.3*
Baltimore, MD	*1,755,000*	*1989*	*n/a*	*n/a*	*n/a*	*3.6*
Boston, MA	*2,679,000*	*1972*	*5.9*	*2.0*	*2.1*	*4.7*
Population Group	Over 1,000,000	1960-68	5.6	1.1	1.1	3.0

Note: [a] See Note "[a]," Table 18-17.

[b] Based on 1960 Census in the case of population group ranges; 1980 Census in the case of individual urbanized areas.

[c] See Note "[d]," Table 18-17.

[d] Home Based Work (HBW), 8.1; Home Based Other (HBO), 3.6; Non-Home Based (NHB), 2.7; all Portland values are weighted averages computed from sector data in TDA Inc. (1988) by the Handbook authors, and are derived from a full 12-hour survey.

Sources: Committee on Parking (1971), Weant and Levinson (1990), TDA Inc. (1988), Wilbur Smith (1974).

Table 18-21 CBD Parking Activity Classified by Hours Parked (in Percentages)

Urbanized Area Population Group (1960 Census)	0 to 0.5 Hours	0.5 to 1 Hours	1 to 2 Hours	2 to 5 Hours	Over 5 Hours
10,000-100,000 [a]	60%	15%	10%	10%	6%
100,000-250,000	46	14	11	13	16
250,000-500,000	38	15	17	15	15
500,000-1,000,000	24	12	13	18	33
Over 1,000,000	16	12	20	12	40

Note: Compiled from parking studies in 111 U.S. cities made between 1960 and 1968. Parking duration is in part a function of trip purpose, and this older data may reflect conditions prior to shifts in retail and services to suburban locations and corresponding changes in trip purpose mix.

[a] See Note "[d]," Table 18-17.

Source: Committee on Parking (1971).

The overall averages and the percentage distributions are subject to the same age-of-data issues raised above because changes in the mix of purposes, and thus the mix of short- and long-term parking, may affect overall averages and duration distributions. Reported average parking durations, especially for work trips and all trips, may also be affected by survey duration. For example, a 12-hour survey such as taken in Portland, Oregon (TDA Inc., 1988), is more likely to pick up the full duration of long-term parking than observations for a shorter period, such as the 9-hour time span reported in *SR 125* (Committee on Parking, 1971).

Parking Turnover. Length of time parked (duration) combines with intensity of demand for parking to determine how many cars per day can and will be accommodated by a single parking space. Turnover is the number or cars actually accommodated per parking space during the time span of the survey used to obtain the data. Table 18-22 provides average parking space turnover rates for different types of parking, clearly illustrating that the primary role of curb spaces is to supply short-term parking, associated with high turnover. Conversely, off-street parking is shown to be more oriented to long-term parking with its necessarily lower turnover.

Table 18-22 CBD Parking Turnover Rates Classified by Type of Facility

Urbanized Area Population Group (1960 Census)	Curb Parking				Off-Street Parking		
	Metered	Special	Posted	Average	Lot	Garage	Average
10,000-100,000 [a]	7.8 [b]	2.8 [b]	3.7 [b]	6.4	1.7	0.6	1.6
100,000-250,000	8.1	3.1	4.4	5.7	1.6	1.0	1.5
250,000-500,000	7.1	2.5	3.3	5.2	1.4	1.1	1.4
500,000-1,000,000	6.6	1.1	3.9	4.5	1.2	1.4	1.2
Portland, OR (1,050,000 in 1980)	*n/a*	*n/a*	*n/a*	*4.5*	*n/a*	*n/a*	*1.4*
Boston, MA (2,679,000 in 1980)	*n/a*	*n/a*	*n/a*	*3.3* [c]	*1.4*	*1.1*	*1.2*
Over 1,000,000	5.5	3.6	2.9	3.8	1.1	1.0	1.1

Notes: Parkers per space during the weekday survey period, compiled from parking studies in 111 U.S. cities made between 1960 and 1968, excepting the data for Boston, MA, and Portland, OR, (in italics), which are from 1972 and 1988 surveys, respectively. Parking duration and turnover are in part a function of trip purpose, and the older data may reflect conditions prior to shifts in retail and services to suburban locations, and corresponding changes in trip purpose mix. Off-street parking turnover may also be affected by possible shifts over time in the mix of attendant and self-park facilities. Turnover rates may be slightly elevated in the case of longer than typical surveys, such as the full 12-hour Portland survey.

[a] See Note "[d]," Table 18-17.

[b] 50,000-100,000 population group only (average 6.1 for curb parking).

[c] Legal curb spaces only (5,869 in number including truck and taxi spaces). Turnover for illegal curb spaces (8,420 in number) was 2.6.

Sources: Committee on Parking (1971), TDA Inc. (1988), Wilbur Smith (1974).

The 1988 findings for Portland exhibit consistency with the 1960-68 averages by population range, particularly when the full 12-hour duration of the Portland study — which would tend to increase turnover values slightly — is taken into account.

Additional data from the Boston 1972 survey highlights the association between curb parking, short duration, high turnover, and use of curb parking by non-work purpose trip makers. The percentage of non-work purpose trips utilizing parking in Boston was found to be 76.8 percent non-work for legal curb spaces, 40.7 percent for lots, and 46.7 percent for garages. Average parking duration was determined to be 2.5 hours for legal curb spaces, 5.3 hours for lots, and 5.0 hours for garages. Corresponding turnover rates, given in Table 18-22, reflect not only these parameters but also a lower utilization of garages relative to lots and legal curb spaces found in the Boston survey (Wilbur Smith, 1974).

Table 18-23 provides overall average parking turnover rates for individual cities, assembled for a sample of spaces in 1990, with Portland, Oregon, inserted. The order of listing is from lowest to highest reported turnover rate. A very low rate such as that reported for Phoenix reflects oversupply of parking relative to demand. A higher rate — after discounting any rate inflation attributable to longer-than-typical survey duration — reflects some combination of shorter average parking duration, and higher intensity of demand. In effect, a higher turnover rate is an indicator of more efficient use of parking space.

Table 18-23 CBD Parking Space Turnover for Selected Cities

City	Number of Spaces Surveyed	Number of Vehicles Parked [a]	Turnover Rate [b]
Phoenix	2,919	2,055	0.70
Denver	3,704	3,945	1.07
Washington, DC	10,401	12,433	1.20
Houston	9,347	11,363	1.22
Cleveland	4,358	5,430	1.25
Indianapolis	3,492	4,553	1.30
Milwaukee	2,576	3,470	1.35
St. Louis	5,031	7,027	1.40
Detroit	7,212	10,119	1.40
Los Angeles	10,223	14,726	1.44
Seattle	2,193	3,160	1.44
Philadelphia	1,111	1,610	1.45
Baltimore	1,991	2,912	1.46
Columbus	1,263	2,087	1.65
Portland	41,514	75,500	1.82
Boston	2,422	4,530	1.87
Chicago	22,674	45,116	1.99
San Francisco	10,191	24,665	2.42
Pittsburgh	2,729	7,510	2.75

Note: [a] Number of vehicles parked during the weekday survey period.

[b] Parkers per space during the weekday survey period, ordered from lowest to highest.

Source: Institute of Transportation Engineers, *Technical Notes* (April, 1981) as presented in Weant and Levinson (1990), TDA Inc. (1988).

Note that Table 18-23 gives the number of spaces surveyed. Normally, other things being equal, a CBD survey covering a smaller number of spaces will exhibit a somewhat elevated turnover rate because of excluding observations outside the central core of highest parking demand. The examples in this table exhibit an average turnover rate of approximately 1.5, suggesting that two spaces are being provided to accommodate every three parked cars in the average CBD.

Parking Accumulation. Table 18-24 illustrates how parking space occupancy accumulates and disperses, building up in the early part of the weekday and tapering off as the afternoon wanes. Although dated, these data probably give a fairly accurate representation of parking patterns even today, at least in the sense of parking in any given hour relative to other hours.

Table 18-24 Hourly CBD Parking Accumulation as Percentages of Parking Supply

Urbanized Area Population Group (1960 Census)	**10:00 AM**	**11:00 AM**	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM
10,000-100,000 [a]	54%	56%	52%	51%	54%	54%	52%	44%	24%
100,000-250,000	70	74	74	72	73	71	66	48	29
250,000-500,000	69	71	71	71	70	67	63	45	23
500,000-1,000,000	69	79	81	81	78	74	67	48	30
Over 1,000,000	77	74	75	75	75	74	68	48	26

Note: Compiled from parking studies in 111 U.S. cities made between 1960 and 1968.

[a] See Note "[d]," Table 18-17.

Source: Committee on Parking (1971).

Table 18-25 extracts the peak parking accumulation percentages from Table 18-24 and arrays them together with newer information assembled for individual cities. Parking supply and demand have both grown over time, yet the percentage of supply occupied at the time of peak CBD parking accumulation appears to be mostly independent of when the surveys were taken. The Needham Center observation presents an anomaly.

Table 18-25 illustrates that peak parking demand in cities of over 1,000,000 population tends to utilize 80 to 90 percent of the supply. Some number of empty spaces serve as a cushion to facilitate turnover and keep finding a space from becoming too difficult, with attendant adverse effects on street congestion. Empty spaces occur even with a tightly constrained parking supply because of inherent inefficiencies in both parking distribution and the search for spaces. The effective CBD parking maximum is generally regarded as being 85 to 90 percent of the total supply (Weant and Levinson, 1990). In Portland, Oregon, where parking peaks at 81 percent occupancy, parkers report driving 2.9 blocks on average seeking parking when making work purpose trips, and 8.3 blocks seeking parking for non-work trips. On-street spaces involve the longest average search distance, 9.9 blocks (TDA Inc., 1988).

Table 18-25 Peak CBD Parking Accumulation and Percentage of Parking Supply

City [a]	Urbanized Area Population [b]	Study Year(s) [c]	CBD Parking Supply	Peak Parking Accumulation	Percentage of Supply
Needham Ctr., MA	*29,000*	*1986*	*582*	*660* [d]	*114%* [d]
Population Group	10,000-100,000 [e]	1960-68	3,760	2,120	56
Population Group	100,000-250,000	1960-68	7,710	5,740	74
Charlotte, NC	*351,000*	*1987*	*29,900*	*20,701*	*69*
Population Group	250,000-500,000	1960-68	12,300	8,780	71
Nashville, TN	*518,000*	*1970*	*19,724*	*14,020*	*71*
Tampa, FL	*521,000*	*1983*	*20,841*	*17,740*	*85*
Jacksonville, FL	*598,000*	*1981*	*31,517*	*21,953*	*70*
Rochester, NY	*606,000*	*1977*	*22,231*	*16,935*	*76*
Memphis, TN	*775,000*	*1981*	*16,986*	*12,253*	*72*
Population Group	500,000-1,000,000	1960-68	22,600	18,200	81
Portland, OR	*1,050,000*	*1988*	*42,036*	*34,000*	*81*
Milwaukee, WI	*1,207,000*	*1972*	*30,707*	*28,142*	*92*
Cleveland, OH	*1,752,000*	*1978*	*53,912*	*39,700*	*74*
Baltimore, MD	*1,755,000*	*1989*	*38,636*	*31,129*	*83*
Dallas, TX	*2,451,000*	*1981*	*59,610*	*49,600*	*83*
Boston, MA	*2,679,000*	*1972*	*39,230*	*36,120*	*91*
Population Group	Over 1,000,000	1960-68	58,800	45,000	77

Note: [a] See Note "[a]," Table 18-17.

[b] Based on 1960 Census in the case of population group ranges; 1980 Census in the case of individual urbanized areas, except based on Scully (1988) in the case of Needham, MA.

[c] The older supply and accumulation data may present an understated representation of current parking supply and demand.

[d] Approximations derived from scaling of a percent utilization chart in Scully (1988).

[e] See Note "[d]," Table 18-17.

Sources: Scully (1988), Committee on Parking (1971), Weant and Levinson (1990), TDA Inc. (1988).

Ratios of peak parking accumulation to total daily parkers offer an approach to estimating peak demands. Table 18-26 provides two examples of such ratios. The study values in Table 18-26 suggest that it would on average take 220 to 250 parking spaces 100 percent full to accommodate 1,000 daily parkers attending to non-work purpose activities, but 770 to 780 spaces completely filled to serve 1,000 daily vehicles parked by persons going to work.

Table 18-26 CBD Ratio of Parkers in the Peak Accumulation to Total Daily Parkers by Trip Purpose

Southern Cities [a] (circa 1960-65)		Boston Study (1972 data)	
Trip Purpose	Ratio	Trip Purpose	Ratio
Work	0.77	Work	0.78
		Work Manager	0.75
		Work Employee	0.78
Non-Work	0.22 [b]	Non-Work	0.25
Business	0.18	Personal Business	0.21
Sales-Service	0.16	Sales	0.32
Load/Unload	0.11	Service	0.24
Shopping	0.26	Shopping	0.24
Other	0.22	Recreational	0.22
		Other	0.34
		All Purposes	0.44

Note: [a] Based on Chattanooga, Nashville, and New Orleans.

[b] It is not known exactly which subcategories are included within this non-work value.

Sources: Wilbur Smith (1965), "Boston Study" derived by Handbook authors from Table 18-18.

Walking Distances. Driving to and parking in a CBD incurs walking between available parking — or parking the motorist is willing to select based on price — and the ultimate destination. These walking distances, averaged over individual sectors of the CBD,[6] can reach or even exceed the corresponding average walking distances incurred by public transit riders. This is one of many reasons why transit tends to be relatively more competitive with the auto for travel to downtown than to most other destinations, especially in large cities.

Table 18-27 gives area-wide average walking distances to destinations for CBD parkers. The newer overall average values are generally consistent with the 1960-68 data from *SR 125*, suggesting that the averages available from *SR 125* for individual trip purposes are probably still sound. Table 18-28 provides relationships between length of time parked and parking space to destination walking distances. These relationships are only available from the older *SR 125* tabulations, but judging from the consistency noted in Table 18-27, are probably a fair representation of what might be expected even now.

[6] In other words, traffic analysis zones or small district aggregations thereof.

Table 18-27 Average Distance Walked (Feet) from Parking Space to CBD Destination Classified by Trip Purpose

City [a]	Urbanized Area Population [b]	Study Year(s)	Work	Shop-ping	Personal Business	Other	Overall Average
Population Group	10,000-100,000 [c]	1960-68	360 feet	280 feet	240 feet	220 feet	260 feet
Population Group	100,000-250,000	1960-68	500	470	390	340	420
Charlotte, NC	*351,000*	*1987*	*n/a*	*n/a*	*n/a*	*n/a*	*770*
Population Group	250,000-500,000	1960-68	670	570	450	380	550
Jacksonville, FL	*598,000*	*1981*	*n/a*	*n/a*	*n/a*	*n/a*	*285*
Population Group	500,000-1,000,000	1960-68	650	560	590	500	600
Portland, OR [d]	*1,050,000*	*1988*	— [e]	— [e]	— [e]	— [e]	*660*
Cleveland, OH	*1,752,000*	*1978*	*n/a*	*n/a*	*n/a*	*n/a*	*671*
Baltimore, MD	*1,755,000*	*1989*	*n/a*	*n/a*	*n/a*	*n/a*	*670*
Boston, MA	*2,679,000*	*1972*	*972*	*800*	*844*	*985*	*895*
Population Group	Over 1,000,000	1960-68	n/a	n/a	n/a	n/a	n/a

Notes: [a] See Note "[a]," Table 18-17.

[b] Based on 1960 Census in the case of population group ranges; 1980 Census in the case of individual urbanized areas.

[c] See Note "[d]," Table 18-17.

[d] All Portland, OR, distances are computed from blocks-walked data in TDA Inc. (1988) on the basis of a 264 foot average CBD street spacing.

[e] Portland, OR, distances walked averaged by trip purpose are Home Based Work (HBW), 720 feet; Home Based Other (HBO), 590 feet; and Non-Home Based (NHB), 540 feet.

Sources: Committee on Parking (1971), Weant and Levinson (1990), TDA Inc. (1988), Wilbur Smith (1974).

Table 18-28 Average Distance Walked (Feet) from Parking Space to CBD Destination Classified by Length of Time Parked

Urbanized Area Population Group (1960 Census)	0.5 to 1 Hours	1 to 2 Hours	2 to 5 Hours	Over 5 Hours
10,000-100,000 [a]	270 feet	300 feet	340 feet	420 feet
100,000-250,000	420	380	500	440
250,000-500,000	440	510	590	740
500,000-1,000,000	480	480	560	910
Over 1,000,000	520	560	680	900 [b]

Notes: Compiled from parking studies in 111 U.S. cities made between 1960 and 1968.

[a] See Note "[d]," Table 18-17.

[b] Estimated from limited sample.

Source: Committee on Parking (1971).

Suburban Single-Use Parking

Suburban parking may be classified into parking associated with more or less stand-alone building/land uses (single-use parking), and the parking associated with mixed land uses that has been specifically designed as shared parking. Single- or individual-use suburban parking is addressed briefly here. Shared parking serving mixed land uses is covered, together with relevant accumulation characteristics data, in the next section — "Shared Parking" — which encompasses both suburban and CBD applications.

Demand for the single-use parking associated with stand-alone developments has traditionally been analyzed as predominantly occurring in negligible transit use environments, with the implicit assumption of nominal ridesharing, no parking charges, and no special travel demand management activities. Public parking and particularly paid parking are relatively rare in most suburban development. Probably for this reason, little investigation has been made of characteristics such as parking duration and turnover. The primary emphasis has been on how many spaces are required to support a given amount of individual land use, and more recently, on how to minimize vehicle trip making.

Table 18-29 summarizes "parking generation" values standard to traffic planning practice, developed by the Institute of Transportation Engineers (ITE, 1987). The original source should be consulted for full detail. The table indicates the unit of measure for quantifying size of the development, and the demand in parking spaces per unit. Demand is given both in terms of averages and 85th percentile values observed for each general type of development. Parking design guidelines recommend using the 85th percentile and adding a 10 percent cushion or safety factor, in most cases, although perhaps not for residential development (Weant and Levinson, 1990). Retail malls are a special case because of the strong seasonal peaks (see Table 18-29, footnote "[c]").

Individual types of commercial buildings, offices and other uses may have widely varying parking demands. For example, among individual retail uses, observed weekday average parking demand ranges from an average of 1.2 spaces per 1,000 square feet of GLA for furniture and carpet stores to 3.6 for discount stores. Variability among individual observations for a particular use may also be high. One of the higher variabilities is exhibited by general office buildings, with a standard deviation of 2.25 around the mean of 2.79 spaces per 1,000 square feet GLA, and a range of rates among 207 studies of 0.75 to 32.93 (ITE, 1987).

Variability is a key reason for adopting 85th percentile values plus a cushion for design purposes in standard practice. Such contingency provisions need to be balanced, however, against other objectives such as achieving more efficient use of land and encouraging alternative travel modes. They may be particularly amenable to scaling back where shared parking can absorb variability among individual buildings (even when the uses are in the same general category), and in instances where overflow parking is available.

The values summarized in Table 18-29 serve only as a starting point for parking needs assessments. They assume that all or most people come by auto. They should be adjusted downward, when appropriate, for the parking demand mitigation of non-negligible transit use, parking pricing, and realistic travel demand management effects. Adjustments may be based on applicable local survey data, on information in the earlier sections of this chapter and other relevant sections of this Handbook — particularly Chapter 13, "Parking Pricing and Fees" and Chapter 19, "Employer and Institutional TDM Strategies" — and on guidance from other sources.

Table 18-29 Summary of ITE Parking Demand Values for Individual Developments in Predominantly Negligible Transit Use Environments

Use	Evaluation Unit	Day of Week	Spaces per Evaluation Unit [a]	
			Average	85th Percentile
Industrial parks, manufacturing, and light industry	1,000 sq. ft. building area	Weekday	1.5 – 1.6	2.1 – 2.4
Office parks and general offices	1,000 sq. ft. building area	Weekday	2.5 – 2.8	3.3 – 5.0 [b]
Shopping Centers [c]	1,000 sq. ft. GLA	Weekday Saturday	3.2 4.0	4.4 5.1
Family, fast-food, and quality restaurants	1,000 sq. ft. GLA	Weekday Saturday	9.1 – 12.5 7.0 – 15.9	11.2 – 17.4 n/a – 20.1
Movie theatre	Seat	Weekday Saturday	0.19 0.26	0.30 0.37
Low-rise condominiums and apartments	Dwelling unit	Weekday Saturday	1.0 – 1.1 1.0 – 1.2	1.4 – 1.4 1.2 – 1.5
Convention motels and motels with restaurant/lounge	Room	Weekday Saturday	0.8 – 0.9 1.0 – n/a [d]	1.1 – 1.5 n/a

Notes: [a] The ranges of observed average values and 85th percentile values reflect the differences exhibited among the various use subcategories. The 85th percentile values are average parking demand plus one standard deviation. See original source for further detail, including values specific to the individual subcategories and additional use classifications.

[b] A judgmentally adjusted 85th percentile value of 3.0 spaces per 1,000 sq. ft. gross leasable area (GLA) has been suggested for general offices (Weant and Levinson, 1990).

[c] Much of the ITE shopping center data is for average business periods. Recommended design hour values for shopping centers have been developed and regularly updated by the Urban Land Institute on the basis of periodic studies. The study results have lead to a steady decline in recommended design values from 5.5 spaces per 1,000 sq. ft. GLA in 1965 to the 1999 recommendation of 4.0 spaces per 1,000 sq. ft. GLA for centers of 25,000 to 400,000 sq. ft. GLA, with a linear transition to a design value for centers of 600,000 sq. ft. GLA and above of 4.5 spaces per 1,000 sq. ft. GLA (5.0 in 1982 as found in Table 18-30) (Urban Land Institute, 2000).

[d] Only one Saturday sample for motels with restaurant/lounge.

Sources: ITE (1987), and supplemental sources as indicated in footnotes "[b]" and "[c]."

Shared Parking

Shared parking is a parking supply strategy designed primarily to take advantage of differential individual use parking accumulation characteristics, where individual uses are combined into mixed land use with common parking, to save on the number of parking spaces needed. This strategy is neither inherently reliant on any special traveler response to the shared parking, nor is it intended — in its pure form — to bring about any particular response. It simply takes advantage of the different time-of-day demands inherent in normal parking accumulation patterns to allow dual or multiple use of parking spaces. This synergy can work when the parking needs associated with two or more different land/building uses are at or near their peak at different times.

There is also a second effect reducing parking requirements that may occur by virtue of the mixed land use that is part of the shared parking equation. This pertains when the land use mix allows proximate multiple destinations on a single car trip, such as working in an office building and visiting a restaurant. It is actually a traveler response to the mixed land use. As will be seen, this second effect tends to be stronger in downtown locations.

Differential Parking Accumulation Synergy

Table 18-30 provides representative parking accumulation percentages by hour for major land or building uses, assembled for application in calculations of shared parking requirements. The values provided are based on surveys and smoothed judgmentally. Note that the percentages are computed using peak accumulation, not parking supply, as the denominator. Note also that each column in this table is independent of the next. For example, to apply the Saturday percentages for office use, one must have an estimate of the peak office parking requirement *on Saturdays*, such as the value of 0.50 parking spaces per 1,000 square feet of GLA provided in the source document for Table 18-30 (Urban Land Institute, 1983) and appended to Table 18-30 as the last row. The Saturday percentages are applied to the estimated Saturday peak requirement, not to a weekday estimate.

The information in Table 18-30 is used by first separately applying the percentages for weekdays, and the percentages for Saturdays, to the weekday and Saturday peak parking requirement estimates, respectively. Then the results are added by hour, to determine both what the peak hour is and the shared parking requirement for that hour (Urban Land Institute, 1983).

The process and the way shared parking works can best be illustrated by example, making use of Table 18-30 and parking demand values such as those presented in Table 18-29, filling in from the bottom row of Table 18-30 as necessary. Consider a 100,000 square foot office building with a 750 seat movie theatre in it, located in a negligible transit use environment with free parking and no travel demand management. By inspection of Table 18-30, it can be seen that on weekdays, the hours of 10:00 or 11:00 AM, 2:00 PM, 6:00 PM, and 8:00 PM are the only hours that can possibly produce maximum shared parking demand estimates. Given that the 11:00 AM estimated demand will be the same as for 10:00 AM, the weekday calculation can proceed as follows:[7]

10:00 AM: 100 (000 sq. ft.) x 3.0 (general office demand rate) @ 100% = 300 spaces
2:00 PM: 100 x 3.0 @ 97% = 291; 750 (seats) x 0.30 (rate) @ 70% = 158; Total = 449 spaces
6:00 PM: 100 x 3.0 @ 23% = 69; 750 x 0.30 @ 80% = 180; Total = 249 spaces
8:00 PM: 100 x 3.0 @ 7% = 21; 750 x 0.30 @ 100% = 225; Total = 246 spaces

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[7] In this example, parking accumulation percentages from Table 18-30 are used in combination with parking demand values that can be and are drawn entirely from Table 18-29 except for the Saturday general office rate, which must come from Table 18-30. The 85th Percentile demand values of Table 18-29 are used, in conjunction with footnote "b" in the case of the weekday office demand rate.

Table 18-30 Representative Hourly Parking Accumulations as Percentages of Peak Hour Parking Demand for Various Uses

								Residential			Hotel				
	Office		Retail		Restaurant		Cinema	Non-CBD		CBD	Guest Room		Restaurant		Conf.[a]
Hour	Week-day	Sat.	Week-day	Sat.	Week-day	Sat.	Daily	Week-day	Sat.	Daily	Week-day	Sat.	Week-day	Sat.	Daily
6:00 AM	3%	—	—	—	—	—	—	100%	100%	100%	100%	90%	20%	20%	—
7:00 AM	20	20%	8%	3%	2%	2%	—	87	95	95	85	70	20	20	—
8:00 AM	63	60	18	10	5	3	—	79	88	90	65	60	20	20	50%
9:00 AM	93	80	42	30	10	6	—	73	81	87	55	50	20	20	100
10:00 AM	100	80	68	45	20	8	—	68	74	85	45	40	20	20	100
11:00 AM	100	100	87	73	30	10	—	59	71	85	35	35	30	30	100
12:00 PM	90	100	97	85	50	30	30%	60	71	85	30	30	50	30	100
1:00 PM	90	80	100	95	70	45	70	59	70	85	30	30	70	45	100
2:00 PM	97	60	97	100	60	45	70	60	71	85	35	35	60	45	100
3:00 PM	93	40	95	100	60	45	70	61	73	85	35	40	55	45	100
4:00 PM	77	40	87	90	50	45	70	66	75	87	45	50	50	45	100
5:00 PM	47	20	79	75	70	60	70	77	81	90	60	60	70	60	100
6:00 PM	23	20	82	65	90	90	80	85	85	92	70	70	90	90	100
7:00 PM	7	20	89	60	100	95	90	94	87	94	75	80	100	95	100
8:00 PM	7	20	87	55	100	100	100	96	92	96	90	90	100	100	100
9:00 PM	3	—	61	40	100	100	100	98	95	98	95	95	100	100	100
10:00 PM	3	—	32	38	90	95	100	99	96	99	100	100	90	95	50
11:00 PM	—	—	13	13	70	85	80	100	98	100	100	100	70	85	—
12:00 AM	—	—	—	—	50	70	70	100	100	100	100	100	50	70	—
Peak	3.0	0.5	3.8	4.0-5.0[c]	20.0	20.0	see	1.0	1.0	1.0	1.25	1.25	10.0	10.0	see
Spaces[b]	per 1,000 sq. ft. of gross leasable area (GLA)						note[d]	per D.U. (per auto)			per room[e]		per 1,000 sq. ft…		note[a]

Notes: [a] Conference rooms (peak demand 0.5 spaces per seat) and convention areas (peak demand 30.0 spaces per 1,000 sq. ft. GLA).

[b] "Representative" peak parking spaces required (per unit of measure indicted) at 100% accumulation. These corresponding demand values from the source document date from prior to publication of the ITE parking demand values of Table 18-29.

[c] See Table 18-29, footnote "c."   [d] 0.25 spaces weekdays and 0.30 Saturdays per seat.   [e] At 100% auto use by hotel guests.

Source: Urban Land Institute (1983).

The maximum weekday parking space demand is thus estimated to be 449 spaces, with the demand occurring at 2:00 PM. Using a similar approach, the estimated maximum Saturday demand would occur at 8:00 PM:

8:00 PM: 100 x 0.5 @ 20% = 10; 750 x 0.37 @ 100% = 278; Total = 288 spaces

The weekday maximum parking demand thus governs at 449 spaces. The corresponding calculation for *individual* office and movie theatre developments of comparable size would produce a 516 space total parking demand estimate. Mixing uses coupled with sharing parking thus offers a 13 percent savings in parking spaces required — in this example — before taking account of any other synergies or opportunities for parking demand reduction.

Multiple Destinations Synergy

Mixed land use may reduce the absolute numbers of cars parked by allowing uses such as retail shops, restaurants, and other services to draw upon on-site workers for their patrons. Such patrons add no more autos to the parking demand, even if they have driven to the site, because their parking demand is already accommodated on behalf of their worksite. There are also other land and building use combinations that may allow multiple destinations to be visited, especially those including hotels and residences.

Table 18-31 provides survey results taken from the perspective of determining the amount of market support provided by employees in a mixed use development, as compared to a single use site (Urban Land Institute, 1983). Note that the percentages given are the proportion of employees who are also patrons, and not the other way around.

Table 18-31 Percentage of Employees Who Are Also Patrons in the Same or a Nearby Development

	CBD Site		Non-CBD Site	
Type of Site	**Average**	**Range**	**Average**	**Range**
Single-use sites	29%	0-76%	19%	0-78%
Mixed-use sites	61%	22-85%	28%	0-83%
All sites	43%	0-85%	24%	0-83%

Source: Urban Land Institute (1983).

Interestingly, the data set presented in Table 18-31 shows mixed land and building use to be more effective in trip reduction potential relative to single use sites when placed in CBD environments than when placed in non-CBD environments. This advantage for CBD sites holds in both a relative and absolute sense (Urban Land Institute, 1983).

Information from Portland, Oregon, conforms generally with the CBD data in Table 18-31. Parkers giving their trip purpose as "work" reported an average of 1.6 places visited "on the last trip downtown." It may be inferred that this suggests 60 percent were also patrons of downtown Portland retail or services, or had multiple work-related destinations. Some sites visited may have entailed intra-CBD driving. That possibility, and the possible inclusion of secondary work-related destinations, suggests that the percentage would naturally be higher than the CBD all-sites value of 43 percent in Table 18-31. Portland parkers identifying non-work purposes as their reason for a downtown trip reported 1.82 places visited on average (TDA Inc., 1988).

Hotel developments appear to offer an even stronger synergy than other mixes, effective in both CBD and non-CBD environments. For eight hotels surveyed, 73 to 100 percent of guests indicated they were also patrons of retail establishments or restaurants within or adjacent to the hotel, with the range a tighter 70 to 80 percent for six hotels (Urban Land Institute, 1983). Note that the synergistic effects of mixed land use are addressed more extensively and in a broader context within Chapter 15, "Land Use and Site Design," under "Response by Type of Strategy" — "Land Use Mix."

Empirical Validation Findings

An empirical validation evaluation of the parking spaces that may be saved through shared parking in conjunction with mixed use development is presented in Table 18-32 for 17 real-world mixed use projects. Parking requirements based on typical individual use zoning regulations are shown in the first numerical column, but are not used as a basis for comparison calculations. Requirements estimated on the basis of representative individual use parking demand values are given in the second numerical column. An estimate on the basis of shared parking is given in the next column, followed by calculations (by the Handbook authors) of parking space savings. The last three columns give actual peak parking demand as measured on one day during the October to December 1982 period. It is not known if the one day was truly representative in each case. Neither seasonal factors nor captive market effects were considered in the estimates. Other qualifiers are listed in the Table 18-32 notes (Urban Land Institute, 1983).

Key findings that may be derived from Table 18-32 are:

- Shared parking, based on calculations like those described above, offers estimated parking space savings ranging from 5 to 49 percent for the 17 projects examined.

- Both the individual-use-based and shared-parking-based estimates were generally higher than the observed peak parking accumulations (16 out of 17 cases for individual-use-based calculations and 13 out of 17 cases for shared-parking-based calculations).

- Many of the overestimates of parking requirements were substantial in both cases, and were about half again as large for the individual-use-based estimates.

- The underestimates of requirements range from -3 to -19 percent, in the 4 out of 17 cases where shared-parking-based estimates fall below the observed demand, and are mostly if not all well within leeway provided by safety factors built into standard parking design guidelines.

Table 18-32 Test Calculations of Mixed Use Parking Requirements with Comparisons to Actual Observed Parking Accumulation

Type of Mixed-Use Project [a]	Typical Zoning Parking Space Require -ment [b]	Individual Use Estimate of Peak Demand	Shared Parking Estimate of Peak Demand	Spaces Saved Relative to Individual Use Est. [c]	Percent of Parking Spaces Saved [c]	Actual Peak Parking Accumulation [d]	% Overestimate for Individual Use Estimate	% Overestimate for Shared Parking Estimate
Office/Retail	5,858	5,749	5,229	520 [e]	9% [e]	5,570	3%	-6%
Office/Retail	3,744	2,936	2,788	148	5%	2,352	25%	19%
Office/Retail	900	772	617	155 [e]	20% [e]	633	22%	-3%
Office/Retail	3,048	2,814	2,291	523 [e]	19% [e]	2,592	9%	-12%
Office/Retail	196	162	154	8	5%	154	5%	0%
Office/Entertainment	1,879	1,458	1,326	132	9%	1,163	25%	14%
Office/Entertainment	1,016	812	714	98	12%	464	75%	54%
Office/Entertainment	2,112	1,724	1,501	223	13%	614	181%	144%
Office/Hotel	1,399	1,145	1,006	139	12%	882	30%	14%
Office/Hotel	1,346	1,125	743	382	34%	594 [f]	89% [f]	25% [f]
Office/Hotel/Entertainment	1,933	1,627	1,323	304	19%	725 [f]	124% [f]	82% [f]
Office/Hotel/Entertainment	1,452	1,236	990	246	20%	525 [f]	135% [f]	89% [f]
Office/Hotel/Entertainment	862	784	659	125 [e]	16% [e]	809	-3%	-19%
Office/Hotel/Entertainment	3,188	2,588	2,183	405	16%	1,498 [f]	73% [f]	46% [f]
Office/Retail/Hotel/Entertainment	9,610	8,316	4,242	4,074	49%	2,287 [f]	264% [f]	85% [f]
Office/Retail/Entertainment	1,094	869	754	115	13%	600	45%	26%
Office/Retail/Entertainment	5,157	5,099	3,755	1,344	26%	2,869 [f]	78% [f]	31% [f]

Notes: [a] Nationwide sample of projects.

[b] Office = 4.0 spaces per 1,000 sq. ft. GLA, retail = 4.0 to 5.0 per 1,000 (depending on size), restaurant = 25.0 per 1,000, residential = 1.0 per dwelling unit, hotel = 1.0 per room, conference rooms = 0.5 per seat, convention space = 30.0 per 1,000 sq. ft.

[c] Calculated by Handbook authors.

[d] One-day survey observations.

[e] Savings indicated are wholly or partially hypothetical given the underestimate of shared parking demand relative to actual peak parking accumulation.

[f] Observed actual demand understated due to depressed hotel occupancy and/or presence of offsite parking, with corresponding overstatement of the overestimate percentages.

Source: Urban Land Institute (1983) except as noted.

Travel Choices After Parking Supply Modification

The only empirical information available on mode or other travel choice outcomes for non-work travel, in response to parking supply modification, appears to be whatever can be inferred from a few measured responses to applications involving a mix of travel purposes. An example is the Eugene, Oregon, on-street parking management demonstration, covered under "Response by Type of Strategy" — "On-Street Residential Neighborhood Parking Management" — "Effects on Curb Parking Behavior." That demonstration, like some others of its type, encountered a primary response of change in parking behavior rather than mode choice behavior. Ninety-five percent of targeted parkers continued to drive alone to the area, rather than shifting mode. However, they either parked in private facilities or managed their parking time to stay within the newly applicable two-hour limit.

There are, however, observations of "after" commuter mode shares along with comparative trip rate information in the case of worksite parking management. There is also a provocative examination of the actual travel choices made by commuters in the Hague when their centrally located parking lot was closed. These are reported here.

Mode Choices with Worksite Parking Management

Table 18-33 summarizes available mode share information for selected instances of site-specific parking supply management efforts applied as a key component of a multifaceted workplace program. There is no mode shift information per se for these cases, but the vehicle trip rate per capita is given and compared with ambient trip rates for nearby sites or areas without TDM, and the "after" employee mode shares are provided. This summary is derived from case studies within this Handbook, and the respective case studies (identified within the table) should be consulted for descriptions of the parking supply management approaches, alternative modes, and complementary measures involved. These are examples of parking supply management proving effective in encouraging use of alternative modes in the presence of a full array of high quality alternative modes and done in company with carefully selected supporting measures.

Travel Choices of Displaced Parkers

An analysis of short-term effects of closing a parking lot in the center of The Hague, in the Netherlands, gives one glimpse of outcomes when CBD commuter parking supply is reduced with excellent public transit alternatives but without complementary supporting measures. Not covered in the study were:

- Effects on the user cost of parking.
- Effects on anyone other than motorists who had been parking in the closed lot.
- Long-term effects.

Table 18-33 Mode Shares and "With" and "Without" Vehicle Trip Rates for Multifaceted TDM Programs Emphasizing Parking Supply Management

	Employee Commute Mode Shares *with* TDM Program					Vehicle Trip Rate *per capita* [a]		
Case Study (Handbook Chapter)	Drive Alone	Car-pool	Van-pool	Tran-sit	Other	With	With-out [b]	Differ-ence
US WEST Parking Pricing and Management – Bellevue, WA (13)	26	45	2	13	15 [c]	0.57	0.83	-31%
NRC Site Parking Management – Montgomery County, MD (18)	42	27	—	28	3	0.54	0.92	-42
CH2M Hill Employee Parking Management – Bellevue, WA (18)	54	12	—	17	17	0.59	0.86	-31
City Hall Employee TDM – Bellevue, WA (19)	52	30	4	7	8	0.64	0.86	-26

Notes: [a] Standardized computation of the vehicle trip rate per capita; the ratio of motorized vehicle trips to the person trips in the travel population, in these cases, the employees traveling to and from work. Values may differ from Table 13-21 due to use of different sources.

[b] The "Without [TDM Program]" value is computed on the basis of control sites or areas.

[c] Includes 13 percent "multimodal," such as driving to carpool or transit. These were assigned to "Drive Alone" for computation of the US West vehicle trip rate per capita.

Sources: Refer to the case study indicated (in the Handbook chapter identified in parentheses).

The Hague lot in question parked about 200 cars, apparently all used by commuters. In the surrounding 35 hectares (86 acres, or roughly 5 small city blocks) there were 1,270 legal long-term parking spaces used at nearly 120 percent occupancy. The commuter parking space reduction in the area was thus 16 percent. Mode choices over five working days, immediately before and 3 months after closure, were obtained from interviews with 93 users of the closed facility. The results are given in Table 18-34 (Gantvoort, 1984).

The fact that the lot served commuters to work meant that the users presumably had very restricted choice as to where, and whether or not, to travel. Among surveyed users of the closed facility, 55 percent reported having a free choice of travel modes. Of the remaining 45 percent, half reported needing their car and the other half reported lack of an alternative. Those who elected to continue driving accepted numerous penalties. During the first week, these included average search times of 10 minutes, affecting 75 percent, and a need to leave home earlier by an average of 18 minutes, affecting 40 percent. Also during the first week, 30 percent parked illegally and 15 percent were ticketed one or more times.

The average walking distance from parking space to work for those continuing to drive increased by roughly a third, from about 300 meters (984 feet) to 400 meters (1,312 feet), while the median walking distance increased by some 60 percent, from about 250 meters (820 feet) to 400 meters (1,312 feet). The walking distance outcomes were, nevertheless, still better than the 550 meter (1,804 foot) average and median obtained in a parking survey in the center of The Hague 4 years previous.

Table 18-34 Mode of a Week's Work Trips in The Hague Before and After Closure of the Parking Lot Previously Used

Commute Mode	Trips Before	Mode Share	Trips After	Mode Share	Percent Change
Auto Driver	386	91%	312	74%	- 19%
Auto Passenger	0	0%	15	4%	+ …
Transit	22	5%	80	19%	+ 265%
Moped/Bike	15	4%	17	4%	+ 13%
Walk	1	<1%	0	0%	- …
No Trip that Day	41	n/a	41	n/a	no change
Total	465	100%	465	100%	

Note: Includes only users of the affected parking lot; not all central area parkers or commuters.

Source: Gantvoort (1984).

The study author observed that with essentially 4 out of every 5 previous auto driver trips having not changed mode, they must have forced away other car parkers in the vicinity (Gantvoort, 1984). There may therefore have been some second-order effects on mode shares not picked up in the survey of directly affected parking lot users. A 16 percent reduction in available parking supply led to a 19 percent drop in driving by those directly impacted, with an unknown effect on others.

It should be reiterated that the mode shift information provided in both Tables 18-33 and 18-34 pertains only to commuters, who in general have very restricted choice as to where to travel to and whether or not to make the trip. Persons contemplating travel for non-work purposes generally have more choices of destinations for their activities, and more latitude to forgo travel altogether. They may choose alternative destinations or avoid travel as their response to tight parking supply. It should also be noted that the specific commuters covered in Tables 18-33 and 18-34 represent closely targeted workforce populations. Effects on broader travel populations tend to be diluted, often substantially. The dilution phenomenon is addressed in Chapter 19, "Employer and Institutional TDM Strategies."

Cost Effectiveness

Assessing the cost effectiveness of a reduced parking supply involves a complex mix of factors, including real estate market forces, regulatory requirements, public infrastructure investments (such as in transit alternatives), and identification of beneficiary. Parking has become as essential to a development project as an entrance lobby or elevators in a building. What parking has in common with these other "common elements" is that they are all essential parts of the ultimate "useable" space, and they account for a significant share of the building's cost, but they do not generate rent directly. The developer must balance the size and character of these non-revenue producing facilities against their cost and contribution to the success of the total project (Cambridge Systematics, 1998).

Code Requirement Implications

The decision by a developer on how much parking to provide, and whether that parking will be in surface or structured facilities, depends heavily on local building and zoning codes. Since these codes normally stipulate a minimum ratio of on-site parking spaces to leasable floor area, the developer's decision is whether to meet or exceed the minimum requirement. Conversely, where parking codes limit parking supply by prescribing "maximum ratios," developers must decide whether their project can be economically viable under these constraints, and will need to consider potential mitigating factors such as quality of transit service or other off-site or adjacent parking opportunities for tenants. Unless the parking maximum is actually enforced as a requirement, developers may opt to exceed the maximum either as a hedge to ensure the project's competitiveness, or because the financing institutions may require a larger supply of parking (Nelson, Meyer and Ross, 1997; Valk, 1990).

Local building and zoning codes have been found to typically require more parking than is normally necessary for a site's needs. For a complete discussion of these findings, see "Response by Type of Strategy" — "Maximum and Minimum Parking Requirements" — "Minimum Parking Ratio Outcomes." To encapsulate the essence, codes for areas not well served by transit generally require between 3.0 and 4.0 spaces per 1,000 gross square feet (GSF) for worksites. At the same time, individual studies have found workplace parking supplies ranging from 15 to 114 percent in excess of demand. Such findings need to be tempered by the need for some margin of safety in the provision of parking, to accommodate variability and operational needs. Nevertheless, they suggest that local parking codes contribute to an oversupply of parking in many areas, an outcome noted elsewhere as often conflicting with efforts to increase transit utilization or reduce traffic congestion. Examples of center cities and even certain relatively suburban downtowns where parking requirements are set much lower have been provided under "Response by Type of Strategy" — "Maximum and Minimum Parking Requirements" — "Maximum Parking Ratios and Minimum Ratio Reductions" and "Areawide Parking Management."

Cost Considerations

Providing parking at a development project obviously involves major costs. Avoidance of these costs is a key benefit of reduced parking requirements. However, as discussed later, the benefit of these cost savings depends upon who ultimately bears these costs, the land owner, the developer, or the tenant. Which party does bear the costs is strongly influenced by local economic and real estate market conditions. This determination further depends on the setting, and on whether the facility will generate offsetting revenues through parking fees.

The cost to provide parking depends primarily on the type of parking — surface, structured, or underground — and the cost of land, which can vary greatly by location and with real estate market conditions. Real estate market and location are the critical factors that determine the "opportunity cost" of using land for parking, in other words, the land's value if placed in its highest and best economic use. Costs also depend upon the method of financing and prevailing interest rates.

For a parking facility to "break even," its revenues must equal or exceed the amortized annual costs of developing and operating the facility. Various studies have estimated the required break-even revenues per space. Results from two of these studies are summarized here:

- *Parking*, a monograph by the Eno Foundation, provides break-even revenue requirements estimated on a per-space basis. Assumed are land costs of $10 per square foot, 25-year revenue bonds, and 24 years of operation. The estimated break-even monthly incomes in 1990 dollars are about $66 per space in open lots, $165 in freestanding above-grade structures, and over $250 in underground facilities (Weant and Levinson, 1990).

- *TCRP Report 35* contains estimates of break-even per-space costs amortized over a 24-year service life for providing each type of parking (Cambridge Systematics, 1998). Equivalent monthly average break-even costs per stall, as approximated by the Handbook authors, are $68 per space for surface lots, $135 for above-ground multi-level structures, and $240 for below-ground facilities.

The *TCRP Report 35* per-space costs are built up from estimated component costs of land and construction along with design, engineering, and contingencies. Discounted operating costs incurred over the life of the facility are added in, and a 9 percent interest rate is assumed. As can be seen in the Table 18-35 presentation of these estimates, low and high ranges as well as averages are provided for each parking type (Cambridge Systematics, 1998). In the "Benefits from Reduced Parking" subsection below, the estimates are used to explore avoidable costs in the instance of not providing the parking.

Table 18-35 Total and Monthly Cost Estimates per Parking Stall (1997 Dollars)

	Surface Lot			Above-Ground Multi-Level Structure			Below Ground		
	Low	**High**	**Average**	**Low**	**High**	**Average**	**Low**	**High**	**Average**
Land	$600	$12,000	$6,300	$500	$1,000	$750	$0	$0	$0
Construction	1,500	4,000	2,750	8,800	20,000	14,400	16,000	40,000	28,000
Design, Contingency	200	800	500	1,800	5,000	3,400	3,200	10,000	6,600
Project Costs	**$2,300**	**$16,800**	**$9,550**	**$12,100** (sic)	**$26,000**	**$19,050**	**$19,200**	**$50,000**	**$34,600**
Present Value of:									
Interest Payments	$2,100	$14,700	$8,400	$9,700	$22,700	$16,200	$16,800	$43,700	$30,250
Operating Costs	700	2,800	1,750	2,800	5,600	4,200	2,800	5,600	4,200
Total Break-Even Cost per Stall [a]	**$5,100**	**$34,300**	**$19,700**	**$24,600**	**$53,300** (sic)	**$38,950**	**$38,800**	**$99,300**	**$69,050**
Monthly Equivalent [b]	**$17.71**	**$119.10**	**$68.40**	**$85.42**	**$185.07**	**$135.24**	**$134.72**	**$344.79**	**$239.76**

Notes: [a] Amortized over a 24-year service life at a 9 percent interest rate.

[b] Average monthly break-even cost per stall, approximated by dividing the amortized 24-year cost per stall by 24 x 12 = 288 months.

Sources: Cambridge Systematics (1998), Monthly Equivalents approximated by Handbook authors (see table footnote "[b]").

The *TCRP Report 35* authors note that while these costs are generic and are based on a set of assumptions constant across all three parking types, the high and low figures depict national averages, and actual values would depend on a particular project. In dense urban areas, for example, with limited vacant land, land costs may be far in excess of the averages shown (Cambridge Systematics, 1998). Caution should be used in their application, and indeed, the "low" costs are significantly below those found under most circumstances. The average and high costs are generally consistent with those reported by others, although lower than those of the other set of estimates actually presented above. The average costs may be presumed to offer a starting point for possibly conservative estimation of cost saving benefits attainable from reduced parking.

Benefits from Reduced Parking

The break-even costs per parking stall shown in Table 18-35 represent the approximate range of costs that a developer can avoid by not building a parking space. These numbers however, do not represent net savings. To calculate a net benefit, parking revenues (if any) must be subtracted from the break-even cost and compared to the net earnings on leasable space that might be substituted in place of the parking.

The beneficiary of lower parking requirements is determined by the markets for land and building space. A complex array of market forces determine whether the land owner, the developer, or the tenant realizes some or all of the benefits. Table 18-36 depicts the candidate beneficiaries (landowner, developer, or tenant) and the degree to which each would or would not benefit under different market conditions. The market conditions are framed in terms of land availability (scarce or available) and tenant occupancy rates (high or low vacancy rates).

Table 18-36 Determination of Beneficiaries from Reduced Parking Requirements

	Benefits of Reduced Parking to:		
Market Conditions	**Land Owner**	**Developer**	**Tenant**
Available Land High Vacancy	No Benefit	Modest Benefit *(reduced land cost)*	Large Benefit *(lower lease cost)*
Available Land Low Vacancy	No Benefit	Large Benefit *(reduced land cost)* *(high lease rates)*	No Benefit
Scarce Land High Vacancy	Moderate Benefit *(higher land prices)*	No Benefit	Moderate Benefit *(lower lease cost)*
Scarce Land Low Vacancy	High Benefit *(higher land prices)*	Large Benefit *(higher lease cost)* *(more leasable space)*	No Benefit

Source: Cambridge Systematics (1998).

A significant investment in employer parking capacity currently exists in the United States. The previously mentioned 1995 national survey of such parking estimated that 83.7 percent of the spaces in employer-owned facilities for employees, visitors, etc. is provided in surface lots, 11.1 percent in above-ground structures and 5.3 percent in underground garages (KPMG, 1995). Applying this distribution to the average monthly break-even cost estimates approximated on the basis of *TCRP Report 35* results in a weighted average monthly cost of $84.48 per space. Thus, any employer who is or is planning to provide parking for employees could expect to pay roughly $85 per month on average.

The 1995 national survey also found only 0.1 percent of all employers charge for employee parking, and that this charge averages $62.69 per month (KPMG, 1995). Thus, there is very little revenue from parking fees to offset the cost borne by employers for employee parking.

In light of these cost relationships, it would appear that employers could save considerable money by providing less employee parking or by charging a fee to recoup some of the costs. However, on a space-by-space basis, all but about 1 percent of employer parking is either directly owned by the employer (74 percent) or conveyed through a building lease (25 percent) (KPMG, 1995). Thus it is not usually practical to divest of this parking for other uses or strategies.

Environmental Relationships

Parking supply management can be an effective strategy for reducing emissions, provided that the form of the implementation ultimately reduces vehicle travel. If parking becomes difficult (scarce) or expensive, travelers have the option of switching modes (to one which is potentially less polluting), traveling less (telecommuting, compressed work weeks, grouping trips), or traveling to another destination for the activity. Either of the first two choices should result in fewer emissions. The third choice, however, may well result in increased emissions, particularly if it causes the traveler to make a longer trip.

A key role that parking management might play in environmental enhancement is through its deployment as part of a land use rationalization strategy. A major reason why suburban areas are so heavily dominated by private auto travel is that land uses are segregated, such that complementary uses are not "next door," and parking facilities — typically sprawling surface lots — place large distances between activities and services in office and commercial developments. When development is spread out and disassociated by function, private vehicle use is the only feasible means to create access.

Areas attempting to combat sprawl and build more compact, mixed-use communities find that parking supply is a crucial variable. In such areas, policies may be designed to limit on-site parking ratios, may require structured parking only or severely limit surface parking, may insist on providing a pivotal share of the parking supply through publicly owned and managed facilities, or may arrange for sites with different temporal needs for parking — such as office buildings and apartments — to "share" parking in the same facility, thus stemming the proliferation of surplus parking and parking lot acreage. In turn, an area where parking is to be restricted will certainly find environmentally sound implementation aided by provision and enhancement of other travel alternatives, and application of well-planned pedestrian and transit-friendly land use and site design principles including compactness and provision of mixed uses.

Critical Aspects of Parking Supply Management

Parking supply management is especially subject to extensive governmental intervention, particularly at a micro-scale. This control makes itself felt through zoning regulations and building ordinances, in addition to outright ownership and operation of public parking. Governmental involvement is matched, however, by a strong private sector role. The private sector involvement limits what government can do, not just because of private ownership and operation of the majority of parking facilities (Allen, 2002), but most significantly through the process of land development. Private sector influences include the developer's sometimes conflicting desires for profit and property salability, lending institution practices keyed to their view of development viability, and the ultimate right of buyers, lessees, and renters to decide against location in developments or districts they perceive to be unattractive to their customers, employees, or themselves. Critical aspects of parking supply management to be considered in this context and in light of traveler response findings include the following:

- Governmental bodies and their constituents vary widely in needs, attitudes, and parking ownership within their jurisdictions. One city may need to balance development potential against having parking revenues exceed costs, another may be concerned with sustaining competitiveness while encouraging transit use, and meeting air quality standards may be the overriding consideration in still another locale.

- Parking supply management involves balancing not just benefits against costs, but also an exceptional degree of trading off one public interest for another. On the one hand, requiring or allowing an extra margin of parking capacity guards against variability in demand and peak demand parking overflows (Allen, 2002), provides useful operational flexibility, and is frequently viewed as being essential for attracting and sustaining economic development. On the other hand, constraining parking conserves land, and is shown to reduce single occupant auto use in appropriate circumstances, with attendant potential for reductions in congestion, resource use, and emissions. While the findings reported under "Response by Type of Strategy" — "Maximum and Minimum Parking Requirements" — "Minimum Parking Ratio Outcomes" suggest pervasive over-reaction to parking capacity concerns, all perspectives need to be considered and balanced.

- Parking supply and price are interrelated; limited supply militates against free parking and begets higher parking fees. Where pricing exists, "travelers are probably responding more directly to price" (Allen, 2002). This chapter addresses supply aspects of parking, while Chapter 13, "Parking Pricing and Fees," covers the pricing aspects. In application, parking supply and price need to be considered together.

- Planners and managers of parking supply must be alert to significant potential for unintended consequences of either excess or constrained parking. Existing experience with parking constraints is highly focused on commuter parking management, with some evidence from highly urban mixed-use environments. Parking management involving predominantly retail centers is an area largely untouched except in theoretical analyses, and is likely fraught with unknowns and especially unpredictable outcomes (Allen, 2002). Most authorities consider provision of short-term non-commuter parking as not inconsistent with parking management goals.

- Parking restrictions *by themselves* do not generally "work." In order to induce desired responses (e.g., mode shifting) to constraints on parking, people must have or be given suitable options. Transportation options may accrue through transit service proximity, ridesharing support, pedestrian-friendly design, and other means, preferably through multiple approaches. Parking management cannot reasonably be done in isolation. On the contrary, it needs to be part of a program that not only relates to alternatives but also supportive actions. Success depends on the context, the alternatives available, and the other measures taken (Allen, 2002).

- Parking spaces needed may be reduced from parking ratios applicable to auto oriented, segregated land uses by actions and circumstances other than parking supply constraints per se. Use of shared unreserved parking for multi-use projects allows reductions through balancing hourly variations amongst land uses (Urban Land Institute, 1983 and 2000) and averaging out variability among building occupants. Availability of superior transit service and TDM actions reduce parking demand, as covered in other chapters, although significantly less when the synergy of parking pricing and supply management is absent.

ADDITIONAL RESOURCES

The Federal Transit Administration maintains a planning library on its website at http://www.fta.dot.gov/ntl/planning/index.html that offers an online *TDM Status Report*, including the topic *Parking Supply Management* (K.T. Analytics, 1995). This provides an overview of the state of the art, with examples, for deployment of six parking supply strategies: preferential parking for carpools, reduced minimum code parking requirements, maximum parking requirements, caps on overall supply of parking, timed curb parking, and peripheral parking with shuttles.

Similarly, the Victoria Transport Policy Institute maintains an "Online TDM Encyclopedia" at its http://www.vtpi.org/tdm/ website. This online compendium offers information on various TDM strategies including several parking supply management and related topics. Written from both demand management and "smart growth" perspectives, the coverage includes encapsulated travel demand response observations and estimates along with periodically updated reference listings (Victoria Transport Policy Institute, 2003).

Handbooks such as *Parking*, published by the Eno Foundation for Transportation (Weant and Levinson, 1990); *The Dimensions of Parking*, issued by ULI (Urban Land Institute, 2000); and the latest editions of the *Transportation Planning Handbook*, the *Traffic Engineering Handbook*, and *Parking Generation*, all published by the Institute of Transportation Engineers, Washington, DC, provide valuable information with regard to commonplace parking design issues and approaches and observed parking demand. An "ITE Parking Management Report" is, as of this writing, under preparation for the ITE Parking Council by Todd Litman of the Victoria Transport Policy Institute.

CASE STUDIES

NRC Site Parking Management — Montgomery County, Maryland

Situation. In the late 1980's The Nuclear Regulatory Commission (NRC) moved its headquarters to the White Flint area of Montgomery County, Maryland, in the North Bethesda planning area. The area lies along Rockville Pike, a heavily traveled shopping and commercial strip corridor between Bethesda and Rockville. While North Bethesda is an auto-dominated suburban environment, the Washington Metrorail system's Red Line has three stations within North Bethesda, including a station at White Flint. At the time of NRC's relocation, North Bethesda was under a development moratorium, since traffic congestion had exceed standards set under Montgomery County's Adequate Public Facilities Ordinance (APFO). While NRC's initial move of 1,400 employees into its One White Flint North building was allowable under conditions at the time of its building permit, in order to complete the relocation of all of its 2,500 employees, it needed to gain approval to build the second planned building at the site. To gain approval under conditions of the moratorium, NRC needed to introduce a plan for managing their vehicle trip generation at the first as well as the second White Flint site.

Actions. The actions comprising NRC's TDM program were based on a restrictive parking management plan. Only 365 spaces were to be provided on-site for the 1,400 employees at One White Flint North. In addition, a parking fee of $60/month was introduced. While carpools were offered preferential parking at the site, there was no fee discount for pools. Transit subsidies were provided under a special program of the County, and the potential for parking spillover to nearby shopping center lots was limited by a parking enforcement program. Nearby Metrorail was anticipated to be the major option for NRC employees.

Analysis. NRC's modal split was determined as a result of employee surveys required by the APFO development approval process. The mode split was then converted to a vehicle trip generation rate and compared with rates from other typical sites determined through a North Bethesda employer survey conducted in 1987.

Results. NRC's program measures led to a modal split at One White Flint North of 42 percent drive alone, 27 percent carpool, 28 percent transit, and 3 percent other, calculated to produce 53.7 vehicle trips per 100 employees. Compared to an average vehicle trip generation rate of 91.9 per 100 for other employment sites in North Bethesda, the NRC site's vehicle trip rate was 41.6 percent less than this average.

Sources: Comsis Corporation, "Technical Memorandum: Characteristics of Effective TDM Programs. Final Report." Transit Cooperative Research Program Project B-4. Transportation Research Board, Washington, DC (1996). • Comsis Corporation and Institute of Transportation Engineers, "Implementing Effective Travel Demand Management Measures: Inventory of Measures and Synthesis of Experience." Prepared for Federal Highway Administration and Federal Transit Administration, Washington, DC (1993).

CH_2M Hill Employee Parking Management — Bellevue, Washington

Situation. CH_2M Hill is a consulting firm located in the Bellevue, Washington CBD. When the company moved to downtown Bellevue from a more remote location, it realized that it would be facing a near-term parking shortage. The parking provisions of the building lease signed by CH_2M Hill stipulated that the number of on-site spaces available to the company would decrease over time according to a set schedule. This provision stemmed from the city of Bellevue's management plan for the Bellevue CBD, where parking ratios for all new buildings were limited to 2.4 spaces per 1,000 square feet. Whereas the company had ample free parking for its approximately 400 employees at its previous outlying location, moving to Bellevue meant that employees would have to adjust their commuting behavior to realize fewer vehicle trips to the site. It also meant that as the space ratio continued to fall over time — while the company also hoped to be growing — a creative and lasting solution would be necessary to address the firm's commuting habits.

Actions. As a transportation engineering firm, CH_2M Hill viewed the tight parking supply as a challenge that it would try to solve. Its employees formed a committee to study the problem and frame solutions that would not only work, but also be supported by the staff because of common objectives and a desire to make the new site work. The selected program had several integrated elements. First, it was agreed that all employees who parked should pay a monthly charge for the privilege. A monthly payment of $40 was designed to exceed the $35/month cost of the parking to the company, in order to create an incentive fund. To smooth acceptance of the decision to charge employees for parking, the company also voted in a one-time increase in salary of $40/month, to be treated as an allowance for transportation. Parking overpayment revenues — the incentive fund — were used to underwrite carpool parking, with pools of two or more provided free parking in the garage. Transit users were given an additional $15 per month on top of their $40 "allowance" as a transit subsidy.

Analysis. The vehicle trip rate of employee travel to the site was calculated from modal split information provided by CH_2M Hill. This rate was then compared with several datums to gauge how effective the company's measures were in engineering the desired changes in vehicle use.

Results. Whereas virtually all of the company's employees drove alone to work at their previous site, in the presence of the restricted parking at the downtown Bellevue site, the economic measures that the restriction induced in CH_2M Hill's TDM program, and the availability of transit options at the new site, the company realized a vehicle trip rate of 59.4 vehicle trips per 100 employees. This was achieved through a mode split of 54 percent drive alone, 12 percent carpool, 17 percent transit, and 17 percent walk, bike, or other. The trip rate of 59.4 was considerably below an average of 86.4 estimated by Seattle Metro from a control sample of similar regional sites. The Metro estimate was similar to a datum of 90.0 vehicle trips per 100 employees derived from 1990 CTPP data for the immediate area.

More… The overall experience of Bellevue with its efforts to manage land use and traffic hinges heavily on its management of downtown parking supply. The goal was to limit the amount of private site parking, both to encourage higher-intensity land use with better pedestrian circulation and more of a "downtown" feel, as well as to make parking limitations be a stimulus for employer and employee consideration of other travel alternatives. The city of Bellevue negotiated service agreements with Metro, the regional transit operator, to supply higher levels of transit service to and within downtown Bellevue in exchange for its efforts to engineer a more transit-serviceable environment. The overall experience of the city with this program is covered in Chapter 19, "Employer and Institutional TDM Strategies." The individual experiences of CH2M Hill, US WEST, and Bellevue City Hall presented here; in Chapter 13, "Parking Pricing and Fees"; and in Chapter 19, "Employer and Institutional TDM Strategies, respectively, are case studies of some of the more notable individual employer responses to this program.

Sources: Comsis Corporation and Harold Katz and Associates, "Evaluation of TDM Measures to Alleviate Traffic Congestion." Federal Highway Administration, Washington, DC (1990). • Comsis Corporation and Institute of Transportation Engineers, "Implementing Effective Travel Demand Management Measures: Inventory of Measures and Synthesis of Experience." Prepared for Federal Highway Administration and Federal Transit Administration, Washington, DC (1993).

CBD Parking Supply Management in Portland, Oregon

Situation. In 1972 carbon monoxide (CO) air quality standards were exceeded in downtown Portland, Oregon on one out of every three days on average. Primarily in response, a "Downtown Circulation and Parking Policy" was adopted in 1975 that featured a lid on downtown parking, maximum parking ratios for new development, and surface lot restrictions. Parking supply management was accompanied by enhanced transit service, including a 139 percent increase in systemwide revenue hours of bus service between 1971 and 1983, free downtown transit starting in 1975 (see the case study "CBD Free Fare Zones in Seattle, Washington, and Portland, Oregon" in Chapter 12, "Transit Pricing and Fares"), the downtown bus mall in 1978, and the first light rail line in 1986. Between the early 1970s and 1995, downtown Portland employment grew from 70,000 jobs to more than 90,000 jobs, while Metropolitan Statistical Area population grew from 900,000 to 1,300,000. In 1995, the area covered by the parking policy was substantially expanded, the deployment of maximum parking ratios and surface lot restrictions was refined, and the lid was removed, as further described below.

Actions. The *parking lid* of the 1975 "Downtown Circulation and Parking Policy" established a maximum number of parking spaces in the CBD, approximately 40,000, from which only hotel and residential parking was exempt. The *maximum parking ratio* provisions restricted the number of spaces per square foot of new buildings to 1.0 spaces per 1,000 square feet of development in most downtown areas, and 0.7 spaces per 1,000 along the bus mall. All parking required conditional use permit approval. The *surface lot restrictions* limited the conditions under which buildings could be razed for parking, and required 3-year permits for surface lot operation.

The 1975 policy received major updates in 1980 and 1986, and amendments in 1988, 1991, and 1992. In 1995, it was replaced — for reasons described below under "Results" — by a "Central City Transportation Management Plan" that removed the lid but maintained the system of parking ratios, limited commuter parking spaces for new development by extending the parking ratio system to areas outside of downtown (including the Lloyd Center retail mall and commercial district across the Willamette River), and closed loopholes in the surface lot restrictions. Provisions were included for allowing new parking in support of historic and other older structures, for increasing the availability of short-term parking, and for streamlining permitting processes including elimination of conditional use permit requirements in specified cases. Maximum parking ratios were based on the availability of transit, with provisions for reducing the ratios as transit service improves. A new parking ratio category of 2.0 parking spaces per 1,000 square feet maximum was introduced for use in the Lloyd District and other fringe areas newly encompassed.

The plan adopted in 1995 also includes a variety of measures supportive of walking, bicycling, carpooling, and alternative work hours, and to encourage development of housing near jobs and transit. It reflects a shift in air quality emphasis from downtown CO emissions control to regional ozone precursor emissions reduction, which is aided by central area (versus suburban) employment growth even if downtown parking has to be increased. The focus now is on accommodating 75,000 new jobs and 15,000 new dwelling units in the Central City by 2010.

Analysis. CBD parking supply management in Portland, Oregon, has not been the subject of a "before and after" or other quasi-experimental travel demand impacts study per se. Instead, available information has been extracted from published policy evaluations, one-time technical studies, post-implementation trend analyses, planning documents, and personal interviews and communications. In addition, comparisons with parking characteristics in other cities, provided in various tables of the "Related Information and Impacts" section of this chapter under "Characteristics of Parking Demand" — "Central Business District Parking," are commented upon.

Results. The number of CO air quality violations dropped to zero between 1972 and 1985. While most of the air quality improvements are attributed to advances in tailpipe emissions controls, vehicle inspections, and improved traffic management, the parking policy and expanded transit service are credited with contributing to both better air quality and less congestion downtown. Based on rough estimates of CBD square footage in office and commercial uses, and of long-term parking spaces, the 1973 ratio of approximately 3.4 such spaces for every 1,000 square feet of office/commercial appears to have been reduced to 1.5 long term parking spaces per 1,000 in 1990.

Regional transit ridership nearly doubled in absolute terms between 1971 and 1980, then dropped but regained by 1990, and continued to grow post-1990. Downtown conditions and transit ridership have heavily influenced this performance (in 1990 roughly half of all transit commuters worked in the CBD), but other factors have been the late 1970s fuel shortages, a weak job market in the early 1980s, and a strong economy in the 1990s. (See Chapter 7, "Light Rail Transit," for additional Portland transit ridership information.)

Data comparability issues over the three decades in question make it difficult to track CBD mode shifts, though it is fairly clear that higher transit mode shares are associated with the era of parking management. A pre-parking-management mode share for downtown commuters of 20 to 25 percent transit in the early 1970's is reported. A different source indicates that the post-parking-lid CBD work trip transit mode share reached 48 percent at one point, dropping to 43 percent in 1987 (a time of lower gasoline prices and some transit service reductions), with a 17 percent carpool rate. Presently available evidence suggests, however, that transit shares in the 40-odd percent range assuredly pertain to peak commuting only. All-day home-to-work and work-to-home CBD transit mode share was found to be 35 percent in 1985 travel surveys and 30 percent in 1994, with a 1994 4:00 to 6:00 PM CBD worker transit share near 40 percent. Even comparison of 1985 and 1994 survey findings must be approached with caution, for reasons that include different survey instruments and survey factoring procedures.

Monitoring has allowed more definitive tracking of parking costs. They serve as an indicator of the incentive for use of transit and ridesharing produced by the parking management. As illustrated in Table 18-37, the daily equivalent of CBD monthly parking costs increased by 26 percent in constant (inflation adjusted) dollars between 1987 and 1999.

Downtown growth notwithstanding, the Central City of Portland's share of the region's multi-tenant office market declined from approximately 90 percent of the market in 1970 to 50 percent in 1990. With this decentralization, combined with a strengthening local economy and national auto use trends, regional vehicle miles of travel (VMT) rose 40 percent between 1980 and 1990, while population increased 14 percent. The air quality problem shifted from downtown CO to regional ozone precursor emissions. With excess downtown parking wrung out of the system, and with historic and other older buildings inequitably impacted by the tight parking, the city in 1995 removed the parking lid and made the other supply management adjustments described above. These changes were part of putting in place land use and transportation policies supportive of further downtown development.

Table 18-37 Portland CBD Trends in Daily Equivalent Monthly Parking Costs, in 1985 Constant Dollars [a]

Survey Area	1983	1985	1987	1990	1991	1993	1995	1997	1999
CBD n/o W. Burnside	$2.12 [b]	$2.01 [b]	$2.02	$2.28	$2.30	$2.22	$2.26	$2.38	$2.86
CBD s/o W. Burnside	$2.79 [b]	$2.96 [b]	$3.08	$3.54	$3.67	$3.40	$3.48	$3.74	$3.91
CBD Overall (Total)	n/a	n/a	$3.01	$3.38	$3.50	$3.26	$3.33	$3.57	$3.79
Lloyd District	n/a	n/a	n/a	n/a	n/a	$2.06	$2.13	$2.15	$2.21

Notes: [a] Average monthly parking fee (weighted by number of sampled spaces), converted to 1985 dollars, and divided by the average number of working days per month (22).

[b] Scaled from Figure 7 in Horowitz (1993).

Sources: Metro (1999), Horowitz (1993).

More… Referring back to the "Central Business District Parking" subsection under "Related Information and Impacts" — "Characteristics of Parking Demand," it may be inferred from the tables containing 1988 Portland parking survey data that Portland CBD parking demand characteristics are similar to those of other healthy CBDs. The trip purpose distributions of parkers are like those of other comparably sized cities (see Table 18-18 and the discussion surrounding it). Parking duration is longer than for other cities of comparable size (Table 18-20), but this is probably an artifact of the full 12-hour survey taken in Portland. Daily turnover per space is at least as high and perhaps higher than for like cities (Tables 18-22 and 18-23), suggesting efficient use of the parking spaces. The vehicle accumulation as a percentage of parking supply is typical of comparably sized cities (Table 18-25). Walking distances are also in line with those of other CBDs (Table 18-26). The circumstantial evidence, though it lacks peer city pricing comparisons, certainly suggests that Portland's CBD parking supply management has underpinned parking fees just high enough to keep tight supply and the presumably dampened parking demand at a workable equilibrium.

Sources: TDA Inc., "Phase 6 Technical Memorandum - Portland Downtown Parking Plan and Circulation Update." City of Portland Bureau of Traffic Management, Portland, OR (1988). • Higgins, T. J., "Parking Management and Traffic Mitigation in Six Cities: Implications for Local Policy." *Transportation Research Record 1232* (1989). • Horowitz, D. M., *Transportation System Monitoring Activities.* Planning Department, Transportation Division, Travel Forecasting Section, Metropolitan Service District, Portland, OR (1993). • City of Portland Office of Transportation and Bureau of Planning, "Central City Transportation Management Plan - An Overview." Office of Transportation, Portland, OR (1995a). • City of Portland Office of Transportation and Bureau of Planning, "Central City Transportation Management Plan - Plan and Policy." Office of Transportation, Portland, OR (1995b). • City of Portland Office of Transportation and Bureau of Planning, "Central City Transportation Management Plan - Summary of Amendments to the Zoning Code." Office of Transportation, Portland, OR (1995c). • Parsons Brinckerhoff Quade and Douglas, Inc., "Public Policy and Transit Oriented Development: Six International Case Studies, Transit and Urban Form, Vol. 2, Part IV. *TCRP Report 16.* Washington, DC (1996). • Metro Regional Government, "1999 Parking Rates Survey of Portland, Oregon." Metro, Portland, OR (1999). • Iwata, S., and Lindmark, K., City of Portland Office of Transportation Planning. Personal Interviews with followup communications. Portland, OR (June, 2000). • Lawton, K., and Kim, K. H., METRO Regional

Government. Personal Interviews with followup communications. Portland, OR (June, 2000). • Walker, R. E., METRO Regional Government. Email communications. Portland, OR (March 20 and 22, 2002) • Observations by the Handbook authors.

Minneapolis Third Avenue Distributor Garages

Situation. In 1992, the transition of former Highway 12 into Interstate highway I-394, connecting downtown Minneapolis with its western suburbs, was completed. Highway 12 had routinely been one of the most congested arteries serving Minneapolis. A condition for its upgrading to a limited access highway was that it be a multi-modal facility. The upgraded facility was designed as a six-lane freeway with two of the lanes reserved for buses, carpools and vanpools. The two HOV lanes were with-flow inside lanes in the suburbs, and barrier separated reversible lanes in the median within Minneapolis. An important part of the design of I-394 into a multimodal corridor was the decision to introduce "interceptor" garages at the downtown freeway terminus, Third Avenue North.

Actions. Since 1969, the city's downtown parking plan had recognized the need for garages at the Third Avenue "fringe" location on the periphery of downtown. Under the I-394 design, it was decided to use the garages in conjunction with the HOV lanes to give priority to carpools and buses in a manner that would benefit the downtown environment, generate income, provide safety, and reduce congestion. The Third Avenue North Distributor (TAD) Garages were built on the air rights over I-394, with direct freeway ingress and egress. There are three separate facilities:

- Garage "A" (Seventh Street Parking and Transit Garage) contains 3,000 spaces and serves the commuter fringe parking system, plus the Target Center sports arena.

- Garage "B" (Fifth Street Parking and Transit Garage) contains 1,600 spaces and serves both commuters and warehouse district office, commercial, and entertainment patrons.

- Garage "C" (Fourth Street Parking Garage) contains 1,400 spaces and likewise serves multiple functions.

The TAD garage rate structure provides a substantial cost advantage to carpoolers, as a companion incentive to the increased reliability and the 2 minutes average travel time savings (compared to the mixed traffic lanes) offered by the HOV reserved lanes on I-394. Monthly HOV parking fees range from $25 to $30, compared to the standard contract fee of $85 to $100. There is direct garage access to and from I-394, and there are convenient connections to the enclosed downtown skyway pedestrian system. The garages are designed and operated as intermodal transfer facilities, linking I-394 express bus service and carpools/vanpools to buses serving the downtown area. Other elements of this multimodal corridor system include expanded express and local bus service, expanded park and ride lots along the corridor, HOV ramp meter bypass lanes, and rideshare matching and other public information programs.

Analysis. In this case, success is measured by the increase in van and carpooling and a marked decrease in congestion on the route served by the garages and expanded highway. It is difficult to isolate the benefits accruing parking management because the project involved freeway construction including addition of lanes and completion of an HOV system.

Results. Corridor HOV lane volumes remained stable from 1986 through 1990, despite construction activities. Large increases in HOV and transit ridership volumes accompanied the 1992 completion of I-394, its HOV facilities, associated transit improvements, and the TAD garages. (The "Minneapolis I-394 HOV Facilities" case study in Chapter 2, "HOV Facilities," especially Table 2-25, should be referred to for detailed I-394 HOV usage and transit ridership information covering 1989, 1992, 1994, and 1996.)

More... With respect to the Third Avenue Distributor Garages themselves, as of 1994 some 3,600 of the 5,302 contract spaces in the three TAD garages (or 68 percent of the 5,302 contract spaces) were sold, and 1,933 (54 percent) were used by I-394 HOVs. Early studies identified violations of the carpool requirements for reduced HOV parking fees in the garages. Compliance has been improved by requiring all carpool members to be present at the parking facility when signing the carpooling agreement, and by certification and witnessing by parking facility personnel every six months.

Source: Finstad, G. A., "Garages: The Key to a Successful Transportation System." *ITE Journal Vol. 66, No. 5* (May, 1996).

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AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
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