PARKING

ROBERT A. WEANT AND HERBERT S. LEVINSON

Acknowledgements

This monograph presents the best of contemporary North American practice in regard to parking space planning, design and operation. In this effort, we have drawn on the insights and experience of many individuals. We especially appreciate the help and materials provided by: **Craig Barber**, Buffalo Civic Auto Ramps; **Richard Beebe**, Ralph Burke Associates; **Paul C. Box**, Paul C. Box Associates; **Howard R. Chapman**, City of Charleston, SC; **Joseph M. Conner**, Massachusetts Bay Transportation Authority; **Robert W. Crommelin**, R. Crommelin Associates; **Robert T. Dunphy**, The Urban Land Institute; **Raymond H. Ellis**, Peat-Marwick-Mitchell & Co.; **P. Kay Griffin**, California DOT; **Roy A. Flynt, Jr.**,, White Plains Parking Authority; **Harold R. Hirsch**, Chicago Transit Authority; **Howard M. Haywood**, Massachusetts Bay Transportation Authority; **E. Carlton Heeseler**, Consultant; **James M. Hunnicutt**,, Hunnicutt & Associates; **Donald P. Ingold**, Wilbur Smith Associates; **Edward A. Izzo**, Wilbur Smith Associates; **Jean M. Keneipp**, Barton-Aschman Associates; **Frank J. Koepke**, Metro. Transportation Group, Inc.; **A.F. Leach**, Toronto Transit Commission; **Melvin B. Meyer**, City of Cedar Rapids, IA; **Robert P. Pearsall**, Metro-Dada Transit Agency; **Jesse N. Polan**, Federal APD, Federal Signal Co.; **Charles O. Pratt**, Wilbur Smith Associates; **Richard T. Roberts**, The Port Authority of NY & NJ; **Richard F. Roti**, International Parking Design, Inc.; **Mary S. Smith**, Walker Parking Consultants; **Thomas P. Smith**, American Planning Association; **James Staif**, Carl Walker Engineers; **James M. Staniewicz**, New Haven Parking Authority; **Vergil G. Stover**, Texas Transportation Institute; **Ronnie L. Taste**, The Port Authority of NY & NJ; **Joseph L. Tracy, Jr.**, Montgomery Co. Department of Parking; **E.M. Whitlock**, Consultant, Columbia, SC; **John M. Wright**, Hunncitt & Associates; and **Joseph H. Voccia**, Illinois DOT.

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Contents

List of Tables

List of Figures

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Foreword

Parking continues to be a major concern of communities, institutions, developers, and the motoring public throughout the world. No other aspect of urban transportation has received as much discussion and emphasis by both the public and private sectors. Cities want parking to make their established centers viable, and to complement their road and transit systems. Developers want parking to attract tenants and patrons, helping to make projects profitable and competitive. Institutions want parking to enhance access to help attract and retain professional staffs and patrons. Transit systems want parking to improve access to their express transit lines. And, above all, the general public wants convenient, inexpensive and safe places to park.

Today, the parking problem extends far beyond the city center. It extends to suburban office and shopping centers — to the miles of drive-in establishments oriented to the auto user; to airports and along express transit lines, where the amount of parking provided sometimes exceeds that in the city center.

Parking, indeed, has become a major part of the urban landscape. How well it is planned, designed and managed has important bearing on the vitality of activities and the livability of cities.

The Eno Foundation has long recognized the need for safe, convenient, and efficient parking. Over the past 50 years, it has published some 17 monographs dealing with many aspects of parking. This monograph synthesizes and updates the vast body of literature on parking within the context of current needs, attitudes, and resources. It brings together in a single volume the salient aspects of parking practices, characteristics, problems, policies, design, operation and management. We believe it will be helpful to administrators, planners, engineers, and others concerned with parking.

Any study of this sort is inevitably a cooperative effort by many people. Accordingly, the Foundation wishes to express its deep appreciation to the many city officials, parking agencies, garage managers, consulting engineering firms, public agencies and individuals who provided data for this monograph. The Transportation Research Board, Institute of Transportation Engineers, U.S. Department of Transportation, National Parking Association, Institutional and Municipal Parking Congress, Urban Land Institute, Downtown Research and Development Center and American Planning Association are among the many agencies that provided information, insights and suggestions.

We hope this document will prove useful in assessing and solving our parking problems.

ROLAND A. OUELLETTE
President

APPENDIX **C**

Surveyed Zoning Requirements for Off-street Parking

Building Type	*Range*	*Mode*[a]
Commercial and Industrial	(spaces per 100 sq ft)	
Office buildings, banks	0.08 - 1.33	0.25
Business and professional services	0.08 - 1.33	0.33
Commercial recreational facilities	0.16 - 2.00	1.00
Shopping goods (retail)	0.06 - 3.00	0.50
Convenience goods (retail)	0.10 - 1.33	0.50
Restaurants	0.06 - 2.00	1.00
Personal services and repairs	0.08 - 1.00	0.50
Manufacturing	0.08 - 1.00	0.20
Warehouses	0.02 - 0.67	0.10
Wholesale	0.03 - 1.33	0.15
Residential	(spaces per unit)	
Single family dwellings	0.50 - 3.00	1.00
Duplexes	0.50 - 2.00	1.00
Multiple family dwellings	0.50 - 2.00	1.00
Apartment hotels, rooming houses	0.25 - 1.50	1.00
Hotels (spaces per bedroom)	0.16 - 2.00	1.00
Motels (spaces per bedroom)	0.25 - 1.25	1.00
Public Buildings	(spaces per 100 sq ft)	
Museums, libraries	0.10 - 3.33	0.33
Public utilities	0.10 - 1.00	0.33
Welfare institutions	0.10 - 0.67	0.25
Medical Buildings	(spaces per 100 sq ft)	
Medical and dental offices	0.08 - 1.33	0.50
Hospitals	0.10 - 2.00	1.00
Convalescent homes	0.08 - 1.00	0.50
Auditoriums	(spaces per seat)	
General auditoriums, theaters	0.06 - 0.33	0.25
Stadiums and arenas	0.05 - 0.33	0.25
School auditoriums	0.05 - 0.25	0.10
University auditoriums	0.06 - 0.25	0.10

a. The mode is the value usually recommended for zoning ordinances.

Source: D.K. Witheford and G.E. Kanaan, *Zoning, Parking and Traffic* (Westport, CT: Eno Foundation for Transportation, Inc., 1972), p. 196.

APPENDIX **A**

Provisions for Joint Usage of Off-street Parking Facilities, Seattle, Washington

MIXED OCCUPANCIES

a. In the case of two or more uses in the same *building*, the total requirements for off-street parking facilities shall be the sum of the requirements for the several *uses* computed separately. Off-street parking facilities for one use shall not be considered as providing required parking facilities for any other use, except as hereinafter specified in Section 23.28 for joint use.

USES NOT SPECIFIED

a. In the case of a use not specifically mentioned in Section 23.3, the requirements for off-street parking facilities shall be determined by the *board*. Such determination shall be based upon the requirements for the most comparable use specified in Section 23.3.

COOPERATIVE PARKING FACILITY

Up to 15 percent reduction in the number of required parking spaces for 4 or more separate *uses*; 10 percent for 3 separate *uses*; and 5 percent for 2 separate *uses* may be authorized by the *Superintendent* following approval of a plan which complies with the following conditions:

a. The plan shall be for a collective parking facility serving two or more *buildings* or *uses* developed through voluntary cooperation or under any parking district which may hereafter be provided by law.
b. Such collective parking facility shall occupy an *area* of no less than 20,000 square feet.

JOINT USE

The *board* may authorize the joint use of parking facilities by the following uses or activities under the following conditions:

a. Up to 50 percent of the parking facilities required by this section for a theater, bowling alley, dance hall, bar or restaurant may be supplied by the off-street parking facilities provided by certain other types of *buildings* or uses specified in Section 23.28 (d).

b. Up to 50 percent of the off-street parking facilities required by this section for any *building* or *use* specified under (d) below may be supplied by the parking facilities provided for uses specified in Section 23.28 (e).

c. Up to 100 percent of the parking facilities required by this Section for a *church* or for an auditorium incidental to a public or private or graded school may be supplied by the off-street parking facilities provided by uses specified in Section 23.28 (d).

d. For the purposes of this section, the following uses are considered as day-time *uses*; banks, business offices, retail stores, personal service shops, household equipment or furniture shops, clothing or shoe repair or service shops, manufacturing or wholesale *buildings* and other similar primarily day-time *uses* when authorized by the *board*.

e. For the purposes of this Section, the following *uses* are considered as night-time or Sunday *uses*: auditoriums incidental to a public or private graded school, *churches*, bowling alleys, dance halls, theaters, bars or restaurants; and other similar primarily nighttime *uses* when authorized by the *board*.

f. Conditions required for joint *use*:

   1. The building or use for which application is being made to utilize the offstreet parking facilities provided by another building or use, shall be located within 800 feet of such parking facilities.
   2. The applicant shall show that there is no substantial conflict in the principal operating hours of the two *buildings* or *uses* for which joint *use* of offstreet parking facilities is proposed.
   3. A properly drawn legal instrument, executed by the parties concerned for joint use of offstreet parking facilities, duly approved as to form and manner of execution by the Corporation Counsel shall be filed with the *Superintendent*. Joint *use* parking privilege shall continue in effect only so long as such an instrument, binding on all parties, remains in force. If such instrument becomes legally ineffective, then parking shall be provided as otherwise required by Article 23.

APPENDIX **B**

Parking Requirements in Selected Jurisdictions

1. PARKING REQUIREMENTS FOR RETAIL USES IN SELECTED JURISDICTIONS

Jurisdiction	*Parking Requirements (Spaces/1,000 GLSF)*
Eno Foundation (1972)	Mean - 4.4, Min. - 1.0, Max - 13.3
Washington Metro Area	
Montgomery County	10/1,000 SF patron area + 3.33 - 0.67/1,000 SF add 1 area[a]
Gaithersburg	5.56 for floors at grade + 2.5 for other floors[b]
Rockville	7.5 up to 10,000 GLSF + 5.0 for additional area
Prince George's County	By parking generation group: 6.67/1,000 GSF normal; 10.0 high; 2.0 low
District of Columbia	No req't 1st 1,000 GSF; 0 - 5/1,000 GSF additional area
Alexandria	3.03 - 5.22 for buildings over 20,000 GLSF
Arlington	5.0/1,000 GLSF
Fairfax County	5.0 for 1st 1,000 GLSF + 6 for each additional 1,000 GLSF
Moderate to Large Cities	
Baltimore, MD	1.66 - 3.33/1,000 GLSF
New Orleans, LA	1.66 - 5/1,000 GSF
Oakland, CA	2.5 - 5/1,000 GLSF
Phoenix, AZ	-
Richmond, VA	5.0/1,000 GLSF
St. Paul, MN	6.67/1,000 SF "usable floor area"
Tampa, FL	2.0/1,000 GSF
Suburban Counties or Municipalities	
Bellevue, WA	Min. 4.0/1,000 GSF, Max. 5.0/1,000 GSF
Cambridge, MA	1.11 - 2.0 min.; 1.67 - 4.0 max.
Evanston, IL	3.33/1,000 GSF over 2,000 GSF
Henrico Co., VA	5.0/1,000 GLSF
Oak Park, IL	2.0/1,000 GSF
Tempe, AZ	4.0/1,000 GSF
Walnut Creek, CA	3-4SF parking/ 1 GSF floor area

a. Regional shopping centers in separate category with 5.41/1,000 GLSF.
b. For shopping centers over 600,000 GLSF, 5.0 for floors at grade plus 2.5 for other floors.

Source: JHK & Associates, *Parking Policies Study for Montgomery County, Maryland,* November 1982.

2. PARKING REQUIREMENTS FOR OFFICE BUILDINGS IN SELECTED JURISDICTIONS

Jurisdiction	*Parking Requirements (Spaces/1,000 GSF)*
Eno Foundation (1972)	Min. - 0.8, Max. - 13.3, Mean - 3.33
Washington Metro Area	
Montgomery County	2.0
Gaithersburg	3.3
Rockville	3.33
Prince George's County	4.0 1st 2,000 GSF + 2.5 for additional GSF
District of Columbia	0 - 1.67, depending on zone
Alexandria	2.5 - 3.0, depending on planning district
Arlington	3.33 1st 5 floors + 2.5 for additional units
Fairfax County	4.5/1,000 NSF[a] + 1.0/company vehicle
Moderate to Large Cities	
Baltimore, MD	0.5 - 2.5 depending on zone
New Orleans, LA	2.0 - 2.5
Oakland, CA	-
Phoenix, AZ	3.33
Richmond, VA	2.5
St. Paul, MN	5.0/1,000 SF "usable floor area"
Tampa, FL	1.0
Suburban Countries or Municipalities	
Bellevue, WA	Min. 2.0, Max. 3.0/1,000 Net SF
Cambridge, MA[b]	1.0 - 1.67 min.; 1.5 - 3.33 max
Evanston, IL	2.5/1,000 GSF over 2,000 GSF
Henrico Co., VA	3.33
Oak Park, IL	2.0
Tempe, AZ	5.0
Walnut Creek, CA	4.0/1,000 GLSF

a. Net square feet.
b. Maximums may be exceeded but with floor area ratio (FAR) penalty. This has been done on some occasions.

Source: JHK & Associates, *Parking Policies Study for Montgomery County, Maryland,* November 1982.

3. PARKING REQUIREMENTS FOR MULTI-FAMILY DWELLINGS IN SELECTED JURISDICTIONS

Jurisdiction	*Parking Requirements (Spaces/unit)*
Eno Foundation (1972)	Mean - 1.2, Min. - 0.5, Max. -2.0
Washington Metro Area	
Montgomery County	1 BR - 1.0. 2 BR - 1.25, 3 + BR - 1.5
Gaithersburg	-
Rockville	1 BR - 1.0. 2 BR - 1.25, 3 + BR - 1.5
Prince George's County	1 BR - 1.33, 2 BR - 1.66, 3 BR - 1.99
District of Columbia	0.25 - 1.0/unit
Alexandria	1 BR - 1.0, 2 + BR - 1.5
Arlington	1.13 1st 200 units + 1.0 for additional units
Fairfax County	1.5/units
Moderate to Large Cities	
Baltimore, MD	0.25 - 1.0/unit
New Orleans, LA	1.0/unit
Oakland, CA	1.0 - 1.5/unit
Phoenix, AZ	1 BR - 1.3; 2 BR - 1.5; 3 + BR - 2.0
Richmond, VA	1.5/unit
St. Paul, MN	1.5/unit
Tampa, FL	1.0/unit
Suburban Countries or Municipalities	
Bellevue, WA	Min. 1.0/unit, Max. 2.0/unit
Cambridge, MA	1.0/unit
Evanston, IL	1.0 for units 700 SF;1.25 for units 700 SF
Henrico Co., VA	1.5/unit
Oak Park, IL	1.0/unit (max. 2.0/unit)
Tempe, AZ	1 BR - 1.5; 2-3 BR - 2.0
Walnut Creek, CA	1.25 - 1.67/unit

Source: JHK & Associates, Parking Policies Study for Montgomery County, Maryland,

APPENDIX **D**

Examples of Fees-in-Lieu of Parking Ordinances

MILL VALLEY, CALIFORNIA, ZONING ORDINANCE

Where it can be demonstrated that the reasonable and practical development of property precludes the provision of required off-street parking, the City Council, upon recommendations of the Zoning Administrator, may permit the requirements thereof to be satisfied in all areas zoned CG, CN, and PA by the payment to the city of a sum equivalent to the estimated, normal, current cost to the city of providing required parking spaces to serve the contemplated use. Any off-street parking satisfied in this manner shall run with the land, and any subsequent change of use that requires more parking shall require subsequent action to satisfy the additional parking requirement. No refund of such payment shall be made when there is a change to use requiring less parking. Such payment shall be made to the city in one lump sum prior to the issuance of a building permit and/or business license.

The amount of payment for each required parking space shall be fixed by resolution adopted from time to time by the City Council. Funds derived from such payments shall be deposited by the city in a special fund, and, unless the applicant consents otherwise, shall be used and expended exclusively for the purpose of planning, designing, acquiring, and developing off-street parking facilities located, insofar as is practical, in the general vicinity of the property for which the in-lieu of providing off-street parking shall be made at least two weeks prior to the next Planning Commission meeting. Application shall consist of a letter of request, together with a proposed site plan or other information as may be required by the Planning Director.

When a variance is granted from all or a portion of the off-street parking requirements of this title, such variance may be granted upon the condition that the applicant make payment to the city in accordance with the provision of this section. [Ord. 743, Sec. 1; Ord. 805, Sec. 1; Ord. 836, Sec 1; Ord. 852, Sec 1; Ord. 932, Sec. 1; Ord. 961, Sec. 4; June 2, 1980.]

LAKE FOREST, ILLINOIS, ZONING ORDINANCE

Municipal off-street parking facilities shall continue to be developed and maintained by the city on city-owned or leased land and may, upon payment of the fee provided herein, be used in lieu of off-street parking required to be provided by existing and future buildings, structures, and uses.

1. When, in the B-2 Community Business District, additional off-street parking is required to be provided for an existing building because of:

a. a change of use of all or any portion of a building or structure form a use of one parking class to a use of another parking class; or

b. an interior increase of floor area, as defined in Article II, for which off-street parking must be provided, and such required off-street parking cannot be provided because of the nonavailability of space in the zoning lot upon which such building of structure is located, the City Manager, upon written application, may permit the payment of a fee by the applicant to allow the city to provide such additional required off-street parking in lieu of the applicant providing such required off-street parking. The fee to be charged shall be a one-time fee of $3,500 per space in accordance with administrative policies established by the City Council. The Plan Commission shall annually review the amount of such fee and shall make a recommendation to the City Council. Variations in established administrative policy with reference to the method of payment of the one-time fee may be considered by the City Council upon written request of a property owner or owners or lessee acting for the owner.

2. When, in the B-2 Community Business District, a new building or structure is erected or structural addition is added to an existing building or structure for which off-street parking is required by the provisions of this chapter, upon written application, the City Council may authorize the payment of a fee by the applicant to allow the city to provide such required off-street parking in lieu of the applicant providing such off-street parking for up to seventy-five percent (75%) of such required off-street parking. The fee to be charged shall be a one-time fee of $3,500 per space for each parking space required hereunder but not provided, payable in accordance with terms agreed to by the City Council and the applicant at the time of authorization. The Plan Commission shall annually review the amount of such fee and shall make a recommendation to the City Council.

Source: Thomas P. Smith, *Flexible Parking Requirements* (Chicago, IL: American Planning Association, 1983).

APPENDIX **E**

Examples of Parking Management Ordinances

CITY OF NORWALK, CALIFORNIA

Adjustment of Parking Requirements

The minimum number of required parking spaces may be reduced and requirements adjusted subject to Precise Development Plan approval when the Board of Administrative Review (BAR) or Planning Commission finds that adequate parking is provided for customers, clients, visitors, and employees. The following provisions may be used to adjust requirements

Parking Management Plans. Parking management plans may be approved if they provide alternative modes of transportation, such as vanpools, varied work shifts, use of company-operated buses, and other such means that will reduce the number of vehicles using the premises and include the following:

1. Plans shall show how the alternative mode(s) will be implemented, the permanency of such mode(s), the extent of the program, number of vehicles the mode(s) will replace, and other pertinent information.
2. A covenant running with the land, with the city a party thereto, shall be provided designating the method by which the required parking will be provided at the time the BAR determines the criteria of this section cannot be or have not been met.

CITY OF BELLEVUE, WASHINGTON

Use of Transportation and Parking Alternatives

1. Upon demonstration to the Planning Director that effective alternatives to automobile access are in effect, the Director may reduce, by not more than 50 percent, the parking requirements otherwise prescribed for any use, or combination of uses on the same or adjoining sites, to an extent commensurate with the permanence, effectiveness, and demonstrated reduction in off-street parking demand effectuated by such alternative programs.

2. Alternative programs that may be considered by the Planning Director under this provision include, but are not limited to, the following:
   private vanpool operation;
   transit/vanpool fare subsidy;
   imposition of a charge for parking;
   provision of subscription bus services;
   flexible work-hour schedule;
   capital improvement for transit services;
   preferential parking for carpools/vanpools;
   participation in the ride-matching program;
   reduction of parking fees for carpools and vanpools;
   establishment of transportation coordinator position to implement carpool, vanpool, and transit programs; or
   bicycle parking facilities.

SCHAUMBURG, ILLINOIS

Adjustments to Required Parking

Purpose. The Village Board may grant relief to the parking regulations through the variation procedure in specific cases without meeting the hardship requirements of Article XIV, Section 4.1, herein. In the following cases, adjustments may be made to required parking demand.

Shared-Ride Programs. Shared-ride programs, by increasing the passengers per motor vehicle, decrease parking demand. Examples are employer-sponsored vanpooling and subscription bus service. For buildings or complexes of minimum of 50,000 square feet gross floor area, a reduction of up to 30 percent of required parking may be allowed based on substantiated projections of reduction in demand.

To qualify for vanpooling or subscription bus service, the petitioner must submit evidence to the satisfaction of the Zoning Board Appeals that:

1. The petitioner is participating or shall participate in an approved carpooling program established under the carpooling programs provisions below and either;
2. Petitioner will obtain or lease to qualified employees vans, buses, or other high passenger-capacity vehicles, for the purpose of providing transportation of additional passengers (vanpooling); and/or
3. Petitioner will operate or hire vans, buses, or other high passenger-capacity vehicles to provide exclusive or nonexclusive commuter transportation of employees from residential areas, train stations, or to other transit terminals.

In furtherance of the petition, the petitioner may show any other activities that will ease the creation of vanpools and carpools. For example:

1. Petitioner will employ working day policy known as flextime where employees are given some latitude on starting and quitting times.
2. Petitioner will provide adequate lunch facilities on the site.
3. Petitioner will provide preferential parking.

As a part of his request for a variation, the petitioner shall show to the satisfaction of the Zoning Board of Appeals that the actions proposed by the petitioner shall reduce the parking demand by the amount requested.

Carpooling Programs. A variation of up to 10 percent of required parking, based on substantiated projections of reduction in demand, may be granted for any building or complex of 50,000 square feet of gross floor area that institutes or proposes to institute a carpooling program that meets the following minimum requirements:

1. Carpooling program must be a specific responsibility of a designated individual or department.
2. Program must provide an active matching service using manual or automated matching of addresses

and providing employees with potential carpools (passive matching alone such as bulletin boards is not acceptable).

3. Program must endeavor to register all existing and all new employees.
4. Program must actively promote carpooling to employees through newsletters, posters, and other media.

Transit. A reduction of required parking may be granted for any complex within one-half mile of any regularly scheduled bus route or commuter train station, with service available during commuting hours, equal to the substantiated projections of use of public transportation by employees of such complex.

Enforcement of Carpooling and Shared-Ride Programs. Development plans, where parking could be constructed equal to the number being reduced. If the programs are not being conducted as testified to the Zoning Board of Appeals, the owner must construct the parking required to meet the regulations of the village, during the next construction season. The petitioner, in accepting a parking reduction, agrees to construct such additional parking as would otherwise be required under the provisions of the Zoning Ordinance, if the Village Board shall determine after hearing by the Zoning Board that the reasons for granting said reduction no longer exist.

Prior to the issuance of any occupancy permit, the employer(s) must verify that such ridesharing plans, as shown at the time the variation was granted, are being implemented. Such verification must include copies of any contracts, lease agreements, purchase agreements, and other documentation to show that such ridesharing has taken or is about to take place.

Prior to the issuance of an annual business license, the employer(s) shall submit a report evaluating its ridesharing program. Such report shall include the number of participants involved, the percentage of participants to total work force, number and types of vehicles used, and the percentage of parking spaces normally used by employees.

The commitments agreed to by the petitioner and recommended by the Zoning Board of Appeals and adopted by the Board of Trustees shall be applicable to all successors in title and to all tenants. The petitioner shall record a covenant, the content and form of which must be approved by the Director of Planning, which binds all successors in title to the commitments approved and the petitioner shall include in all leases a clause, content and form approved by the Director of Planning, which binds all tenants to this commitment made by the petitioner.

Source: Thomas P. Smith, *Flexible Parking Requirements* (Chicago, IL: American Planning Association, 1983).

APPENDIX **F**

Example of Parking Requirements for Downtown Zones

GENERAL STANDARDS

1. Long-term parking requirements shall be established for all new uses, except as provided in subsection A2. The long-term requirement shall be determined by the accessibility of the area to transit, according to the Transit Access Map. Short-term parking shall also be required for offices and retail sales and service uses in all areas, except as provided in subsection A2.
2. The following exceptions to the parking requirement shall be made:
   a. No parking shall be required for new uses locating in existing structures, or when existing structures are remodeled.
   b. No parking shall be required for residential uses.
   c. No parking, either long-term or short-term, shall be required for the first 30,000 square feet of retail sales and service use on lots in areas with high transit access, according to the Transit Access Map. No parking, either long-term or short-term, shall be required for the first 7,500 square feet of retail sales and service use on lots in other areas.
   d. No parking shall be required for the first 2,500 square feet of any use which is not a retail sales and service use.
   e. No parking shall be required for expansion of an existing use by up to 2,500 square feet. This exemption may be used only once by any individual use.
   f. No parking shall be required in the Pike Market Mixed Zone.
3. Required parking may be provided in one or more of the following ways:
   a. The required parking may be located on the lot; and/or,
   b. The required parking may be located within 800 feet of the lot on which the use is located if:
      1) the parking is located in an existing structure; or,
      2) the parking is located in a new structure in either the DOC1, DOC2, or DMC zones.
   c. In lieu of providing required long-term parking, payment may be made of the Downtown Parking Fund, according to the provisions of subsection B4.
4. Parking which is determined by surveys to be used as short-term parking shall not be removed unless it is replaced.
5. For the purposes of determining parking requirements, institutions shall be considered retail sales and service uses. Nonresidential public projects and city facilities shall be considered on a case by case basis to determine the appropriate parking requirement.

PARKING REQUIREMENTS

1. The long-term and short-term parking requirement for offices, retail sales and service uses, and other nonresidential uses shall be as established on Chart 54.24A. The unrestricted long-term parking requirement may be reduced through the provision of additional carpool spaces, vanpools, or subsidized transit passes, according to subsection B.

Chart 54.24A Parking Requirements
(Expressed in parking spaces per 1,000 square feet of gross floor area of the use)

Use	Long-term Parking Requirement						Short-term Parking Requirement in All Areas
	Areas with High Transit Access[a]			Areas with Moderate Transit Access[a]			
	Unrestricted Long-term	Carpool	Total	Unrestricted Long-term	Carpool	Total	
Office	.54	.13	.67	.75	.19	.94	.1
Retail sales and service, except lodging	.32	.08	.40	.56	.14	.70	.5
Other nonresidential	.16	.04	.20	.16	.04	.20	None
Lodging	1 space per 4 rooms (all areas)						None

a. According to the Transit Access Map.

2. Carpool spaces provided in order to meet the requirements of subsection B1 shall meet one of the following provisions:
   a. Required carpool spaces shall be physically set aside and designated for exclusive carpool use between 6:00 A. M. and 9:30 A. M. Such spaces shall not be leased to tenants for long-term parking, except for carpools and vanpools. If the required carpool spaces are not used by carpool vehicles by 9:30 A. M., they shall be used as public short-term parking and appropriate signage provided.
   b. Required carpool spaces shall be subsidized rather than physically reserved, provided that the discount shall be equal to at least 30 percent of the monthly market rate charged the general public for a parking space. Discounted spaces shall be provided at the rate that carpools are formed.
3. The following substitution rates shall be used in reducing the long-term parking requirement for all nonresidential uses, except lodging:
   a. One vanpool shall equal six parking spaces. No more than 10 percent reduction in the unrestricted long-term parking requirement shall be allowed for vanpool substitutions. If the proponent wishes to use the vanpools option, the necessary number of vans meeting the standards of the Commuter Pool division of Metro shall be acquired, or an acceptable bond shall be posted; and, vanpools shall be organized for employees in the structure. Details of the vanpool program shall be spelled out in a Memorandum of Agreement executed between the proponent, his or her Transportation Coordinator, the Department, and the Seattle Rideshare office, prior to issuance of a Certificate of Occupancy.
   b. Each carpool space in excess of those required in subsection B1 which is physically reserved or discounted in price according to the provisions of subsection B2 shall equal 1.9 parking spaces. No more than 50 percent of the total number of long-term parking spaces provided shall be set aside or discounted for carpools.

c. Provision of free transit passes to all employees in the structure for at least 5 years shall equal a maximum 15 percent reduction in the unrestricted long-term parking requirement.

4. In lieu of providing parking spaces on the lot or within 800 feet of the lot, the Director may permit long-term spaces to be provided by a payment to the Downtown Parking Fund, if it is determined that the parking impacts of the development can be substantially mitigated by means other than provision of long-term parking on the same lot. In making this determination, the Director's consideration shall include but not be limited to the following factors:
   a. Proximity of the site to public parking.
   b. The level of transit service to the site.
   c. Proposals by the applicant to encourage building tenants to use alternatives to single occupancy vehicles.
5. All nonresidential uses shall do the following:
   a. A Transportation Coordinator shall be established and maintained within the proposed structure to implement alternative means for employee commuting. The coordinator shall be trained by the Commuter Pool division of metro or by an alternative organization with ridesharing experience, and shall work with City and Metro Commuter Pool staff, building tenants, and other building lessors. The coordinator shall disseminate ridesharing information to building occupants to encourage use of public transit, carpools, vanpools and flextime; administer the in-house ridesharing program; and aid in evaluation and monitoring of the ridesharing program. The transportation coordinator in addition shall survey all employees once a year to determine commute mode percentages.
   b. The Seattle Rideshare office, in conjunction with the Transportation Coordinator, shall monitor the effectiveness of the ridesharing/transit incentive program on a quarterly basis. The proponent shall grant a designated Seattle Rideshare representative right of entry to the parking facility to periodically review operation of the carpool set aside program.
   c. A transportation information center shall be provided and maintained, which has transit information displays including transit route maps and schedules and ridesharing program information. The transportation display shall be provided in the lobby or other location highly visible form the main entrance within the structure prior to issuance of Certificate of Occupancy.

MAXIMUM PARKING LIMIT

Except when required in IDM and IDR zones by the International District Special Review Board, provision of more than one long-term parking space per 1,000 square feet of office use shall be a special exception. In determining whether additional parking shall be permitted, the Director shall consider evidence of parking demand and alternative means of transportation, including but not limited to the following factors:

1. Whether the additional parking will substantially encourage the use of single occupancy vehicles
2. Characteristics of the workforce at the site and employee hours, such as multiple shifts or shifts which end when transit service is not readily available.
3. Proximity of transit lines to the site and headway times of those lines.
4. The need for a motor pool or large number of fleet vehicles at the site.
5. Proximity to existing long-term parking opportunities downtown which might eliminate the need for additional on-site parking.
6. Whether the additional parking will adversely affect vehicular and pedestrian circulation.

BICYCLE PARKING

Bicycle parking shall be required at the rate of 1 bicycle space for every 20 parking spaces provided in development requiring 20 or more parking spaces.

OFF-STREET LOADING

Off-street loading spaces shall be required according to the standards of Section 23.54.30.

Source: Experts form Seattle Zoning Ordinance (1988).

APPENDIX G

Comparative Analysis of Zoning Design Requirements for Selected Cities

ZONING DESIGN REQUIREMENTS

City	*Stall Size*	*Compact Stall Size*	*Compact Spaces Allowed*
Albany, NY	300 square feet per space (including maneuvering areas) 180 square feet per space (including maneuvering areas) attended	NA	NA
Austin, TX			25% min 40% max; must be grouped & clearly marked
Boston, MA	Suggested stall width: 8'6" max, 7'6" min Curb depth (perp to aisle): 90 : 20' max, 17'6" min; 60 : 17' max, 17' min; 45 : 18' max, 13' min	NA	NA
Buffalo, NY	160 square feet per space (not including maneuvering areas) 126 square feet per space (not including maneuvering areas) attended	NA	NA
Creve Coeur, MO	Stall width: 90: 10' min; 60, 45, & 30: 9' min; 0: 8' min Curb depth perp to aisle: 90 : 20' min; 60 : 21' min; 45 : 20' min; 30 : 17' min; 0 :8' min	Stall width: 90 : 8' min; angled: 7' min Curb depth (perp to aisle): 90 : 16' min; angled: proportioned	30% max must be grouped & clearly marked
Minneapolis, MN	Stall width: 8'6" min Stall length: 20' to 23'	NA	NA
Newburgh, NY	300 square feet per space (including maneuvering areas)	NA	NA
New York, NY	Stall width: 8'6" min Stall length: 18' min (applies only to accessory facilities)	None	None
Philadelphia, PA	Stall width: 9' min Stall length: 18' min		
Portland, OR	Curb length: 90 : 8'6" min, 9' desir; 60 : 9'10" min 10'5" des; 45 : 12' min 12'8" desir; 30 : 17' min, 18' desir; 0 : 22'6" min + desir Curb depth (perp aisle): 90 : 19' min & desir; 60 : 20' min & desir; 45 : 19' min & desir; 30 : 16'5" min, 17' desir; 0 : 8' min & desir Stall Width: 8'6" min; 9' desir; 0 : 8' min & desir	NA	NA
San Francisco, CA	160 square feet per space (not including maneuvering areas)	127.5 square feet per space (not including maneuvering areas)	Approx 50% max; must be clearly marked
Seattle, WA	Stall width: 8'6" min Curb length: 90 : 8'6" min; 75 : 8.8' min; 60 : 9.82' min; 45 : 12.02; min; 0 : 24' min Stall length: 19' min Curb depth (perp aisle): 90 : 19' min; 75 : 20.55' min; 60 : 20.70' min; 45 : 19.44' min Other angles: Curb length: (stall width)/(sin a); Curb depth: (stall length)(sin a) + (stall width)(cos a)	Compact cars: stall width: 7'6" min; stall length: 15' to 18'; angled: Medium cars: stall width: 8' min; stall length: 16' to 20'	Non-residential: 35% min & max compact; 35% min large; 30% mix: medium & large Residential: 60% min medium; 40% any size
Toronto, Canada	Stall width: 8.5' min Stall length: 19.4' min	NA	NA

ZONING DESIGN REQUIREMENTS

City	Aisle Widths *Standard Cars*	Aisle Widths *Compact Cars*	Curb Cut *Widths*	Curb Cuts *Sight and Visibility*	Curb Cuts *Numbers Allowed*
Albany, NY	300/180 sq ft/space includes maneuvering area	NA	NA	Min visibility of 100' in either dir from where driveway hits prop line	NA
Austin, TX	90 : 25-28' min 75 : 22-25' min 60 : 15-18' min 45 : 12.5-13' min 30 : 12.5' min	90 : 18' min 75 : 18' min 60 : 18' min 45 : 13' min 30 : 12.5' min	One-way: 15' min; 25' max Two-way: 25' min; 45' max Industrial: 30' min Downtown: "special permit" needed; 30' max	Visibility of and between pedestrians, bicyclists and motorists shall be "assured"; CBD: clear 10% cones of vision at intersection of sidewalk and access/egress lane	NA
Boston, MA	(Suggested) 90 : 23' max; 20'5" min 60 : 18' max; 14' min 45 : 14' max; 11' min	NA	(Suggested) 20' max 20' min	NA	NA
Buffalo, NY	NA	NA	Case-by-case approval	NA	NA
Creve Coeur, MO	90 : 22' min 1 or 2 way 60 : 18' min 1 way 45 : 13' min 1 way 30 : 11' min 1 way	NA	Case-by-case approval	"safe" arrangement of driveways	No more than one exit or entrance (or combined exit/entrance) without approval
Minneapolis, MN	90 : 22' min 60 : 18' min 45 : 12' min 0 : 12' min	NA	12' min 25' max	NA	NA
Newburgh, NY	300 sq ft/sp includes maneuvering areas	NA	12' min 20' max	NA	NA
New York, NY	None	None	Not in zoning	None	None
Philadelphia, PA	NA	NA	Maj through sts: 30' min Svc/lcl sts: 24' (proposed)	NA	NA
Portland, OR	90 : 24' min; 25' desir 60 : 20' min; 24' desir 45 : 20' min; 24' desir 30 : 20' min; 24' desir 0 : 20' min; 24' desir	NA	NA	NA	NA
San Francisco, CA	NA	NA	NA	NA	NA
Seattle, WA	90 : 24' min 75 : 20' min 60 : 17.5' min 45 : 13' min; 20' min 2 way 0 : 12' min; 20' min 2 way	compact cars: 90 : 20' min 75 : 16.5' min 60 : 13' min 45 : 11' min 0 : 10' min medium cars: 90 : 22' min 75 : 18.5 min 60 : 15' min 45 : 13' min 0 : 10' min	Non-residential: 1 way: 12' min; 15' max 2 way: 22' min; 25' max Residential: 1 way: 10' min 2 way: 20' max	Sight triangles required of all driveways; Can be replaced by mirrors or other approved safety measures in downtown	Residential: On sts w/less than 15,000 vehicles/day: St frontage of: 0-80' 1 max 81-160' 2 max; 161-240' 3 m 241-320' 4 max. On sts w/15 + veh/day: 0-160' 1 max; 161 - 320' 2; 321-480' 3. Non-residential: (downtown) 2 one-ways or 1 two-way max
Toronto, Canada	NA	NA	NA	NA	NA

ZONING DESIGN REQUIREMENTS

City	*Curb Cuts—Location: Min. Dist. from Intersection*	*Curb Cuts—Location: Min. Dist. from Other Curb Cuts*	*Curb Cuts—Location: Other*	*Curb Cuts—Other*
Albany, NY	25' min	NA	"Limited to several well-defined locations"	–
Austin, TX	NA	20' min	NA	2 way: 90' to street 1 way: 45' or 90' to street
Boston, MA	40' min	NA	"Appropriate" access to street	–
Buffalo, NY	NA	NA	NA	–
Creve Coeur, MO	NA	NA	"Adequate" and "safe" arrangement of driveways	Vehicles may never back out into public rights-of-way
Minneapolis, MN	NA	NA	NA	–
Newburgh, NY	20' min	30' min (same lot) 40' min corner lot	5' from lot lines; 200' from schools, playgrounds, libraries, churches, etc	–
New York, NY	50' min	None	Restrictions on specific wide streets in certain areas	None
Philadelphia, PA	Signalized Intersections: Ex upstrm/entr dwnstrm: 100' major thru street 50' min thru/svc/lcl 30' svc/lcl w/minr pedestrian action Ex dwnstrm/entr upstrm: 50' major thru street 50' min thr/svc/lcl w/ major pedes action 30' minr thr w/min ped 20' svc/lcl w/min ped Unsignalized Intersections: the width of the curb cut (Proposed)	100' major through street 50' minor through street 50' servic/local street with major pedestrian activity 30' servic/local street with minor pedestrian activity	NA	–
Portland, OR	NA	NA	Restrictions on specific wide and major pedes sts	–
San Francisco, CA	NA	NA	NA	–
Seattle, WA	40' min	Residential: 30' (same lot) Non-residential: 40' (same lot)	NA	–
Toronto, Canada	NA	NA	NA	–

ZONING DESIGN REQUIREMENTS

City	Handicapped Accessible Space Size	Total Spaces	HC Spaces Req'd	Layouts of Facilities	Attended vs. Self-park	Vertical Clearance	Turning Radius	Slopes	Reservoir Spaces	Lighting	Fences and Bumpers
Albany, NY	NA	NA		300 sq ft per space including maneuvering areas	300 sq ft/ sp self-pk 180 sq ft/ sp attend'	NA	NA	NA	NA	Away from residential properties	NA
Austin, TX	18'6" x 13' (a 5' wide area may be shared by two adjacent stalls	1-19: 20-50: 51-100 101-150: 151-200: 201+:	0 1 2 3 4 2%	"Adequate" internal circulation in accordance with accepted principles	NA	7'5" min	NA	Accessible space not on grade in excess of 2%	NA	Away from residential uses	Safety barriers, protective bumpers or curbing ...to assure safety, efficient utilization...to prevent encroachment onto adjoining property
Boston, MA	9' wide minimum	NA		"Facilities must have maneuvering areas"	NA	NA	(Suggested) 18' to inner rear wheel	NA	NA	Downward and away from residential uses	NA
Buffalo, NY	NA	NA		Aisles and access of "usable" shape and condition	160 sq ft/sp self-pk 126 sq ft/ sp attend	NA	NA	NA	NA	Away from residential uses	NA
Creve Coeur, MO	12' wide min	11-50: 51-100: 101+:	1 2 3	NA	NA	NA	NA	NA	NA	Away from adjoining prop; must be "adequate" for night use	Screening required everywhere; 5' landscaped buffer on lot before next property
Minnea-polis, MN	NA	NA		All plans must be approved	NA	6'6" min	NA	NA	NA	Away from resid; 3 ft candles max	NA
Newburgh, NY	NA	NA		300 sq ft/sp includes manuev areas, all plans need approval	NA	NA	NA	NA	NA	Away from street & residential prop	No portion of the area to be used for parking shall be closer than 5' to a sidewalk
New York, NY	Not in zoning	Not in zoning		Accessory only 300/ 200 sq ft sp includes manuev areas	Accessory only; 200 sq ft attd 300 self	None	None	Not in zoning	20% for 1st 50 + 5% x above 200 max 50	None	Not in zoning
Philadel-phia, PA	18' x 10'	NA		An additional area of 25% of stall area must be provided for maneuvering	NA	NA	NA	No parking on grades in excess of 10%	Proposed: 2-20: 1 21-50: 2 + 1 for add'l 50	Away from dwellings; must be adequate for night use	Substantial barriers around all parking areas of 10 or more cars; Proposed: If next to sidewalk, walls or hedges
Portland, OR	NA	NA		NA	NA	NA	NA	NA	NA	NA	Screening to keep cars from lot line
San Fran-cisco, CA	Designed adequately	4% of total		Downtown: must be approved	NA	7' min	NA	NA	Adequate reservoir	Must fall inside lot	Fences or bumpers to keep cars off sidewalk
Seattle, WA	NA	NA		"Adequate" ingress & egress	NA	6'9" min	18' (for driveways)	H/C sp: 2% max grade			
Toronto, Canada	NA	NA		NA	NA	NA	NA	NA	NA NA	NA Downward; away from residential	NA Perimeter fences of steel

Note: NA indicates that the information was not available.
Source: *Operation and Design Improvements Study for Off-street Parking Facilities* (New York: New York City Department of City Planning, October 1988).

APPENDIX **H**

Typical Off-Street Parking Space Zoning Ordinance

OFF-STREET PARKING SPACE ZONING ORDINANCE

Sec. 59-E-1.1. Required

Off-street parking spaces with adequate provisions for ingress and egress by motor vehicles shall be provided, in accordance with the provisions of this article, for any main building or structure at the time of construction and when any main building or structure is enlarged or increased in capacity. All off-street parking facilities provided, whether required or in addition to minimum requirements, shall conform to all standards contained in this article. (Ord. No. 10-32, § 8.)

Sec. 59-E-1.2. Structured Parking

All garage or other structured space allocated for the parking of vehicles in basements, on the roofs of buildings, or otherwise within buildings shall be considered part of the required off-street parking facilities. For all structured parking facilities, a parking facilities plan shall be submitted to either the director or the planning board, as specified in the parking facilities plan requirements contained in Section 59-E-4.1, for approval of interior traffic circulation; the slope of ramps; sight distances at all entrances, exits and corners of intersecting public roads; and the effective screening of the cars located in or on the parking structure from adjoining properties and from public roads. (Ord. No. 10.32, § 8.)

Sec. 59-E-1.3. Distance from Establishment Served

(a) All automobile off-street parking facilities shall be located so that the major point of pedestrian access to a parking facility is within 500 feet walking distance of the entrance to the establishment to be served by such facilities. For regional shopping centers, however, the major point of pedestrian access for off-street parking facilities that occupy continuous land areas integral to the shopping center property may extend more than 500 feet walking distance from an entrance to the center in order to satisfy the number of spaces required in division 59-E-3.

(b) Off-street parking facilities with pedestrian entrances located more than 500 feet walking distance from the entrance to an establishment to be served may be permitted by the director/planning board under the following circumstances;

1. If approved by the board of appeals in accordance with the special exception provisions of section 59-G-2.40.

2. An off-site parking facility proposed to satisfy seasonal peak shopping periods for a regional shopping center may be approved in accordance with the parking credit provisions of section 59-E-3.32B. (Ord. No. 10-21, § 2; Ord.No. 10-32, § 8.)

Sec. 59-E-1.4. Off-street Loading Space

For any building or land used for commercial or industrial purposes, adequate space for off-street parking to accommodate the loading and unloading of materials shall be provided, consistent with the size and proposed use of the building. Such space, whether inside or outside a building, shall be in addition to the schedule of requirements in section 59-E-7.7 and shall be designed so as not to impede normal vehicular and pedestrian circulation. (Ord. No. 10-32, § 9.)

DIVISION 59-E-2. PLANS AND DESIGN STANDARDS

Sec. 59-E-2.1. Subject to Approval

Designs and plans for areas to be used for automobile off-street parking shall be subject to approval by either the planning board or the director in accordance with the parking facilities plan procedures of section 59-E-4.1. Plans for such off-street parking facilities shall show in detail the location, extent of the facility, the design features, and other elements necessary to satisfy the standards or requirements of this chapter. The following standards or requirements shall apply to all such areas except for the parking required for one-family dwelling. (Ord. No. 10-32, § 10.)

Sec. 59-E-2.2. Size and Arrangement of Parking Spaces

59-E-2.21. Arrangements and Marking. All off-street parking areas shall be arranged and marked so as to provide for orderly and safe loading, unloading, parking and storage of vehicles. Individual parking spaces shall be clearly defined, and directional arrows and traffic signs shall be provided as necessary for traffic control. Each space or area for small-size motor vehicle parking must be clearly marked to indicate the intended use.

59-E-2.22. Size of Spaces

(a) Each standard size parallel parking space shall have minimum dimensions of 7 feet by 21 feet. A parallel parking space is defined as one in which the long side of the space parallels the travel lane.

(b) Each standard size perpendicular parking space shall be a rectangle having minimum dimensions of 8 1/2 feet by 18 feet. A perpendicular parking space is defined as one in which the long side of the space is a straight line that intersects the travel lane and curb at a right angle.

(c) Each standard size angled parking space shall be a parallelogram having minimum dimensions in accordance with the table contained in subsection g., below. An angled parking space is one in which the acute angle formed by the intersection of the long side of the space and the curb is between 45 degrees and 75 degrees. The width of an angled parking space is measured parallel to the curb or travel lane along the short side of the parallelogram; and the length of the space is measured along the side of the parallelogram, from the curb to the travel lane.

(d) Within regional shopping centers, the director or planning board may approve smaller than standard size parking spaces for up to 20 percent of the total parking spaces at the center. This modified standard size space shall be for employee use only and shall have minimum dimensions in accordance with the table contained in subsection g., below. Such spaces may be allowed in addition to small car spaces and must be located in a separate area marked for employee parking only.

(e) Each small-car size automobile parking space shall have minimum dimensions in accordance with the table contained in subsection g., below. The director/planning board may permit up to 10 percent of all required spaces to be small-car size spaces, only in exceptional cases where the configuration of the site prevents exclusive use of standard space dimensions. This provision does not apply to parking facilities for residential uses.

(f) If a column or other obstruction is adjacent to a parking space and would interfere with car door openings, then the minimum stall width of that space shall be increased by 1 foot. The inner face of the column or other obstruction shall form the actual boundary of the space when measuring the width or length of the spaces.

(g) The minimum widths and lengths for parking spaces shall be as prescribed in the following table:

Parking Angle	*Standard Size Space Width / Length*		*Modified Standard Size Space (for Regional Shopping Centers Only) Width / Length*		*Small-Car Size Space Width / Length*	
(Parallel) 0°	7'	21'	6.5'	20.5'	6'	19.5'
45°-59°	12'	26.5'	11'	22.5'	N/A	N/A
60°-7°	10'	23'	9'	22'	8.5'	21'
(Perpen-dicular) 90°	8.5'	18'	8'	17.5'	7.5'	16.5'

N/A = Not Applicable

59-E-2.23 Spaces for Handicapped. Parking spaces for handicapped persons shall be provided in accordance with the standards specified in the Maryland Building Code for the Handicapped as contained in the Code of Maryland Regulations 0.5.01.07, dated September 5, 1980, and as subsequently amended. (Ord. No. 10-32, § 10.)

Sec. 59-E-2.3. Standards for Bicycle and Motorcycle Parking

(a) All parking facilities containing more than 50 parking spaces shall provide 1 bicycle parking space or locker for each 20 automobile parking spaces in the facility. Not more than 20 bicycle parking stalls or lockers shall be required in any 1 facility.

(b) Bicycle parking facilities shall be so located as to be safe form motor vehicle traffic and secure from theft. Interior storage and lockers are encouraged. They shall be properly repaired and maintained.

(c) Any owner or operator of a parking facility which charges a fee for the storage of motor vehicles may charge a reasonable fee for bicycle storage.

(d) All parking facilities containing more than 50 parking spaces shall provide motorcycle stalls equal to at least 2 percent of the number of auto spaces. Not more than 10 motorcycle stalls shall be required on any one lot.

(e) The provisions of subsections (a), (b), (c), and (d) pertaining to bicycle and motorcycle parking shall not be applicable for determining eligibility for parking lot district tax exemption. (Ord. No. 10-32, § 10.)

Sec. 59-E-2.4. Access and Circulation

Each parking space shall have access to a street or alley open to use by the public via adequate interior aisles and entrance and exit driveways; provided, however, that where cars will be parked by attendants, at least 50 percent of all parking spaces shall have direct access to interior aisles, and entrance and exit driveways.

59-E.2.41. Driveways.

(a) Interior aisles are vehicular travelways with parking stall along the sides.

(b) Entrance and exit driveways are vehicular travelways, without parking stalls along the sides.

(c) Driveways for one-way movements shall be at least 10 feet in width to allow safe and expeditious movement of vehicles. Entrance and exit driveways shall be separately provided wherever possible. If entrance and exit driveways are combined, the combined driveway shall be not less than 20 feet in width. Aisles designed to accommodate one-way movements shall having the following minimum widths based on the configuration of the adjacent parking spaces: Perpendicular, 20 feet; 60 to 75 degrees, 18 feet; 45 to 59 degrees, 16 feet; parallel, 10 feet. Aisles designed to accommodate two-way movements shall have a minimum width of 20 feet.

59-E-2.42. Walkways. In addition to all required parking spaces and driveways, pedestrian walkways or sidewalks shall be provided in all off-street parking facilities where necessary for pedestrian safety. Such walkways and sidewalks shall be protected from vehicular encroachment by wheelstops, curbs or other methods approved by the director or planning board.

59-E-2.43. Separation from Parking Spaces. All parking spaces shall be separated form sidewalks, roads, streets or alleys be curbing. All roads, streets, alleys, sidewalks and other public rights-of-way shall be protected form vehicular overhang by wheelstops, curbs, spacing between the right-of-way line and the parking area or other method approved by the director/planning board. (Ord. No 10-32, § 10.)

Sec. 59-E-2.5. Drainage

All off-street parking facilities shall be drained so as to prevent damage to abutting properties and public streets, and shall be constructed of material which will assure a surface resistant to erosion. (Ord. No. 10-32, § 10.)

Sec. 59-E-2.6. Lighting

Adequate lighting shall be provided for surface parking facilities used at night and for structure parking as required by construction codes. Lighting shall be installed and maintained in a manner not to cause glare or reflection into abutting or facing residential premises, nor to interfere with safe operation of vehicles moving on or near the premises. (Ord. No. 10-32, § 10.)

Sec. 59-E.2.7. Landscaping

The minimum landscape requirements of this section are intended to alleviate adverse visual and environmental effects associated with parking facilities. The application of these standards will serve to improve compatibility and the attractiveness of such facilities, provide relief from unshaded paved areas, and minimize noise, glare and lights associated with parking areas. In addition, these requirements will improve pedestrian safety, optimize traffic circulation patterns with better defined space, and will provide better definition of entrances and exits through the use of interior islands. The following requirements establish minimum acceptable standards for alleviating the visual and environmental problems associated with off-street parking facilities. Under the site plan review procedures of division 59-D-3, the planning board may require additional landscaping in order to ensure compatibility with adjoining properties.

59-E-2.71. Landscape Strip Area Adjacent to a Street Right-of-way. Parking facilities located adjacent to a street right-of-way shall provide a landscaping strip at least 10 feet in width. This area shall be planted with either shade or ornamental trees. A minimum of 1 tree for every 40 feet of lot frontage shall be provided as well as an evergreen hedge (at least 3 feet in height), a wall or fence, or other methods to reduce the visual impact of the parking facility. For properties located in a central business district (CBD), the minimum width requirement for a landscaping strip adjacent to a street right-of-way may be reduced by the director/planning board in order to achieve a better design solution through the provision of walls or fences in conjunction with landscaping. Any request for reduction for parking facility plans submitted to the director, however, shall be referred to the planning board for review and comment in order to ensure that such reduction is compatible with urban design objectives for the area. The planning board staff shall submit comments to the director within 10 working days from the date of the referral.

59-E-2. 72. Perimeter Landscape Area Adjoining Property Other than a Street Right-of-way. Landscaped areas shall be provided along the perimeter of a parking facility, other than area adjacent to a street right-of-way. The perimeter landscape strip shall be at least 4 feet in width but not less than the setback required in section 59-E-2.8 where a parking facility adjoins a residential zone. Such area shall contain a minimum of 1 shade tree for every 40 feet of lot perimeter and, if space permits, shall incorporate landscaped beams. For properties located in a CBD, the width for a perimeter landscaping strip may be reduced by the director/planning board in order to achieve a better design solution through the provision of walls or fences in conjunction with landscaping. Any request for reduction for parking facility plans submitted to the director, however, shall be referred to the planning board for review and comment in order to ensure that such reduction is compatible with urban design objectives for the area. The planning board staff shall submit comments to the director within 10 working days from the date of referral. Perimeter landscaping shall not be required in addition to screening required in section 59-E-2.9 or where the director/planning board determines that parking areas are already effectively landscaped with natural features such as existing woodland or hillside.

59-E-2. 73. Internal Landscaping of Surface Parking Facility. A minimum of 5 percent of the internal area of a surface parking facility shall be landscaped with shade trees. The internal area of a parking facility is defined by the perimeter of the curbs or edge of paving. The internal area shall include all planting islands and corner areas within the facility. The shade trees should be distributed in order to increase shade. Where possible, existing trees should be saved for this purpose. For properties located in a CBD, the minimum internal landscaping requirements may be reduced by the director/planning board. Any request for reduction for parking facility plans submitted to the director, however, shall be referred to the planning board for review and comment by the planning board staff, in order to ensure that such reduction is compatible with urban design objectives for the area. The planning board staff shall submit comments to the director within 10 working days from the date of the referral. Where one off-street parking area adjoins or abuts another parking area under different ownership or use, a landscaped planting strip not less than 5 feet wide shall be provided.

59-E-2.74. Minimum Size of Planting Islands within Internal Landscape Area. Within the interior of a surface parking facility, planting areas shall be provided with shade trees and shall be wide enough to protect the trees from a vehicle's swinging doors and bumper overhang. Planting islands which are parallel to the sides of parking spaces shall be a minimum of 8.5 feet wide. Planting islands at the heads of parking spaces shall be a minimum of 8 feet wide.

59-E-2.75. Type of Plant Material. Deciduous shade trees with ground cover or low shrubs shall be used as the primary landscape material for parking areas. Use of tall shrubs or low branching trees which will restrict visibility should be avoided. (Ord. No. 10-32, § 10.)

Sec. 59-E-2.8. Parking Facilities Adjoining Residential Zone

59-E-2.81. Setback. Where a parking facility adjoins a residential zone that is not recommended for commercial or industrial use on an approved and adopted master or sector plan and is not used for public or private off-street parking, all parking surfaces, spaces and driveways shall be set back a distance not less than the applicable front, rear or side yard setback required in the adjoining residential zone. In addition, screening shall be provided in accordance with the screening requirements of section 59-E-2.9; except as follows:

(a) If the adjoining residentially zoned land is across an existing or planned public right-of-way 120 feet or greater in width, this provision shall not apply.

(b) If the adjoining land is classified in a multi-family zone, only the minimum setback required in the multi-family residential zone shall apply. Any increased setbacks based on building heights that may be specified in the multi-family zone shall not be applicable.

59-E2.82. Location of Access Driveways. If an off-street parking facility adjoins, or is across a street or alley from, property classified in a residential zone, the entrance and exit driveways of such facilities shall, wherever possible, be located so that they will not be in close proximity to or across a street or alley from the residential property. (Ord. No. 10-32, § 10.)

Sec. 59-E-2.9. Screening from Residential Zone or Institutional Property

59-E-2.91. All off-street parking facilities containing spaces for 6 or more vehicles shall be effectively screened on each side that adjoins or faces a residential zone or institutional property.

(a) Required screening shall consist of a solid wall or fence, of adequate height for screening or a compact evergreen hedge of not less than 3 feet in height at the time of original planting.

(b) The fence, wall, hedge, or permanent natural or artificial screen shall be maintained in good condition, and no advertising shall be placed thereon.

(c) The screening shall be designed and maintained so that safe vehicle sight distance shall not be affected at entrances, exits or at street intersections.

(d) The screening normally shall be located abutting the side, rear or front property line but may be located at the most appropriate place, as approved by the director/planning board, between the perimeter of the parking area and the property line to provide the most effective shield for the adjoining or facing premises from car lights, noise and traffic movement.

(e) Additional or new screening shall not be required where the director/planning board determines that a parking facility is already effectively screened by natural features, railroad tracks on elevated ground, a change in grade or other permanent natural or artificial screen.

(f) Screening shall not be required where a parking facility is separated from a residential zone or institutional use by a road containing a right-of-way width of 120 feet or more. (Ord. No. 10-32, § 10.)

DIVISION 59-E-3. NUMBER OF SPACES REQUIRED

Sec. 59-E-3.1. Mixed Uses

(a) When any land and/or building is under the same ownership and used for 2 or more purposes, the number of parking spaces shall be computed by multiplying the minimum amount of parking normally required for each land use by the appropriate percentage as shown in the following parking credit schedule for each of the 5 time periods shown. The number of parking spaces required is then determined by adding the results in each column. The column total that generates the highest number of parking spaces becomes the parking requirement.

	Weekday		*Weekend*		
	Daytime (6 am-6pm)	*Evening (6pm-midnight)*	*Daytime (6 am-6pm)*	*Evening (6pm-midnight)*	*Nighttime (Midnight–6 am)*
Office/industrial	100%	10%	10%	5%	5%
General retail	60%	90%	100%	70%	5%
Hotel, motel inn	75%	100%	75%	100%	75%
Restaurant	50%	100%	100%	100%	10%
Indoor or legitimate theater and commercial recreational establishment	40%	100%	80%	100%	10%
All Other Uses	100%	100%	100%	100%	100%

(b) The following conditions shall apply to any parking facility for mixed-use development:

(1) The mixed-use property and shared parking facility must be owned by the same developer/owner and must be located within 500 feet walking distance of the entrance to the establishment to be served.

(2) Reserved spaces may not be shared.

(3) The director/planning board shall determine at the time of parking facility plan approval that shared parking is possible and appropriate at the location proposed. Particular attention is needed to assure that sufficient and convenient short-term parking will be available to commercial establishments during the weekday daytime period. The shared parking spaces must be located in the most convenient and visible area of the parking facility nearest the establishment being served.

(4) A subsequent change in use requires a new use and occupancy permit and proof that sufficient parking will be available. (Ord. No. 10-32, § 11.)

Sec. 59-E-3.2. Computing Parking Requirements for Office Development

Base parking requirements for offices shall be determined in accordance with a property's office parking policy area designation and the proximity of the property to a metrorail station. The office parking policy areas are identified on the adopted office parking policy area map which was approved by the district council on June 28, 1984, and is maintained by the planning board. The base parking requirements within individual office parking policy areas vary according to the proximity of a property to a metrorail station which is defined in subsection 3.21 which follows. The following table establishes the base office parking requirements for each policy area:

Base Requirements for Office Parking

Proximity to Metro Station			*Minimum Parking Requirements (Spaces / 1000 GSF)*	
	Southern Area	*South Central Area*	*North Central Area*	*Northern Area*
Less than 800'	1.9	2.8	2.6	N/A
800'-1600'	2.1	2.4	2.7	N/A
More than 1600'	2.4	2.7	2.9	3.0

N/A = Not Applicable

59-E-3.21. Proximity to a Metrorail Station. Proximity to a METRO station is defined as the straightline distance between a main pedestrian entrance of a building for which the parking reduction is to be granted and a station entrance controlled by the W.M.A.T.A. This station entrance is defined further as the street-level entrance of any escalator or the gate or similar barrier of any station entrance which has no escalator.

An existing or planned metrorail station may be used as a basis for the office requirement if:

(a) It is currently in use as part of an operating transit line; or

(b) The director/planning board has received a certified letter from the W.M.A.T.A. stating that a construction contract has been signed for any portion of the construction phase which is located on the same transit line immediately south of the phase of construction in which the proposed building or buildings will be located. (Ord. No. 10-32, § 11.)

Sec. 59-E.8.8. Credits for Specific Uses

Percentage reductions in the required number of parking spaces, as specified in this article, may be approved by the director/planning board and shall be enforced by the director. Where multiple credits are granted, each credit allowance shall be applied only on the marginal parking requirement. After an initial percentage reduction is approved for 1 credit, an additional percentage reduction for each successive credit applies to the balance of the parking supply required.

59-E-3.31. Credits for General Office Building. Parking credits are allowed for office developments that actively participate in the county share-a-ride program and/or provide private incentives for ride-sharing. A schedule of parking credits for offices, based on specific criteria for reductions and penalties for noncompliance, is presented in the following schedule:

(a) Sites within share-a-ride districts. Share-a-ride districts are defined in chapter 42A of the Montgomery County Code.

(1) A 15 percent reduction for participation in share-a-ride's continuous, personalized ridesharing assistance program may be approved if the owner of the development submits a written agreement, with the parking facility plan, that stipulates the following conditions:

a. The owner or lessees with more than 25 employees designate a person who shall promote the program to employees in accordance with established county procedures for the share-a-ride program.

b. The owner or lessees shall reserve a sufficient number of conveniently located parking spaces to accommodate all employee carpools and vanpools.

c. The owner shall make an annual payment to the ridesharing account of the mass transit facilities fund for basic share-a-ride services in accordance with the payment schedule of chapter 42A of the Montgomery County Code.

d. The owner shall certify semi-annually to the director that the above requirements are being satisfied.

e. In the event of noncompliance, the director shall require the owner to pay an annual penalty payment to the ridesharing account for supplementary share-a-ride services, in accordance with the payment schedule of chapter 42A of the Montgomery County Code.

(2) A percentage reduction between 1 and 15 percent may be approved for private incentives (*e.g.*, in-house carpool promotion/matching system, private shuttle bus, van lease or purchase, reserved carpool spaces, and transit pass discount programs) if the owner of the development submits a written agreement, with the parking facility plan, that stipulates the following conditions:

a. The owner shall, as a contingency, set aside land for a parking facility or allow for future construction or expansion of a structured parking facility, sufficient to provide additional parking spaces equal in number to the reduction granted.

b. The owner shall make an annual payment to the ridesharing fund for monitoring and enforcement, in accordance with the payment schedule of chapter 42A of the Montgomery County Code.

c. The owner shall certify to the director semi-annually that the above requirements are satisfied.

d. In the event of noncompliance, the director shall require the owner to satisfy at least one of the following penalties:

1. Construction of additional parking spaces, equal in number to the spaces originally reduced.

2. Pay an annual penalty payment to the ridesharing account for basic or supplementary share-a-ride services, in accordance with the payment schedule of chapter 42A of the Montgomery County Code.

3. Suspension of occupancy permit.

(b) Sites within a share-a-ride outreach area. Share-a-ride outreach areas are defined in chapter 42A of the Montgomery County Code.

(1) A 5 percent reduction for participation in share-a-ride's continuous, personalized ridesharing assistance program may be approved if the owner of the development submits a written agreement, with the parking facility plan, that stipulates the following conditions:

a. The owner or lessees with more than 25 employees designate a person who shall promote the program with employees in accordance with established county procedures for the share-a-ride program.

b. The owner or lessees shall reserve a sufficient number of conveniently located parking spaces to accommodate all employee carpools and vanpools.

c. The owner shall make an annual payment to the ridesharing account for basic share-a-ride services in accordance with the payment schedule of chapter 42A of the Montgomery County Code.

d. The owner shall certify semi-annually to the director that the above requirements are being satisfied.

e. In the event of noncompliance, the director shall require the owner to pay an annual penalty payment to the ridesharing account for supplementary share-a-ride services, in accordance with the payment schedule of chapter 42A of the Montgomery County Code.

(2) A percentage reduction between 1 and 15 percent may be approved for private incentives (*e.g.*, in-house carpool promotion/matching system, private shuttle bus, van lease or purchase, reserved carpool spaces, and transit pass discount programs) if the owner of the development submits a written agreement, with the parking facility plan, that stipulates the following conditions:

a. The owner shall, as a contingency, set aside land for a parking facility or allow for future construction or expansion of a structured parking facility, large enough to provide additional parking spaces equal in number to the reduction granted.

b. The owner shall make an annual payment to the ridesharing account for monitoring and enforcement, in accordance with the payment schedule of chapter 42A of the Montgomery County Code.

c. The owner shall certify to the director semi-annually that the above requirements are satisfied.

d. In the event of noncompliance, the director shall require the owner to satisfy at least one of the following penalties:

1. Construction of additional parking spaces, equal in number to the spaces originally reduced.

2. Pay an annual penalty payment to the ridesharing account for basic or supplementary share-a-ride services, in accordance with the payment schedule of chapter 42A of the Montgomery County Code.

3. Suspension of occupancy permit.

(c) Sites in remaining areas (locations where share-a-ride services are unavailable):

(1) A percentage reduction between 1 and 15 percent may be approved for private incentives (*e.g.*, in-house carpool promotion/matching system, private shuttle bus, van lease or purchase, reserved carpool spaces, and transit pass discount programs) if the owner of the development submits a written agreement with the parking facility plan that stipulates the following conditions:

a. The owner, shall, as a contingency, set aside land for a parking facility or allow for future construction or expansion of a structured parking facility, large enough to provide additional parking spaces equal in number to the reduction granted.

b. The owner shall make an annual payment to the ridesharing account for monitoring and enforcement, in accordance with the payment schedule of chapter 42A of the Montgomery County Code.

c. The owner shall certify to the director semi-annually that the above conditions are satisfied.

d. In the event of noncompliance the owner or lessees shall be subject to one of the following penalties:

1. Construction of additional parking spaces, equal in number to the spaces originally reduced.

2. If located within a parking lot district, satisfy condition (1) above or pay the annual ad valorem tax as specified in chapter 60 of the Montgomery County Code.

3. Suspension of occupancy permit.

(d) For any office development eligible for parking reductions under this section, the percent reductions are applied to the development's base parking requirement, as described in section 59-E-3.2 which is concerned with computing the parking requirements for office development.

59-E-3.32. Credits for Specified Commercial Uses.

(a) For general retail uses, regional shopping centers, restaurants, theaters, furniture stores and auxiliary retail uses, the director may approve a 15 percent reduction in the standard parking requirements provided in section 59-E-3.7. This reduction is allowed if the entrance of the proposed use is located within 1,600 feet of a metrorail station entrance as defined in section 59-E-3.21.

(b) For regional shopping centers, off-site parking spaces may be allowed under the following circumstances:

(1) The off-site parking facility shall be used only by employees of the regional shopping center during seasonal peak periods to help satisfy peak parking requirements.

(2) The off-site parking facility will contain no more than 20 percent of the total parking spaces provided for the regional shopping center; and

(3) The director/planning board finds that there are appropriate contractual or lease agreements guaranteeing the continued availability, for specified peak shopping periods, of such off-site parking spaces for the regional shopping center. In addition, the director/planning board must find that appropriate administrative mechanisms exist to ensure that employees will be required to use the off-site parking facility during specified peak shopping periods.

59-E3.33. Credits for Specified Residential Uses

(a) For multiple-family dwellings, townhouses, and fourplex units, the director/planning board may approve a 10 percent reduction in the standard parking requirement, provided in section 59-E-3.7, if such units are located within a CBD or transit station development area. A 5 percent reduction is also allowed where such units are located within 1,600 feet of a metrorail station entrance as defined in section 59-E-3.21. This credit is not applicable to parking for the elderly or handicapped which is eligible for the credit provisions enumerated in paragraph 6) below.

(b) The director/planning board may approve reductions in the standard parking requirements for housing for the elderly and handicapped as contained in section 59-E-3.7. Reductions shall be in accordance with the following parking credit schedule which shall be applied sequentially, with succeeding percentages applying to the balance:

Located within 1,000 feet of metrorail station entrance:	5%
Provision of private shuttle bus for a minimum of 7 years with continued shuttle bus service after that period subject to parking needs of the specific project as determined by the board of appeals:	10%
Provision of subsidized units:	up to 20%[a]
Provisions for dependent living including a kitchen and cafeteria large enough to accommodate at least 50% of the residents:	20%

a. Actual percentage reduction shall be based on the proportion of subsidized units to total number of units. (Ord. No. 10-32, § 11; Ord. No. 10-63, § 1.)

Sec. 59-E-3.4. Off-site Parking Spaces

(a) Generally, off-site parking spaces for development constructed in accordance with a building permit filed after June 28, 1984, may be approved by the director/planning board if (1) the development is in a parking lot district; or (2) the property proposed to be used for such required parking is plat-restricted or deed-restricted. The restrictions must specify that the property provides the required parking spaces for a use on another property. Such restrictions may be lifted if substitute off-site or leased property is found or if the use ceases to exist.

(b) Where existing off-site parking spaces that provide required parking for a use constructed in accordance with a building permit filed prior to June 28, 1984 are eliminated, the owner shall comply with one of the following conditions:

(1) Build or lease the additional required parking spaces in order to conform with the parking requirements of this article.

(2) If located within a parking lot district, satisfy condition (1) above or pay the annual ad valorem tax.

(3) If applicable, take advantage of credit schedules contained in section 59-E-3.3 in order to reduce the amount of parking required.

(c) Failure to comply with subsection (b) above within 1 year of termination of the required off-site parking shall be cause to classify the use on the applicable property as nonconforming, so long as the use satisfied all lawful requirements in effect prior to June 28, 1984. (Ord. No. 10-32, § 11.)

Sec. 59-E-3.5. Computing Number of Employees

For the purpose of this article, the number of employees shall be the average number of persons to be employed taking into consideration day, night and seasonal variations. (Ord. No. 10-32, § 11.)

Sec. 59-E-3.6. Conflict in Requirements

Whenever, in this chapter, a particular zone contains requirements for parking areas, or there are other provisions which vary from the provisions of this article, the more restrictive requirement shall apply. (Ord. No. 10-32, § 11.)

Sec. 59-E-3.7. Schedule of Requirements

Off-street parking space must be provided as follows:

Airport, airpark and airfield. Adequate space for off-street parking for at least 50 vehicles.

Ambulance service or rescue squad. Adequate space to accommodate all motor vehicles operated in connection with such use and 2 additional parking spaces per each such vehicle.

Apartment. Same as multiple-family dwelling.

Apartment, accessory. Normally 2 parking spaces per lot. However, the board of appeals may require more or permit less in accordance with the special exception provisions for accessory apartments contained in section 59-G-2.00(c)(4).

Apartment hotel. One parking space for each transient bedroom; for each apartment or transient suite with no separate bedroom—1 space; for each apartment or transient suite. with 1 separate bedroom 1.25 spaces; for each apartment or transient suite wit 2 bedrooms—1.5 spaces; for each apartment or transient suite with 3 or more separate bedrooms—2 spaces, and 1 parking space for each 2 employees on the major shift; plus 2.5 parking spaces for each 1,000 square feet of area used for ballrooms, private meeting rooms, dining rooms and other similar places of assembly.

Auditorium or stadium. One automobile parking space for each 4 seats or similar vantage accommodations provided. The base requirements may be reduced in accordance with the credit provisions contained in section 59-E-3.3.

Automobile filling station. Two parking spaces for each car wash bay, geese bay or similar service area, and 1 parking space for each employee.

Automobile repair and service station. One parking space for each employee, and 3.3 parking spaces for each 1,000 square feet of total floor area.

Auxiliary retail establishments. Three and one-half space. The base requirement may be reduced in accordance with the credit provisions contained in section 59-E-3.3. Retail establishments must be classified as auxiliary retail uses when located within an office building that contains at least 100,000 gross square feet, contains less than 15 percent of the building's overall gross square footage, and contains less than 30,000 leasable square feet. Auxiliary retail uses shall not qualify for reductions for shared parking in mixed-use developments or parking lot district facilities.

Boardinghouse. One parking space for each guest accommodation on new construction. One parking space for each two (2) guest accommodations in converted structure.

Care home. One parking space for every 4 beds and 1 space for every 2 employees on largest work shift.

Church, synagogue or other place of worship. One parking space for each 4 persons for whom seating is provided in the main auditorium; provided, that the number of spaces thus required may be reduced by not more than 30 percent if the church, synagogue or other place of worship is located within 500 feet of any public parking lot or any commercial parking lot where sufficient spaces are available during the time of services to make up the additional spaces required. This requirement shall not apply to any existing building or structure which is used for religious purposes, nor to additions, alterations or enlargements of such existing buildings and structures, nor to new buildings on land now improved by a building in use for religious purposes, or land contiguous to such improved land, as of May 1, 1962; nor to any such building or structure for which a valid building permit has been issued prior to such date.

Any place of worship used by a congregation whose religious beliefs prohibit the use of motor vehicles in traveling to or from religious services conducted on their Sabbath and principal holidays shall only be required to provide 1 space for each 8 persons for whom seating is provided in the main auditorium; provided further, that the spaces thus required do not have to be provided on the building site if such place of worship is located within 500 feet of any public parking lot or any commercial parking lot where sufficient spaces are available during the time of services or other proposed use of the building to provide the spaces required.

Community center, library, museum, civic club, private club, lodge and similar uses. Two and five-tenths parking spaces for each 1,000 square feet of total floor area.

Dwelling, multiple-family. For each dwelling unit with no separate bedroom, 1 space; for each dwelling unit with 1 separate bedroom, 1.25 spaces; for each dwelling unit with 2 separate bedrooms, 1.5 spaces; for each dwelling unit with 3 or more separate bedrooms, 2 spaces. The base requirement may be reduced in accordance with the credit provisions of section 59-E-3.33. Not more than 50 percent of the total area of the minimum required side and rear yards shall be occupied by parking spaces, drives, access roads to, from and between such spaces, turn-arounds or other surfaces designed for vehicular use, and no parking spaces or vehicular uses, except entrance drives, shall be located within the minimum required front yard. (See R-H zone for controlling provisions in that zone on parking in yards.) In the R-10 and R-H zones and in the 5 CBD zones in section 59-C-6.2, the requirement for each moderately priced dwelling unit, as defined in chapter 25A of this Code, shall be one-half the number of spaces indicated above.

Dwelling, one-family. Two parking spaces for each dwelling unit; except, that when the slope between the standard street sidewalk elevation at the front lot line and side lot line adjacent to a street, established in accordance with the county road construction code, and the finally graded lot elevation at the nearest building line exceeds, at every point along the front lot line, a grade of 3 inches per foot, such space shall not be required.

Dwelling, semi-detached or two-family. Same as one-family dwelling.

Educational institution, private. One parking space for each employee, including teachers and administrators, plus sufficient off-street parking space for the safe and convenient loading and unloading of students, plus additional facilities for all student parking.

Eleemosynary and philanthropic institution. One parking space for each employee, plus 1 parking space for each 400 square feet of total floor area for residents and visitors.

Farm machinery and supply. For retail sales of farm machinery and supply, 5 parking spaces for each 1,000 square feet of interior and exterior sales area, unless, in the opinion of the board of appeals, the required parking spaces can be reduced without adverse impact on adjoining uses; in no instance can the number of required spaces be less than 2 for each 1,000 square feet of interior and exterior sales area. For an establishment devoted solely to storage and service of farm machinery and supply, see ""Industrial or manufacturing establishment or warehouse."

Fourplex. A lot or parcel used for the development of dwellings in this zone shall provide at least 2 off-street parking spaces per dwelling unit. The base requirement may be reduced in accordance with the credit provisions of section 59-E-3.33.

Fraternity, sorority and dormitory. One parking space for each 2 students residing on the premises in a fraternity or a sorority and 4 students in a dormitory, plus 1 additional space for each housemother or manager and each employee.

Furniture store. Two parking spaces for each 1,000 square feet of gross floor area plus 1 space for each employee. This requirement does not apply to the furniture section of a department store or furniture store located in a regional shopping center.

Guest rooms in a country inn. One parking space for each guest room.

Heliport / helistop (public use). If at ground level, adequate space for off-street parking of at least 15 vehicles. If elevated, reasonable parking space shall be provided or be available for use as required by the board of appeals for the convenience of persons using or working at the facility.

Heliport / helistop (private use). Whether at ground level or elevated, reasonable parking space shall be provided or be available for use as required by the board of appeals for the convenience of persons using the facility.

Hospital. One parking space for each 1,000 square feet of total floor area, plus 1 space for each resident doctor, plus adequate reserved space for visiting staff doctors, plus 1 space for each 3 employees on the major shift.

Hotel, motel or inn. If located within a central business district or a transit station development area, one-half space for each guest room plus 10 spaces for each 1,000 square feet of gross floor area used for ballrooms, private meeting rooms, dining areas, and similar places of assembly. For other locations seven-tenths of a space for each guest room, plus 10 spaces for each 1,000 gross square feet of area used for ballrooms, private meeting rooms, dining rooms and similar places of assembly.

Housing for the elderly or handicapped. Base parking for housing for the elderly or handicapped shall be determined in accordance with a property's location relative to the parking policy area designations as approved by the district council on June 28, 1984, and as maintained by the planning board. The base parking requirements vary according to the number of bedrooms in each elderly housing unit.

Base Requirements for Housing for Elderly

	Minimum Parking Requirements (Spaces / Unit)			
No. of Bedrooms	*Southern Area*	*South Central Area*	*North Central Area*	*Northern Area*
0-1	0.50	0.65	0.85	1.00
2 or more	0.65	0.85	1.15	1.35

The base requirement may be reduced in accordance with the credit provisions of section 59-E-3.33.

Industrial or manufacturing establishment or warehouse. One parking space for each employees on the major shift, plus 1 space for every vehicle used in connection with the business, and sufficient additional parking to provide waiting area for loading and unloading. (Follow section 59-C-5.434 for I-3 requirements.)

Medical or dental clinic. Five parking spaces for each 1,000 square feet of the gross floor area of the building.

Mobile home development. Two parking spaces for each mobile home in the development.

Mortuary or funeral parlor. Eighty-three parking spaces for each 1,000 square feet in the main chapel or parlor, plus 1 parking space for each employee on the major shift, and 1 parking space for each vehicle used in connection with the business.

Nursing home. One space for every 4 beds and 1 space for every 2 employees on largest work shift.

Office, general office, and professional buildings or similar uses. Parking shall be provided in accordance with the parking requirements for office developments contained in section 59-E-3.2. The base requirements may be reduced in accordance with the credit provision of section 59-E-3.3. The calculation of building square footage is based on the sum of the gross areas of the several floors of the building, measured from the exterior faces to the exterior walls or from the center line of party walls, which area shall include cellars or basements but shall not include floor area used for off-street parking.

Office, medical practitioner's. Not less than 4 parking spaces for each practitioner occupying or using such office.

Office, professional, nonresidential. Five parking spaces for each 1,000 square feet of gross floor area used by medical practitioners and 2.5 parking spaces for each 1,000 square feet of gross floor area used by all other professionals. The gross floor area calculation shall exclude storage area, and the attic and cellar areas of the building if not occupied by professional personnel.

Office, professional, other than medical practitioner. Two spaces for each professional person occupying or using such office.

Railroad station, bus depot or other passenger terminal facilities. One hundred parking spaces.

Recreational establishment, commercial, other than a theater, auditorium or stadium. Twelve and five-tenths parking spaces for each 1,000 square feet of floor area, except as to racquetball, squash, and handball courts. As to racquetball, squash, and handball courts there shall be 3.5 parking spaces per racquetball, squash, or handball court.

Regional shopping centers devoted to retail sales, trade, merchandising or other similar use containing at least 500,000 gross leasable square feet regardless of the amount of land included in the center. Five and one-half parking spaces for each 1,000 square feet of gross leasable square feet as defined herein. In addition, parking requirements for separate standing office and professional buildings shall be as set forth under the category of this subsection pertaining to office buildings, professional buildings or similar uses. As used herein, ""gross leasable square feet" is defined as the total floor area designed for commercial tenant occupancy and exclusive uses, including basements, mezzanines and the upper floors if any, expressed in square feet measured from center lines of joint partitions and exteriors of outside walls. This definition does include banks, furniture stores, and other such activities which are a part of a regional shopping center. In accordance with the exception provision of section 59-E-5.8 all storage space that exceeds 35 percent of the total gross leasable area shall be excluded in calculating the number of required parking spaces. Not included in this definition are separate standing office or professional buildings.

Restaurant or similar place dispensing food, drink or refreshments. Twenty-five parking spaces for each 1,000 square feet of Moor area devoted to patron use within the establishment and 15 parking spaces for each 1,000 square feet of ground area devoted to patron use on the property outside the establishment. The base requirements may be reduced in accordance with the credit provision of section 59-E-3.3.

Retail, general. Commercial establishments devoted to retail sales, merchandising or other similar use, except furniture stores, 5 parking spaces for each 1,000 gross leasable square feet. In accordance with the exception provision of section 59-E-5.8 all storage space that exceeds 35 percent of the total gross leasable area shall be excluded in calculating the number of required parking spaces.

Roadside farm markets. Five parking spaces for each 1,000 square feet of area used for interior and exterior retail display sales.

Swimming pool, commercial. One parking space for every 4 persons lawfully permitted in the pool at 1 time.

Swimming pool, community. One parking space for every 7 persons lawfully permitted in the pool at 1 time except where such pool is a permitted use pursuant to the provisions of section 59-C-1.531 or 59-C-1.621, the number and location of parking spaces required shall be determined by the planning board.

Theaters, indoor or legitimate. One parking space for each 4 seats or similar vantage accommodations provided.

Tourist home. One parking space for each guest room or suite.

Townhouse. Two parking spaces for each townhouse. The base requirements may be reduced in accordance with the credit provisions of section 59-E-3.33.

Trailer coach park. One parking space for each trailer space, and 1 parking space for each employee on major shift.

(Ord. No. 8-55, §§ 10, 11; Ord. No. 8-80, § 2; Ord. No. 8-81, § 16; Ord. No. 9-1, § 1; Ord. No. 9-2, § 4; Ord. No. 10-21, § 1; Ord. No. 10-32, § 11; Ord. No. 10-39, § 12; Ord. No. 10-63, § 2; Ord. No. 10-69, § 7.)

Source: Montgomery County, Maryland.

APPENDIX I

Parking Spaces Per Enplanement

PARKING SPACES PER ENPLANEMENT[a]

Airport	SMSA[b] Population (x 1,000)	1985 Enplanements (x 1,000,000)	On-airport Public Spaces: Total	On-airport Public Spaces: Per 1,000,000 Enplanements	Off-airport Public Spaces	Total Spaces Per 1,000,000 Enplanements	Employee Spaces
Chicago O'Hare	6,157	23.28	13,000	558	3,000	687	3,300
Atlanta	2,393	21.63	13,517	625	4,500	833	631
Los Angeles	7,909	18.82	25,129	1,335	16,942	2,235	--
Dallas-Fort Worth	2,238	18.20	23,162	1,273	1,400	1,350	9,790
Denver	1,609	15.00	10,500	700	3,500	933	5,000
NY-Kennedy	8,391	14.80	13,200	892	--	892	2,900
San Francisco	689	12.60	10,000	794	4,200	1,127	2,000
Newark	1,868	11.80	18,600	1,576	--	1,576	1,485
Boston Logan	3,678	10.23	10,215	999	3,000	1,292	6,000
NY-La Guardia	8,391	10.20	7,325	718	--	718	3,000
St. Louis	2,399	9.95	6,051	608	--	608	1,187
Miami	1,756	9.86	7,000	710	--	710	3,700
Honolulu	805	8.31	3,153	379	--	379	1,541
Detroit	1,801	7.83	10,200	1,303	14,000	3,091	--
Pittsburgh	2,175	7.53	5,029	668	1,950	927	1,765
Washington Nat'l	1,955	6.90	4,643	673	--	673	2,979
Houston Int'l	3,177	6.70	13,300	1,985	8,700	3,284	1,927
Phoenix	1,715	5.80	6,486	1,118	3,525	1,726	1,250
Seattle-Tacoma	2,208	5.75	4,613	802	5,800	1,811	2,500
Philadelphia	4,768	5.66	9,000	1,590	4,000	2,297	1,300
Las Vegas	537	5.40	2,500	463	--	463	1,460
Mpls/St. Paul	2,231	5.14	7,948	1,546	1,500	1,838	900
Orlando	824	4.89	4,309	881	1,800	1,249	1,000
Salt Lake City	1,025	4.64	5,000	1,078	1,000	1,293	1,500
Tampa	1,837	4.36	4,950	1,135	--	1,135	1,600
San Diego	969	4.28	3,993	933	1,400	1,260	869
Baltimore	2,245	3.90	8,463	2,170	--	2,170	1,900
Memphis	935	3.64	3,193	877	200	932	1,133
Kansas City	1,477	3.50	8,300	2,371	--	2,371	1,140
Cleveland	2,783	3.19	5,050	1,583	3,600	2,712	840
New Orleans	1,338	2.82	2,694	955	2,000	1,665	2,000
Portland	1,341	2.52	3,819	1,515	350	1,654	974
Reno	101	2.43	1,678	691	100	732	200
San Jose	1,372	2.35	5,900	2,511	--	2,511	465

a. 1985 data.
b. Standard Metropolitan Statistical Area.

Source: Joseph P. McGee and William C. Arons, "Second National Parking Association Airport Survey." *Parking* (November-December 1986).

APPENDIX **J**

Peak-Parking Demands and Parking Generation Rates

1. SUMMARY OF COMPARATIVE PEAK-PARKING DEMANDS

Activity	*Unit*	*Rate*	*Period*	*Source*
Office	1,000 sq ft GLA	3.00	Weekday day	1
	1,000 sq ft GLA	0.8-2.8	Weekday day	2
	1,000 sq ft occupied building area	3.13	Weekday day	7
	Employee	0.93	Weekday day	3
Retail				
<400,000 sq ft	1,000 sq ft GLA	4.00	Saturday day	8
	1,000 sq ft GLA	4.50	Saturday day	1
	1,000 sq ft GLA	5.00	Saturday day	11
400,000-600,000 sq ft	1,000 sq ft GLA	4.50	Saturday day	8
	1,000 sq ft GLA	6.00	Saturday day	11
>600,000 sq ft	1,000 sq ft. GLA	5.00	Saturday day	8
	1,000 sq ft. GLA	5.50	Saturday day	1
	1,000 sq ft. GLA	6.30	Saturday day	11
All	1,000 sq ft GLA	5.10	Saturday day	3
Convenience stores	1,000 sq ft GLA	3.00	Saturday day	8
	1,000 sq ft GLA	4.00	Saturday day	3
Restaurant (quality)	1,000 sq ft GLA	20.00	Sat evening	1
	1,000 sq ft GLA	20.11	Sat evening	3
Cinema	Seat	0.30	Sat evening	1
	Seat	0.37	Sat evening	3
Hotel	Rooms	1.10	Weekday evening	3
	Rooms	1.25	Weekday evening	8
	Rooms	1.00	Weekday evening	1
Light industry	1,000 sq ft building area	2.43	Weekday day	3
Industrial park	1,000 sq ft building area	2.11	Weekday day	3
	Employee	0.80	Weekday day	3
	Employee	0.35-1.10	Weekday day	2

SUMMARY OF COMPARATIVE PEAK PARKING DEMANDS *(cont)*

Activity	*Unit*	*Rate*	*Period*	*Source*
Industry-all	Employee	0.60	Weekday day	8
Industrial plant	Employee	0.62	Weekday day	5
Heavy industry	1,000 sq ft building area	2.28	Weekday day	3
Hospitals	Beds	2.48	Weekday day	2
	Beds	2.53	Weekday day	4
	Beds	2.54	Weekday day	6
Medical center	Beds	3.22	Weekday day	6
Residential				
Single family	Dwelling Unit	2.00	Evening	8
Condominium	Dwelling Unit	1.41	Weekday evening	3
	Dwelling Unit	1.37	Weekday evening	9
	Bedroom	1.05	Saturday evening	9
Multi-family	Dwelling Unit			
Efficiency	Dwelling Unit	1.00	Weekday evening	6
1-2 bedrooms	Dwelling Unit	1.50	Weekday evening	
3 or more bedrooms	Dwelling Unit	2.00	Weekday evening	
Low-rise apartment	(Occupied) Dwelling Unit	1.53	Saturday evening	3
High-rise apartment/ central areas	(Occupied) Dwelling Unit	0.59	Weekday evening	3
All apartments	(Occupied) Dwelling Unit	0.4-1.3	Weekday evening	2
All multi-family	Per Auto Per Dwelling Unit	1.00	Weekday evening	1
Drive-in bank	Per 1,000 sq ft GFA	12.5	Weekday day	10
<3,000 sq ft	Per 1,000 sq ft GFA	6.00	Weekday day	10
All	Per 1,000 sq ft GFA	5.47	Weekday day	10
				3
Fast food restaurant with drive-in window	Per 1,000 sq ft GLA	13.36	Weekday day	3
	Per 1,000 sq ft GLA	19.80	Weekday day	10
	Per Seat	0.70	Weekday day	3
	Per Seat	0.76	Weekday day	10
University				
Staff spaces	Per Daytime Staff Population	0.92	Weekday day	6
Daytime campus spaces				
Daytime commuter student spaces	Per Commuter Student	0.137	Weekday day	6
Daytime resident student spaces	Per Resident Student	0.36	Weekday day	6

1. Barton-Aschman Assoc., Inc., *Shared Parking*—A Study Conducted Under the Direction of the Urban Land Institute (1983).

2. Jean M. Keneipp, "Parking Demand," in *The Dimensions of Parking*, 2nd ed.

3. *Parking Generation*, 2nd ed. (Institute of Transportation Engineers, 1987). Approximate 85 percentile—mean + one standard deviation.

4. J.M. Hunnicutt, "Parking, Loading and Terminal Facilities," in *Transportation and Traffic Engineering Handbook*, 2nd ed. (Institute of Transportation Engineers, 1982). Approximate 85 percentile—mean + standard deviation.

5. *Parking Facilities for Industrial Plants* (Washington, D.C.; Institute of Traffic Engineers, 1969).

6. E.M. Whitlock, *Parking for Institutions and Special Events* (Westport, CT: Eno Foundation, 1982). Hospitals (Table A-II)—mean + one standard deviation for 14 medical centers and 15 general hospitals.

7. Barkan and Mess, Inc., *Survey of Parking at Corporate Office Buildings in Southwestern Connecticut* (August 1984). Eleven office buildings—mean + one standard deviation.

8. V.G. Stover and F.J. Koepke, *Transportation and Land Development* (Englewood Cliffs, NJ: Institute of Transportation Engineers, 1987).

9. Barkan and Mess, Inc., *1984 Surveys of Two Condominiums in Connecticut—Maximum Rates.*

10. Council of Governments, Central Naugatuck Valley, Connecticut, *Regulatory Off-street Parking through Zoning —A Case Study of Bank and Restaurant Parking*. 85 percentile values.

11. Eighty-five percentile values-20th highest day based on Table A in *Parking Requirements for Shopping Centers—Summary Recommendations and Research Study Report* (Urban Land Institute, 1982).

2. SUMMARY OF ITE PARKING GENERATION RATES

Use	*Period*	*Unit*	*No. of Studies*	*Average Rate*	*Range of Rates*	*Standard Deviation*	*Coefficient of Variation (%)*
Commercial Airport	Weekday	Daily Airplane Movements	73	8.56	3.05-20.93	4.74	55.1
	Saturday	Daily Airplane Movements	13	14.83	6.37-32.25	8.82	59.5
	Sunday	Daily Airplane Movements	11	8.39	5.28-18.15	3.75	44.7
	Weekday	Enplaning Passengers	74	0.44	0.16-1.03	0.20	45.5
	Saturday	Enplaning Passengers	13	0.89	0.18-2.17	0.59	66.3
	Sunday	Enplaning Passengers	11	0.84	0.14-4.60	1.21	144.0
Light Industry	Weekday	1,000 sq ft-Building Area	8	1.55	0.67-3.48	0.88	56.8
	Weekday	Employee	6	0.79	0.36-1.56	0.43	54.4
Industrial Park	Weekday	1,000 sq ft-Building Area	5	1.48	0.75-2.41	0.63	42.6
	Weekday	Employee	3	0.74	0.67-0.81	0.06	8.1
Manufacturing	Weekday	1,000 sq ft-Building Area	20	1.59	0.75-2.97	0.69	43.4
	Weekday	Employee	18	0.73	0.29-1.75	0.35	48.0
Low/mid-rise apartment	Weekday	Dwelling Units	60	1.04	0.24-1.90	0.34	32.7
	Saturday	Dwelling Units	11	1.21	0.68-1.76	0.32	26.4
High-rise apartment (central area)	Weekday	Dwelling Units	6	0.46	0.30-0.60	0.13	29.0
Residential condominium	Weekday	Dwelling Units	32	1.11	0.20-1.61	0.30	27.0
	Saturday	Dwelling Units	8	0.95	0.47-1.36	0.28	29.5
Convention hotel	Weekday	Rooms	22	0.81	0.26-1.32	0.29	35.8
Motel with restaurant/lounge	Weekday	Rooms	10	0.89	0.40-2.58	0.60	67.4
Movie theater	Weekday	Seats	11	0.19	0.06-0.46	0.11	57.9
	Saturday	Seats	9	0.26	0.11-0.42	0.11	42.3
Sports club/health spa	Weekday	1,000 sq ft Gross Leasable Area	43	4.37	1.66-11.70	2.00	45.8
Church/synagogue	Sunday	Attendees	8	0.43	0.12-0.63	0.19	44.2
Hospital	Weekday	Beds	20	1.79	0.74-2.96	0.69	38.5
Medical-rental clinic/office	Weekday	1,000 sq ft Building Area	40	4.11	2.22-9.69	1.39	33.8
General office building	Weekday	1,000 sq ft Building Area	207	2.79	0.75-32.93	2.25	80.6
	Weekday	Employees	22	0.79	0.58-1.07	0.14	17.7
Office park	Weekday	1,000 sq ft Building Area	24	2.52	0.94-4.25	0.76	30.1
		Employees	10	0.76	0.58-0.92	0.11	14.4
Hardware/paint/home improvement store	Weekday	1,000 sq ft Gross Leasable Area	7	2.41	1.74-4.33	0.82	34.0
	Saturday	1,000 sq ft Gross Leasable Area	8	3.29	1.50-4.64	0.90	27.4

2. SUMMARY OF ITE PARKING GENERATION RATES *(cont.)*

Use	*Period*	*Unit*	*No. of Studies*	*Average Rate*	*Range of Rates*	*Standard Deviation*	*Coefficient of Variation (%)*
Shopping center	Weekday	1,000 sq ft Gross Leasable Area	141	3.23	1.02-6.17	1.20	37.2
	Saturday	1,000 sq ft Gross Leasable Area	178	3.97	1.11-6.06	1.13	28.5
Quality restaurant	Weekday	1,000 sq ft Gross Leasable Area	34	12.49	6.25-25.83	4.91	39.3
	Saturday	1,000 sq ft Gross Leasable Area	8	15.89	10.37-23.50	4.22	26.6
Quality restaurant	Weekday	Seats	22	0.38	0.18-0.83	0.16	42.1
	Saturday	Seats	5	0.46	0.30-0.74	0.15	32.6
Family restaurant	Weekday	1,000 sq ft Gross Leasable Area	11	9.08	5.67-13.50	2.07	22.8
	Weekday	Seats	19	0.28	0.08-0.66	0.14	50.0
Fast food restaurant without drive-in window	Weekday	1,000 sq ft Gross Leasable Area	17	11.68	2.77-19.11	3.68	31.5
	Weekday	Seats	5	0.50	0.15-0.97	0.27	54.0
Fast food restaurant with drive-in window	Weekday	1,000 sq ft Gross Leasable Area	18	9.95	3.55-15.92	0.24	52.2
		Seats	17	0.46	6.20-1.02	3.41	34.2
Bank with drive-in and walk-in facilities	Weekday	1,000 sq ft Gross Leasable Area	13	4.23	2.29-7.42	1.24	29.3

Source: *Trip Generation*, 2nd ed. (Institution of Transportation Engineers, 1987).

Note: Data from small samples with very poor stability, or with poor correlations are not included.

APPENDIX **K**

Hourly Parking Characteristics

1. HOURLY PARKING DEMAND RATIOS-DEFAULT VALUES

Hour of Day (start)	Office: Spaces per 1,000 Sq. Ft. GLA — Weekday	Office — Sat.	Retail: Spaces per 1,000 Sq. Ft. GLA — Weekday[d]	Retail — Sat.[c]	Retail — Sat.[d]	Restaurant: Spaces per 1,000 Sq. Ft. GLA — Weekday	Restaurant — Sat.	Cinema: Spaces per Seat — Weekday	Cinema — Sat.[e]	Residential: Spaces per Dwelling Unit[b] — Non-CBD Weekday	Residential — Non-CBD Sat.	Residential — CBD Daily	Hotel — Guest Rooms: Spaces per Room — Weekday	Hotel — Guest Rooms — Sat.	Hotel — Restaurant/ Lounge[a]: Spaces per 1,000 Sq. Ft. GLA — Weekday	Hotel — Restaurant/ Lounge[a] — Sat.	Hotel — Conference Rooms[a]: Spaces per Seat — Daily	Hotel — Convention Area[a]: Spaces per 1,000 Sq. Ft. — Daily
6:00 a.m.	0.1	-	-	-	-	-	-	-	-	1.00	1.00	1.00	1.00	0.90	2.0	2.0	-	-
7:00	0.6	0.1	0.3	0.1	0.2	0.5	0.5	-	-	0.87	0.95	0.95	0.85	0.70	2.0	2.0	-	-
8:00	1.9	0.3	0.7	0.4	0.6	1.0	0.5	-	-	0.79	0.88	0.90	0.65	0.60	2.0	2.0	0.2	10
9:00	2.8	0.4	1.7	1.4	1.7	2.0	1.0	-	-	0.73	0.81	0.87	0.55	0.50	2.0	2.0	0.5	30
10:00	3.0	0.4	2.7	2.0	2.5	4.0	1.5	-	-	0.68	0.74	0.85	0.45	0.40	2.0	2.0	0.5	30
11:00	3.0	0.5	3.4	3.3	4.0	6.0	2.0	-	-	0.59	0.71	0.85	0.35	0.35	3.0	3.0	0.5	30
12:00 Noon	2.7	0.5	3.9	3.8	4.7	10.0	6.0	0.10	0.10	0.60	0.71	0.85	0.30	0.30	5.0	3.0	0.5	30
1:00 p.m.	2.7	0.4	4.0	4.3	5.2	14.0	9.0	0.15	0.20	0.59	0.70	0.85	0.30	0.30	7.0	4.5	0.5	30
2:00	2.9	0.3	3.9	4.5	5.5	12.0	9.0	0.15	0.20	0.60	0.71	0.85	0.35	0.35	6.0	4.5	0.5	30
3:00	2.8	0.2	3.8	4.5	5.5	12.0	9.0	0.15	0.20	0.61	0.73	0.85	0.35	0.40	5.5	4.5	0.5	30
4:00	2.3	0.2	3.5	4.0	5.0	10.0	9.0	0.15	0.20	0.66	0.75	0.87	0.45	0.50	5.0	4.5	0.5	30
5:00	1.4	0.1	3.1	3.4	4.1	14.0	12.0	0.15	0.20	0.77	0.81	0.90	0.60	0.60	7.0	6.0	0.5	30
6:00	0.7	0.1	3.4	2.9	3.6	18.0	18.0	0.20	0.25	0.85	0.85	0.92	0.70	0.70	9.0	9.0	0.5	30
7:00	0.2	0.1	4.6	2.7	3.3	20.0	19.0	0.20	0.25	0.94	0.87	0.94	0.75	0.80	10.0	9.5	0.5	30
8:00	0.2	0.1	4.2	2.5	3.0	20.0	20.0	0.25	0.30	0.96	0.92	0.96	0.90	0.90	10.0	10.0	0.5	30
9:00	0.1	-	2.6	1.8	2.2	20.0	20.0	0.25	0.30	0.98	0.95	0.98	0.95	0.95	10.0	10.0	0.5	30
10:00	0.1	-	1.4	1.7	2.1	18.0	19.0	0.25	0.30	0.99	0.96	0.99	1.00	1.00	9.0	9.5	0.2	10
11:00	-	-	0.8	0.6	0.7	14.0	17.0	0.20	0.25	1.00	0.98	1.00	1.00	1.00	7.0	8.5	-	-
12:00 Midnight	-	-	-	-	-	10.0	14.0	0.15	0.20	1.00	1.00	1.00	1.00	1.00	5.0	7.0	-	-
Peak-parking ratio	3.0	0.5	4.6	4.5	5.5	20.0	20.0	0.25	0.30	1.0	1.0	1.0	1.0	1.0	10.0	10.0	0.5	30
Percent auto usage	100	100	100	100	100	100	100	100	100	NA	NA	NA	80	80	100	100	100	100
Average person/ auto	1.2	1.2	1.8	1.8	1.8	2.0	2.0	2.0	2.0	NA	NA	NA	1.4	1.4	2.0	2.0	2.0	2.0

a. Represents nonguest parking demand, assuming 50 percent of restaurant patrons and 100 percent of conference an convention attendees are nonguests. Conference and convention demands indicated are upper bounds, which are rarely achieved.

b. At one auto per dwelling unit.

c. For less than 400,000 sq. ft. GLA.

d. For more than 600,000 sq. ft. GLA.

e. Saturday peak-Cinema demand may reach 0.35 8-10 PM

Source: Adapted from *Shared Parking.*

2. REPRESENTATIVE HOURLY ACCUMULATION BY PERCENTAGE OF PEAK HOUR

Hour of Day (start)	Office		Retail			Restaurant		Cinema	Residential (non-CBD)		Residential (CBD)	Hotel: Guest Room		Hotel: Restaurant/ Lounge		Hotel: Conference Room	Hotel: Convention Area
	Weekday	Sat.	Weekday[a]	Weekday[b]	Sat.	Weekday	Sat.	Daily	Weekday	Sat.	Daily	Weekday	Sat.	Weekday	Sat.	Daily	Daily
6:00 a.m.	3	-	-	-	-	-	-	-	100	100	100	100	90	20	20	-	-
7:00	20	20	8	7	3	2	2	-	87	95	95	85	70	20	20	-	-
8:00	63	60	18	16	10	5	3	-	79	88	90	65	60	20	20	50	50
9:00	93	80	42	36	30	10	6	-	73	81	87	55	50	20	20	100	100
10:00	100	80	68	59	45	20	8	-	68	74	85	45	40	20	20	100	100
11:00	100	100	87	75	73	30	10	-	59	71	85	35	35	30	30	100	100
12:00 Noon	90	100	97	84	85	50	30	30	60	71	85	30	30	50	30	100	100
1:00 p.m.	90	80	100	86	95	70	45	70	59	70	85	30	30	70	45	100	100
2:00	97	60	97	84	100	60	45	70	60	71	85	35	35	60	45	100	100
3:00	93	40	95	82	100	60	45	70	61	73	85	35	40	55	45	100	100
4:00	77	40	87	75	90	50	45	70	66	75	87	45	50	50	45	100	100
5:00	47	20	79	68	75	70	60	70	77	81	90	60	60	70	60	100	100
6:00	23	20	82	73	65	90	90	80	85	85	92	70	70	90	90	100	100
7:00	7	20	89	100	60	100	95	90	94	87	94	75	80	100	95	100	100
8:00	7	20	87	91	55	100	100	100	96	92	96	90	90	100	100	100	100
9:00	3	-	61	51	40	100	100	100	98	95	98	95	95	100	100	100	100
10:00	3	-	32	30	38	90	95	100	99	96	99	100	100	90	95	50	50
11:00	-	-	13	11	13	70	85	80	100	98	100	100	100	70	85	-	-
12:00 Midnight	-	-	-	-	-	50	70	70	100	100	100	100	100	50	70	-	-

a. Retail less than 400,000 sq ft.

b. Retail more than 600,000 sq ft.

Source: The Urban Land Institute, *Shared Parking* (1983).

APPENDIX **L**

Checklist to Help Assure Optimum Parking Structure Design

SITE SELECTION

1. Has the probable cost (or value) of the site been realistically appraised?
2. Would such a cost be economically justified?
3. Would the garage be within reasonable walking distance of a sufficient number of parking generators not now adequately served to justify its construction?
4. Would pedestrianways between the garage and the generators it would serve be pleasant, attractive and safe?
5. If the proposed site is irregular in shape or size, would remnants not needed for parking be developed as attractive green areas or as covered connections to nearby buildings? (It is often more efficient and economical to build on only part of an irregularly-shaped site, leaving the remainder for other uses.)
6. Would the garage have any other direct pedestrian connection with nearby buildings? (Enclosed pedestrian passageways usually encourage use of a parking facility -- particularly in areas with severe climate.)
7. Would entering and/or exiting cars conflict seriously with large numbers of pedestrians on abutting sidewalks?
8. Would capacity of abutting streets be adequate for the next 10 years under all likely developments to assure that the garage would continue to be easily accessible?
9. Does the plan propose use of two or more streets for exiting traffic? (A choice of exits helps disperse traffic leaving the garage and may assist in avoiding backups within the facility.)
10. Would cars waiting to enter the garage seriously impede other traffic?
11. Could major feeder streets be used easily accommodate logical maneuvers to approach and depart from the garage?
12. Could most patrons enter and exit by making right turns?
13. Would every exit be far enough from the nearest street intersection to preclude blocking the exit by vehicles queued at the intersection?
14. Would every exit offer drivers leaving the garage a choice of lanes at the next intersection; (i.e., left turn, right turn or through)?
15. If traffic controls (such as one-way operation, curb parking restrictions, etc.) on abutting streets were changed, would traffic flow in the garage be adversely affected, and how seriously?

16. Would cars entering the garage conflict with exiting movements?
17. Would traffic movements into and out of the garage be "right-hand"? (Except on one-way streets, it is difficult and dangerous to expect drivers to turn into the left-hand side of a driveway. In countries where motorists drive on the left, of course, the opposite would be true.)

FUNCTIONAL LAYOUT

18. Do proposed dimensions of stalls, aisle widths, and overhead and turning clearances conform with latest and best standards? (State source)
19. Would there be adequate sight distance at reasonable speeds for all normal maneuvers, especially at exits?
20. Would grades of all ramps conform with acceptable standards?
21. If cars would be parked on sloping floors, have adequate precautions been taken to prevent an unattended car left out-of-gear and with brakes unlocked from rolling backward? (One method of avoiding this hazard would be through provision of enough crown in the floor so that the front wheels of the car would be downhill from the rear wheels.)
22. Would headroom for both pedestrians and vehicles comply with standards at *all* points?
23. Could drivers failing to find an empty space recirculate without having to go out into a public street?
24. Would any parking stalls have physical obstructions?
25. Would there be any dead-end bays?
26. Would there be areas for motorcycle or bicycle parking?

STRUCTURE

27. Would cars be prevented by the structural design from crashing through outside walls under any circumstances?
28. Would floors be properly sloped for good drainage as *sidewalks*, and not just as *streets*? (Garage floors are used to walk on as well as to drive on. Also remember that floors are hardly ever constructed *exactly* as shown on plans. Avoid designing flat floors.)
29. If the garage would have sloping floors, would retainers or curbs be necessary to direct water to drains; would trench drains be advisable?
30. Would the floors be properly designed and adequately waterproofed to limit corrosion of reinforcing bars, especially if salt is commonly used for deicing?
31. Would expansion joints be adequate in number, properly placed, assuredly tight, and easy to maintain?
32. Would the proposed pavement surface assure good traction under all conditions?

PEDESTRIAN FACILITIES

33. Would a waiting or passenger loading area be necessary?
34. Is the proposed waiting area (if any) appropriate as to size, amenities, architectural treatment, and other features? (Fay telephones, drinking fountains, seats, lockers, food and drink concessions, etc.)
35. Must public restrooms be provided? (They are reported to be a constant nuisance and expense.)
36. If indispensable, would public restrooms be finished with easily cleaned and vandal-resistant materials?
37. Would stairways be well lighted, highly visible, and placed to assure maximum security for patrons? (Glass enclosed, including elevators.)
38. Would stairway doors open out into clear areas that could never be impinged on by vehicles?
39. Could pedestrian ramps be used rather than steps in some locations? (Check local regulations regarding provision of parking spaces for handicapped drivers.)

40. Would all overhead obstructions with sub-standard clearance be clear of pedestrian areas (considering that the eyes of newly-arrived patrons might not have adjusted to the dimly-lit garage)?
41. Would pedestrians be given a false sense of security by apparently designating certain areas for their exclusive use when in fact cars could impinge on those areas?
42. Would all outside pedestrian entrances have locking doors for limited access nighttime use, with panic bars for emergency exit?

ADMINISTRATIVE/OPERATIONAL AREAS

43. Would the proposed location of the attendant/cashier booth permit control of all parking operations from that one booth during low-activity periods?
44. Would the attendant's booth be large enough to permit reasonable freedom of movement and its use as an office as occasion demanded?
45. Would the attendant's booth have natural ventilation, heating, air conditioning, sun shades and other features as required by climate and the nature of the site?
46. Would the booth have adequate lighting and a sufficient number of electrical outlets? (Time stamp, cash register, fan, etc.)
47. Would the attendants and maintenance employees have access to a conveniently located restroom(s)? (Some codes require two employee rest- rooms if both male and female employees are present.)
48. Would lockers of adequate size (overcoats, boots, work clothes, etc.) be required for employees?
49. Would there be a storage room close to the ticket dispenser?
50. Would the storage room hold all other supplies? (Enclosed storage space is needed for a variety of items such as brooms, mops, replacement lights, etc.)
51. Does the plan incorporate proper equipment for easy operation? (In- and-out counters, ""Full" signs, etc. may be indispensable, depending on the unique features of a particular garage.)
52. Would every installation of ticket-issuing equipment be on a tangent piece of driveway; far enough inside the entrance to provide a reservoir; and so located as to minimize interference with pedestrian movements?
53. If parking meters are to be used, or their use in the future is possible, has a suitable way of mounting them been contemplated?
54. Trash receptacles near entrances to elevators and stairwells?

MECHANICAL

55. If the structure would be wholly or partially underground, would ventilating equipment meet all code requirements and preclude all offensive odors and noxious fumes?
56. Would proposed drains handle exceptionally heavy runoff, including salty slush, to the satisfaction of people walking to or from their cars?
57. Would drain pipes have adequate pitch to flush out leaves, slush and sediment?
58. Would the supply of water to upper levels be adequate for washing floors? (A garden-type hose, for example, would not afford sufficient water pressure to thoroughly clean the floors.)
59. If a sprinkler system would be incorporated, does the design include weatherproofing?
60. If local building codes or standard practices require provision of fire extinguishers, would they be adequately secured against theft? Should they be wired into the fire alarm system, and/or centrally located?
61. Would elevators be easily operated and monitored so that they would not become an ""attractive nuisance" for neighborhood children?
62. Would elevators be finished with easily cleaned, vandal-resistent materials?
63. Would elevator pit have a foolproof drainage system?

64. If the plan incorporates landscaping, could the plants be watered easily (hose bibs)?
65. Would plants be exposed to exhaust fumes and heat?
66. If planters were to be installed in zones where salt is used, not only the plants but all the earth would probably have to be changed every spring. Could a truck reach every planter, and do so without blocking an essential sidewalk, doorway or other element of the garage?
67. If a heating system is contemplated, could it be used for snow-melting?
68. If a drain water sump is required, would a heavy-duty sump pump be installed for cleaning out the sump pit?

ELECTRICAL

69. Does the plan include a central control room separate from the attendant's booth for all master control switches for elevators, sump pump, lighting, fire alarm and fire extinguisher wiring systems, fans, and intercom and/or public address systems?
70. Should the garage have an intercom system: from the entrances; from the elevators; from various parking areas?
71. Would elevators comply with the local building code and be exceptionally well-lighted? Would they be of sufficient size and number for the quality of service sought?
72. Is a standby generator or other arrangement for operating emergency lighting, elevators, and parking equipment incorporated in the design?
73. Does the design incorporate adequate lighting in all parking bays and along clearway ramps?
74. Would stairways be adequately lighted and equipped for emergency lighting?
75. Does the design give special attention to lighting at entrances and exits? (The contrast between bright sunlight and an enclosed parking area often "blinds" drivers -- higher light intensity is required near the entrances.)
76. Does the design permit changing the level of illumination at various times of the day and night on an area-by-area basis? (Lighting circuits should be planned to allow daytime illumination of shaded areas only.)
77. Does the design include conduit for telephone lines into the attend- ant's booth?
78. Has consideration been given to the problems and cost of changing light bulbs in roof fixtures; in all other fixtures?
79. Would proposed electrical outlets be proper in number and location for vacuum-cleaning stairwells and elevators; and operation of all other maintenance equipment?
80. Would there be any electrical provisions for substituting illuminated changeable message signs for initial fixed signs?
81. Would additional lighting be necessary if television surveillance is used?

CONTROL

82. Would the proposed signs be easily read from moving vehicles under indoor and outdoor lighting conditions prevailing at various times of the day and night?
83. Could signs be comprehended and complied with in the allotted time by drivers somewhat handicapped by age, language difficulties, lack of experience, or other problems likely to be fairly common in this particular situation?
84. Are double-line (hairpin) stall markings proposed? (They are highly recommended by many.)
85. If a remote fee indicator is proposed, could it be easily read by paying the cashier?
86. Should provision be made for closed circuit television for observation of remote entrances and safety of patrons?
87. Has consideration been given to use of sound monitors for security in parking areas, elevators and other

public spaces?

88. Should security alarms be hooked into city or campus police head- quarters?

- Should outside pedestrian entrances be controlled at all times or during certain times?

SNOW REMOVAL

89. Has a plan been prepared for expeditious removal of snow at entrances and exits, as well as on all ramps?
90. Would electric or steam snow-melting be advisable at entrances and exits? (A word of caution — melted snow running onto an unheated area may form dangerous patches of ice.)
91. Would the proposed design of the roof area assure easy snow removal?
92. Would proposed clearances and turning radii on all ramps make it possible to get the type of snow removal equipment to be used to and from the roof?

ARCHITECTURE

93. Would the structure have exterior architectural treatment appropriate for the site?
94. Would the structure be instantly recognized as a parking garage by someone seeking such accommodations?
95. Would signs be located for maximum impact on potential patrons?
96. Could the structure be easily maintained, and without undue interference with day-by-day operations?
97. Does the plan-include a janitor's room with slop sink. shelves. and space for cleaning equipment?
98. Has space been designated for mechanical sweepers and other heavy equipment?
99. Does the painting plan, elevator door materials, and other interior treatments contemplate color-coding the various parking areas for the convenience of patrons?
100. In areas of high vandalism, should all vehicular entrances and exits have roll down doors for complete lock-up when desired?

GENERAL

101. Would the general design architect-engineer assemble and submit all equipment manuals and prepare a manual of all other design features requiring periodic inspection and servicing?
102. Would the contractors furnish easy-to-understand instructions concerning electrical switchgear, control equipment, and other items to be operated by employees?

SPECIAL

103. (Features made mandatory or desirable by climate, local codes. local ordinances, and resolutions or standard practices of the sponsoring agency.)

Source: Adapted from checklist developed by *Institutional and Municipal Parking Congress.*

CHAPTER 3

Zoning Requirements

Cities throughout the world view zoning for parking as a way to balance parking supply and demand — as a way to achieve planned and orderly community development. Zoning ordinance provisions normally specify the number of parking spaces required for new construction or major building modifications. They also often indicate how the parking should be provided in terms of minimum design features, setbacks, and usage provisions.

Zoning is a way that communities can help ensure an adequate amount of parking space as they grow. Zoning requirements provide a benchmark for planning and zoning officials to assess the adequacy of parking for new development or renovation proposals. Thus, zoning is a preventative approach for dealing with long-range parking problems. Its legal basis is found in the police power of the state and community, which has as its justification the health, safety and general welfare of the citizenry.

Zoning for parking also is directly involved with traffic operations and safety. It deals with street right-of-way dedications, setbacks, development densities and access controls. Traffic impact studies for new developments are an outgrowth of zoning requirements.

Zoning recognizes that activity concentrations (traffic generators) intensify parking demands. It mandates parking space requirements according to a predetermined schedule for common land uses, based on typical generated parking demands.

Most local governments, through their zoning ordinances, have a parking supply policy that requires land uses to provide sufficient off-street parking space to allow easy, convenient access to activities while maintaining free traffic flow. The objective is to provide enough parking space to accommodate recurrent peak-parking demands. An adequate off-street parking supply enables limitation or prohibition of curb parking, thereby improving street capacity, access, and traffic movement.

At the same time, zoning policies should not require an excessive amount of parking space because of the costs and impacts involved. The underlying goal is reasonable and balanced land-use management.

Because zoning for parking is intended to benefit the total community, sensible parking provisions are supported by business and other community interests. With proper zoning application, including amortization time limits for nonconforming land uses, a city can achieve many of its parking needs through private enterprise. A properly drafted and administered ordinance can be a valuable asset, and it can allay the compounding of parking problems. Zoning regulations, however, are not a complete solution to the urban parking problem.

This chapter presents suggested zoning requirements that reflect parking demands and public policy considerations. It suggests the number of spaces required for new developments, shows how parking space requirements can be modified to account for public transport availability and other factors affecting parking demands and the provision of parking space. It also presents parking design criteria, and suggests implementation procedures for zoning requirements.

BACKGROUND

Parking problems related to land use were recognized early by some cities. Columbus, Ohio, instituted off-street parking requirements for multiple-family dwelling units in 1923. Fresno, California, acting in 1939, may have been the first city to extend the provisions to nonresidential uses.[1] Fresno's regulations subjected hotels and hospitals to mandatory parking provisions.

Zoning for parking was the primary municipal zoning activity after World War II. A 1947 Eno Foundation study found that 70 cities included off-street parking provisions in their zoning ordinances, and a follow-up Eno study in 1951 revealed that the number had grown to 203 cities. New York City, which did not amend its pioneering ordinance to include off-street parking provisions until 1950, was now among the group. The kinds of land uses covered by such provisions also increased. A report published by the American Society of Planning Officials in 1964 revealed up to 29 categories of land use regulated by off-street parking controls in the 20 cities surveyed.[2] A 1971 report by the same organization identified 83 such categories.[3]

A 1972 Eno Foundation study found that 214 of 216 communities surveyed had zoning ordinances that contained provisions dealing with parking and loading.[4] Today, zoning for parking is common not only in North American communities, but in cities throughout the world.

Off-street parking provisions are one example of how the objectives of zoning have broadened in the last 75 years. In addition to controls over building height, area, and size; considerations of traffic, aesthetics, and plan implementation are part of zoning functions that protect public health, safety, and welfare. Zoning is likely to be the principal means of ensuring community development in accord with planned objectives. And, where master plans do not exist, zoning maps may serve as substitutes.

During the 1960s and 1970s parking space requirements in zoning ordinances were based on parking generation rates observed for various land uses. Most of the studies were conducted in suburban settings, resulting in relatively high parking standards if applied to built-up or densely developed city centers.

Since the early 1980s many communities have begun to reassess their parking standards. It has become clear that rates for suburban developments do not necessarily apply in densely developed areas with walk-in or transit traffic. Multi-use developments enable activities to share parking space, thereby reducing parking needs. Trip attraction characteristics of some land uses have changed, affecting parking demands significantly. Parking management activities also have brought about a reduction in certain types of parking demands. The current practice is to consider not only traffic circulation and accessibility, but also land use efficiency, aesthetics, environmental impacts and urban design.[5]

SETTING REQUIREMENTS

Zoning requirements normally cover the number, location and design of parking spaces for specific land uses. The primary concern in most communities is to assure that an adequate number of properly designed and located spaces are available.

Parking Demand Considerations

Zoning ordinances assume that parking demands bear a consistent and predictable relationship to land use. They imply that once the type, intensity, and location of development is identified, parking demands can be estimated with

[1] Charles S. LeCraw, Jr. and Wilbur S. Smith, *Zoning Applied to Parking* (Saugatuck, CT: Eno Foundation for Highway Traffic Control: 1947), p.10.
[2] "Off-Street Parking Requirements," *Planning Advisory Service Information Report No. 182* (Chicago, IL: American Society of Planning Officials, January 1964).
[3] Robert J. Boylan and Neil S. Kenig, "An Approach to Determining Parking Demand," *Planning Advisory Service Information Report No. 270* (Chicago, IL: American Society of Planning Officials, June 1971).
[4] D.K. Witheford and G.E. Kanaan, *Zoning, Parking and Traffic* (Westport, CT: Eno Foundation for Transportation, 1972).
[5] Thomas P. Smith, "'Flexible Parking Requirements," *Planning Advisory Series Report No. 377* (Chicago, IL: American Planning Association: August 1988).

reasonable accuracy. There exists, however, a wide variation in parking demands among otherwise similar land uses.

The proliferation of zoning ordinance formulas to match the variability of parking demands continues despite the difficulties suggested by the following statement in a 1964 report on off-street parking requirements prepared by the American Society of Planning Officials (now known as the American Planning Association):

No one set of standards, with the exception of off-street parking for industrial use, is recommended. The underlying assumptions used in drafting local regulations are often unknown and may not be applicable to other localities. The best approach, of course, is to develop off-street parking requirements based on local parking and traffic studies and the characteristics of the various zoning ordinance use districts.[6]

Defining Parking Demand. For the purpose of zoning ordinance applications, parking demand is defined as the accumulation of vehicles parked at a given time as a result of activity at a given site. Demands may reflect maximum accumulations during the average day, peak day of the week, or during the peak season of the year. Irrespective of when they occur, parking accumulations result from interactions between three traffic variables: total daily trips attracted, time pattern of arrivals, and average lengths of stay.

To illustrate, two sites with the same land area and floor space may attract equal daily numbers of vehicles, yet their parking accumulations can be quite different. If at one location cars arrive nearly simultaneously and park for an average of 8 hours, its parking accumulation could be four times that of the second site, if the second site's vehicle arrivals are spread out evenly over 8 hours and the average length of stay is only 2 hours. Thus, in determining parking needs, the arrival pattern and length of stay (parking duration) are as important as the total number of daily vehicles attracted.

Demand Variations. Parking demands for any given traffic-generating land use vary from one location to another, as well as among cities of similar size. The variations reflect differences in development density, public transport availability, local policies and economic levels. In areas with a complex land-use mix, such as the central business district (CBD), parking demands are reduced by multiple destinations for many trips to the area.

Parking demands also vary over time as employment densities and car ownership levels change. Office floor space per worker, for example, has doubled over the past 25 years. At hospitals and medical centers, treatments on an outpatient basis have increased dramatically since 1960, resulting in greater demands for parking space. As these trends and changes continue, there is need to adjust parking requirements in zoning ordinances. Local parking generation studies are useful in determining parking demands and should be performed periodically as a means of updating zoning ordinances.

Development density and land costs influence type of parking facility that should be provided and will influence parking cost and demands. The actual need for parking and the presence of competitive alternatives will limit both what parkers are willing to pay for parking and demand for parking space.

Reflecting Variations in Demand

Zoning ordinances handle variations in parking demands in several ways.

Variations by District. Zoning ordinances can specify appropriate parking requirements for various land uses in different zoning districts within the city. Requirements may allow variation by district, and may assign different requirements for areas within the CBD, as well as in surrounding urban and suburban areas. CBD requirements reflect public transit availability, while urban and suburban requirements are likely to reflect differentials in development density and car ownership. Further variation can be accommodated by an appeal process.

Planned Unit Development. The Planned Unit Development (PUD) concept enables several different land uses to be incorporated on a single tract of land. The parking demand for the devel-

[6] "Off-Street Parking Requirements," *Planning Advisory Service Information Report No. 182* (Chicago, IL: American Parking Association, 1964).

opment is based on demand for each individual use, and the total is adjusted based on the particular characteristics of the overall PUD. Most zoning ordinances require that the appropriate factor be applied to each land use in the development to determine the parking requirements for the individual land uses. These requirements then are added to determine the total parking requirements for the development. This total requirement may be increased or reduced upon review of plans for the PUD, depending on the mix of land uses and project location.

A smaller-scale modification is the special (or conditional) use permit. Certain land uses are singled out that may have widely varying parking (and traffic or environmental impact) characteristics. These uses receive individual study prior to issuance of a building permit, and developers may be required to supply less or more parking than the district requirement.

Shared Parking. It is sometimes possible to serve the combined parking needs of two or more properties with a common (shared) parking area rather than to require each property to independently meet parking space zoning requirements. The benefits are clear: the total number of off-street spaces is usually reduced, so that urban space is freed for other, perhaps higher, uses. Second, the number of access points to streets may be reduced so that there is less interference with vehicular and pedestrian street traffic.

Shared parking is feasible when two or more parking generators (1) have non-concurrent parking demands, (2) are located within acceptable walking distance to adequate parking, and (3) are mutually agreeable with the terms of shared-use parking.

Permitting shared use of parking facilities by two activities whose peak demands occur at different times is clearly advantageous from land cost, space usage and aesthetic considerations. It usually is implemented as follows: nighttime uses — to fulfill the space requirements of the zoning ordinance — may be allowed to count the spaces provided by nearby daytime activities towards their total. Likewise, weekend uses may do the same with spaces provided for weekday activities.

Seattle's ordinances, for example, (Appendix A) permits collective parking facilities to provide a total number of spaces less than the sum necessary for the individual uses when facilities provide parking for more than 50 cars. The nighttime-daytime shared facility provision permits one use to count half the spaces of its counterpart in time. School auditoriums and churches may count all the spaces provided by suitably close daytime uses toward the total of necessary parking. In permitting shared use, the Seattle ordinance requires a legal agreement among users to be filed with the city. Some such procedure, even if no more than a memorandum of understanding, should accompany any application for approval of shared-parking facilities.

Variance Appeals. Even the wisest and most carefully considered parking requirement may not be appropriate for some circumstances of development and parking demand. For this reason, a method is necessary to handle actual needs for individual variations. This is accomplished by a variation hearing agency, which is often called a Board of Zoning Appeals. In principle, this board should hear requests by developers or individuals for reduction in parking supply and by public agencies for increased parking supply, as related to specific development proposals and specific use permits.

Proximity of Parking

Often it may not be possible for an activity to provide all off-street parking on-site. Very few ordinances, in fact, require that all off-street parking be on the same property as the activity being served. At the same time, it is unrealistic to credit spaces beyond a reasonable walking distance towards meeting total parking requirements. Consequently, many ordinances stipulate a maximum walking distance.

Practices vary widely in defining what is acceptable. The simplest regulation merely states that parking should be within "reasonable" distance. Some cities specify an exact distance (typically a figure between 300 and 600 feet), while other cities vary the distance by land use or district.

Though few ordinances mention them, several methods of measuring walking distances have been stated in various ordinances. One states: "measured along lines of public access from nearest space to entrance." Another says: "two hundred feet without crossing a major thoroughfare." A third requires the distance "as measured along the shortest available pedestrian route."

Though probably difficult to achieve in heavily traveled areas, it is desirable to avoid major street crossings. In any case, wherever distances are specified, it seems equally desirable to include some indication of the route (like the shortest line of public access), as well as the terminal points involved.

Relating Parking Demand to Zoning Requirements

Variations in demands for parking among many types of activities suggest flexibility in applying zoning requirements. Communities can provide this flexibility in various ways. Zoning requirements may use formulas incorporating variables that influence parking demand. A policy of laissez-faire, of not requiring off-street parking by ordinance, can be adopted. A performance-standard policy can be instituted to require all parking off-street without specifying the amount to be provided. Lastly, minimum off-street parking requirements can be set without necessarily attempting to simulate typical demand conditions of each land use. In all cases, it is desirable to recognize the differing requirements of unique activity centers such as the CBD.

Formulas to Match Supply and Demand. This technique of specifying parking in zoning ordinances is used by many cities. As years go by, the ratios proliferate by finer and finer stratifications of land-use categories, and the number of variables increase in attempts to simulate probable parking demands. Problems can arise from both administrative and traffic viewpoints.

Formulas that inadvertently require excessive amounts of parking at particular sites are undesirable in several respects. They can lead to an excessive number of appeals cases, or they can discourage new development. Furthermore, excessive requirements lead to waste of both capital investment and urban space. On the other hand, formulas specifying inadequate requirements can be equally harmful. They may induce the type of congestion the requirements are designed to eliminate. They may create a less than optimum condition for site use, or they may deter investment.

Laissez-Faire Approach. The opposite extreme from a rigidly formulated code of requirements is the alternative of no off-street parking requirements. The impacts of such a policy may be differentiated by land-use category. Whether off-street parking would be provided as a consequence at certain land uses is, to some extent, a function of land values and accessibility alternatives.

An uncontrolled approach to off-street parking need not necessarily be harmful, as long as adequate curb parking controls are enforced. Most businessowners and land developers have clear incentives to provide adequate parking to ensure successful enterprises. On the other hand, failure to require off-street parking may lead to problems in some cases. Certain land uses may fail to provide adequate parking voluntarily because of its cost. Greater walking distances for parkers and the nuisances of parking spillover onto adjacent properties could be a consequence.

A Performance-Standard Approach. A third way of dealing with off-street parking is to establish a simple requirement that all parking generated by an activity must be accommodated off-street. This could be accomplished by on-site parking, shared use of parking facilities, or by demonstrating existing parking availability within reasonable walking distance. The burden is then on developers to provide adequate solutions.

The difficulty with such a course is that, lacking specific guidelines, the potential for disagreement between developers and public officials is considerable. Enforcement problems also arise and the courts apparently become more hesitant in the absence of specific standards. The resolution of subsequent conflicts would undoubtedly be more difficult than in cases with established numerical standards.

Minimum Requirement Approach. Many authorities believe that a policy of establishing plainly designated minimum standards for specifying parking requirements in a zoning ordinance is more attractive than the previously mentioned approaches. Minimum requirements do not attempt to simulate the possibly unique parking demand for an activity, nor are they intended to function as desirable design standards for optimizing site usage. The purpose of minimum standards is to guarantee some provision of off-street parking. Even though these minimum standards may specify insufficient amounts of parking, this inadequacy, it is argued, can be overcome by private decision or by public policy (through a municipal parking program, for instance).

Parking Specification Units

Site characteristics affecting parking demand influence the type of units used as a basis for specifying parking supply. Land area occupied, building floor area, number of seats, or occupancy characteristics are common bases for prescribing parking requirements. Thus, zoning codes may specify the number of spaces required per dwelling unit or dwelling unit bedroom, employee, bed, square footage of building floor area or similar unit of measurement, depending on the specific land use. The unit must be measurable and provide reasonable estimates. How well zoning requirements relate to typical parking demands depends largely on the units chosen. Common parking specification units are given in Table 3-1. In several cases "alternate" units of measurement are indicated.

Residential parking requirements typically are related to each dwelling unit. The number of bedrooms also is an important consideration especially for multi-family dwellings, because apartments and condominiums are developed as everything from "efficiency" units, having pull-down beds, to four-bedroom units. Because fractional numbers of parking spaces are practical for apartment buildings, the specification can be written as a function of the actual number of bedrooms. The zoning district concept, with separate residential parking requirements, also assists in permitting consideration of these and other factors such as car ownership, income, and public transportation access.

Parking requirements for offices are usually stated as spaces per 1,000 square feet of floor area. Although this system is easy to administer, it can become inequitable because of wide variations in floor space actually allotted per employee in various offices. This is a potential problem even though differences in parking generation between downtown and outlying areas can be handled with separate zoning districts.

Retail parking demand is a function of both employee and shopper demand. However, there is no predictable relationship between employment and shopper concentration that applies to most retail uses. Therefore, the total parking requirements for retail uses are usually specified as a function of floor area in zoning ordinances.

Table 3-1. Typical Parking Specification Units

Type of Land Use	Parking-Related Unit	
	Preferred	*Alternate*
Residential single family	Per dwelling unit	Per dwelling unit with range by number of bedrooms
Apartment	Per dwelling unit with range by number of bedrooms	Per dwelling unit
Shopping center	1,000 GLA[a]	—
Other retail	1,000 GFA[b]	—
Office	Per employee	1,000 GFA[b]
Industrial	Per employee	1,000 GFA[b]
Hospital	Per bed	Per doctor
Medical/dental	Per bed	Per office
Nursing home	Per employee	Per bed
Hotel/motel	Per unit	—
Restaurant	1,000 GLA[a]	Per seat
Bank	1,000 GLA[a]	—
Public assembly	Per seat	—
Bowling alley	Per lane	1,000 GFA[b]
Library	1,000 GFA[b]	—

a. Per 1,000 sq ft of gross leaseable area of building.
b. Per 1,000 sq ft of gross floor area of building.

Source: Adapted from Highway Research Board, *Parking Principles*, Special Report 125 (Washington, D.C.: Highway Research Board, 1971).

When using area calculations for shopping centers and restaurants, the parking measure is usually gross leasable area (GLA). GLA excludes floors outside dock service areas, boiler (HVAC systems) rooms, freight tunnels or corridors, elevator shafts and stairways, public restrooms, public lobbies, common mall areas, atriums and courtyards provided solely for pedestrian access to the building from the exterior and/or primarily intended for aesthetic enhancement or natural lighting purposes.

Unless otherwise specified, floor area measurement units are considered gross floor area (GFA). GFA is all occupiable floor area minus vehicular parking and loading areas within the structure and floor area used for building heating, cooling, ventilation and electrical control equipment or apparatus. In some buildings, especially newer office buildings, wall partitioning can be easily changed, thus a gross leasable area base might not be appropriate over time. The differences are usually not great.

Seating capacity is usually an appropriate specification unit for places of public assembly, including restaurants. Medical facility parking needs can be related to several site-specific activity factors, (number of doctors, staff, outpatient treatments or floor area) but typically, the number of beds is the unit measure in most zoning ordinances.

SUGGESTED GUIDELINES

This section contains suggested guidelines for establishing zoning requirements for parking space.

Parking Space Requirements

Parking space demands and suggested minimum zoning requirements for various land uses are summarized in Table 3-2. These guidelines apply to suburban settings where little transit, organized ridesharing or captive market walk-in traffic is anticipated to reduce parking demands. (Typical existing requirements are shown in Appendices B and C.)

The peak-parking demands represent the "85 percentile" demand values, based on comparative design-day studies of similar land uses in various communities. These demands, on average, would be exceeded only 15 percent of the time. Because it is not practical to have *every* space occupied during peak-demand periods, the number of parking spaces that *should* be provided, and hence required by zoning ordinance, should exceed peak demands. Accordingly, the minimum zoning requirements suggested in Table 3-2 are set at 5 to 10 percent more than the peak demands — the percentage depending on type of activity and frequency of peak occurrence.

The attractiveness of particular establishments varies. Retail outlets dealing with certain kinds of convenience goods, such as grocery, pharmacy drugs, and packaged liquor may require up to 9 spaces per 1,000 square feet of gross leasable area, while stores that specialize in shopper-type hard goods, such as furniture, clothing, and appliances, may require as little as one-fourth that amount.

In recent years, an increasing number of zoning ordinances have contained provisions for bicycle and motorcycle parking. These provisions have been handled in some jurisdictions by relating bicycle and motorcycle stalls to the number of automobile parking spaces required. For example, in parking facilities containing more than 50 spaces, the zoning ordinance may require one bicycle parking space or locker for every 20 automobile parking spaces, not to exceed more than 20 bicycle parking spaces in any one lot. For motorcycles, the number of stalls required may be set at 2 percent of the auto spaces but not to exceed 10 motorcycle stalls in any one parking facility. Provision of motorcycle stalls generally is not required in lots containing less than 50 spaces.

Although it is difficult to precisely determine handicapped (HC) parking space requirements for each land use, general needs can be established that result in HC parking space supply most closely matching the demand. The following values for certain land uses were calculated and are recommended for application by the Institute of Transportation Engineers:

Office—0.02 spaces per 1,000 square feet gross floor area (SF GFA), with a minimum of 1 space.

Bank—One space per bank unless occupancy surveys justify the need for a second HC stall.

Table 3-2. Suggested Parking Space Zoning Requirements (Suburban Settings)

Land Use	*Unit*	*Parking Spaces per Unit* — *Peak-Parking Demand*[a]	*Parking Spaces per Unit* — *Suggested Parking Space (Minimum Requirement)*	*Suggested Freight Loading Space*[b]
Residential				
Single family Multiple family	Dwelling	2.0	2.0	None
Efficiency/studio	Dwelling	1.0	1.0	One space for every 100 units after first 25 units
1 Bedroom	Dwelling	1.5	1.5	
2 Bedrooms or more	Dwelling	2.0	2.0	
Elderly housing	Dwelling	0.7	0.5/dwelling unit plus 1.0 space/day shift employee	Same as multiple family
Accessory dwelling unit	Dwelling	1.0	1.0	None
Commercial lodgings				
Hotel/motel	Bedroom	1.2	1.0/sleeping room, plus spaces for restaurant, lounge, banquet and meeting rooms plus 0.25/day shift employee	As required for restaurant and lounge areas
Sleeping rooms	Bedroom	1.0	1.0/sleeping room plus 2.0 for resident manager	None
Medical treatment				
Hospitals	Bed	2.5	The higher of 2.7/bed[c] or 0.4/ employee plus 0.33/bed plus 0.2/ outpatient treatment plus 0.25/ staff physician	One space per 100,000 sq. ft. GFA, plus one space per 200,000 sq. ft. thereafter
Medical center	Bed	5.5	The higher of 6.0/bed[c] or 0.4/ employee plus 0.5/bed plus 0.2/ outpatient treatment plus 0.25/ staff physician plus 0.33/student	
Convalescent/nursing	Resident	0.3	0.3	One
Medical office building	1,000 sq. ft. GLA	5.2	5.7[c]	One per 100,000 sq. ft. GLA after first 5,000 sq. ft. GLA
Business offices				
General office building	1,000 sq. ft. GLA	3.0	4/1,000 GLA for buildings of up to 30,000 sq. ft. GFA; 3.3/1,000 GLA[c] for buildings over 30,000 sq. ft. GFA	One per 100,000 sq. ft. GFA after first 30,000 sq. ft. GFA
Banks/savings & loan	1,000 sq. ft. GFA	3.3	3.6[c]	None for first 10,000 sq. ft. GFA, then one per 50,000 sq. ft. GFA up to 110,000 sq. ft., plus one per 100,000 sq. ft. thereafter
Branch drive-in bank with walkin window services	1,000 sq. ft. GFA	5.5	5.8[d]	
Retail services				
General retail services	1,000 sq. ft. GFA	2.2	2.4[c]	None for first 10,000 sq. ft. GFA, then one/ 30,000 up to 70,000 sq. ft., then one/80,000 sq. ft. thereafter
Personal care	1,000 sq. ft. GFA	3.5	2/treatment station but not less than 4/1,000 sq. ft. GFA	None
Coin operated laundries	Wash/dry clean machine	0.5	0.5	None
Retail goods				
General retail goods	1,000 sq. ft. GFA	3.0	3.3[c]	Same as general retail services

Table 3-2 *(cont.)*

Land Use	*Unit*	*Parking Spaces per Unit*: *Peak-Parking Demand*[a]	*Parking Spaces per Unit*: *Suggested Parking Space (Minimum Requirement)*	*Suggested Freight Loading Space*[b]
Convenience retail	1,000 sq. ft. GFA	4.0	4.4[c]	Same as general retail services
Hard goods retail	1,000 sq. ft. GFA	3.0	2.5/1,000 GFA interior sales space, plus 1.5/1,000 sq. ft. of interior storage and exterior display or storage	Same as general retail services
Shopping centers	1,000 sq. ft. GLA			One per 50,000 sq. ft. GLA up to 100,000 sq. ft., plus one per 100,000 sq. ft. up to 500,000 sq. ft. one per 200,000 sq. ft. thereafter.
<400,000 GLA		4.5	4.7[d]	
400,000 - 600,000		5.0	5.2[d]	
>600,000 GLA		5.5	5.8[d]	
Food and beverage				
Quality restaurant	1,000 sq. ft. GLA	20.0	22.0/1,000 GLA, plus spaces required for any banquet or meeting rooms	One space per 40,000 sq. ft. GLA
Family restaurant	1,000 sq. ft. GLA	11.2	12.3/1,000 GLA, plus spaces required for any banquet or meeting rooms	One space per 40,000 sq. ft. GLA
Fast food restaurant	1,000 sq. ft. GLA	15.4	16.9/1,000 GLA for kitchen, serving counter and waiting areas, plus 0.5/seat provided	One space if seating is provided
Educational				
Elementary & secondary	Classroom	1.5	1.0/classroom and other rooms used by students and/or faculty, plus 0.25 per student of driving age	One space per 100,000 sq. ft. GFA
College & university	Population		1.0/daytime faculty and staff member, plus 0.5/resident and commuter student	
Day care center			1.0/employee, plus 0.1/person of licensed capacity enrollment	None
Cultural, entertainment and recreational				
General public assembly	Permitted occupancy		0.25/person in permitted maximum occupancy	One space per 100,000 sq. ft. GFA
General recreational	Permitted occupancy		0.33/person in permitted maximum occupancy	
Auditorium, theater, or stadium	Seat	0.35	0.38[c]	
Church	Seat		0.5[e]	
Industrial				
General	Employee	0.6 - 1.0	1.0/employee, plus 1.0/1,000 sq. ft. GFA	One space per 25,000 sq. ft. GFA, plus one for next 50,000 sq. ft., plus one per 100,000 sq. ft. thereafter
Storage, wholesale or utility				
General			0.5/1,000 sq ft GFA, plus required spaces for any office or sales areas	One for first 50,000 sq. ft. GFA, plus one per 100,000 sq. ft. thereafter

a. Typically, the 85 percentile demand, based on analysis of comparative studies.

b. Parking Consultants Council, *Recommended Zoning Ordinance Provisions for Off-Street Parking and Loading Spaces* (Washington, D.C.: National Parking Association, 1990).

c. Peak-demand basis increased by 10 percent to compensate for loss of space availability due to parking turnover activity.

d. Peak-demand basis increased by 5 percent to compensate for loss of space availability due to parking turnover activity.

e. Highy variable.

Industrial—None, except HC spaces for employees needing them.
Restaurant—0.30 spaces per 1,000 SF GFA, with a minimum of 1 space.
Retail less than 500,000 SF GFA,—0.075 spaces per 1,000 SF GFA, with a minimum of 1 space; 500,000 SF GFA and over—0.60 spaces per 1,000 SF GFA.

This supply would meet 98 to 100 percent of the demand found for each land surveyed.

It would be desirable to set a minimum parking capacity before any HC spaces are specified. Capacities of at least 20 spaces are recommended to represent the minimum size for specifying any HC spaces for most land uses except medical.

A limited calculation was made of the number of HC spaces produced by application of the above retail supply rates to 23 shopping centers in the under-300,000 SF GFA size group and to 13 centers in the 900,000 SF GFA group. This number was calculated as a percentage of the total parking supply for each center. Fractions were rounded up to the next full space. In the under-300,000 SF GFA group, the proportion ranged from 0.7 percent to 2.3 percent. For the 900,000 SF GFA size group, the proportion ranged from 0.8 percent to 1.2 percent. These findings suggest using the parameters of land use and building area, rather than parking supply, as a basis for calculating the number of HC parking spaces to be provided.

Effects of Transit and Walk-In Traffic. Zoning requirements should be adjusted downward where car ownership and use are low, development densities are high, and where many trips are made by foot or public transport. Thus, zoning requirements can be considerably less for the downtown area, for high-density satellite nodes around the central city, or for individual land uses largely dependent on the attraction of nearby traffic generators for their walk-in business. Multi-use developments allow individual uses to share parking. And, retail, restaurant and entertainment activities that rely on office workers within a 1,000-foot walking distance may have lower requirements.

Effects of Motorization. Table 3-3 shows how parking space requirements for specific developments vary among cities throughout the world. It provides data for the United States, Czechoslovakia, West Germany, Singapore, Madras (India) and Colombo (Sri Lanka) for common kinds of land use. It illustrates how parking requirements reflect economic characteristics and car ownership.

Allowances for Shared Parking. Parking requirements for shared parking in multi-use facilities should be determined on the maximum total parking demand occurring at any given time. It is necessary to estimate daytime and evening demands for specific uses. Examples of uses with non-concurrent peak-parking demands are listed in Table 3-4. Further details and guidelines are contained in Chapter 6.

Table 3-5, drawn from amendments to the Montgomery County, Maryland, zoning ordinance, illustrates how shared parking requirements can be computed. The county applies percentages associated with each land use for each of the time periods mentioned, reflecting shared use of parking spaces. The key point is to set zoning requirements based on the mix of land uses on a project-specific basis.

City-Center Zoning

The CBD should be viewed as one of several urban areas where special zoning requirements are appropriate. Parking requirements should be adjusted downward to reflect walk-in and transit traffic, and parkers making one parking stop for multi-destination trips. Three basic approaches are used: (1) exempt the central area from specific requirements; (2) define specific requirements; and (3) limit the amount of parking that can be supplied. Table 3-6 summarizes downtown parking zoning ordinances bylaws in selected North American cities, and shows how each of these approaches are applied. Although most zoning ordinances generally specify the minimum amount of CBD parking required, several communities (Boston, Portland, Seattle) define maximum limits. Their goal is to control the supply of downtown parking to reinforce transit ridership and to mitigate traffic congestion impacts.

General Approach. For city-center zoning, the general approach is to reduce parking requirements to reflect multiple-destination trips and the availability, quality, and proximity of public transport. Retail parking requirements should

Table 3-3. Parking Space Standards in Various Cities and Countries

			One Parking Space Provided per Indicated Unit							
			United States	Boston Metro. Area[a]	Czechoslovakia		West Germany	Singapore[c]	Madras	Colombo
Per Capita Income (U.S. Dollars)			$7,000	NA		NA	$6,000	$3,500	$100	131[b]
Cars per 1,000 Persons			450-400	350-400		NA	250	100	8	25
Land Use	*Activity*	*Unit*			*City Center*	*Other*				
Residential	Single-family residence	Unit or dwelling	0.5-1.0	1.0-2.0	Inhab. area (350 sq. ft.)	350 sq.ft.	1.0	1.0	3,000 sq. ft.	
	Multi-family residence Apartment-flat-housing scheme	Unit or dwelling	0.5-2.5	1.0-2.5	Inhab. area (350 sq. ft.)	550 sq.ft.			2.0	3.0
Commercial	General office	Gross sq. ft.	200-500	500-No min.	430-650	550-750	400-600	1,000	2,000	1,000
	Government office Shops, shop'g cen.	Gross sq. ft.	125-600	330-500	550 250-550	320-650	300-400	1,000	1,000	1,000
	Restaurant-club	Seats (persons)	2-4	6-No min.	4-7	6-10	5-10	10	20 seats or 25 persons	10 persons
	Hotel or motel	Rooms (beds)	1 Up	1.0-1.4	3-9	3-10 (beds)	(2-8) (beds)	(5-10) (beds)	6(beds)	5
Industrial	Manufacturing, industry	Gross sq.ft. (employees)	200-300	(3.0-5.0) (employees)	No. min.	(5.0-10.0) (employees)	600-800	3,000	2,000	1,000
	Warehouse	Gross sq.ft	—				800-1,000	6,000	5,000	5,000
Institutional	Hospital/nursing home	Beds	0.7-4.0	1.0-1.25	10	10		5-10	—	10
	Church/temple mosque	Seats	3-10	5-7						
	Auditorium/cinema/theater	Seats	3-4	5-8	5	10	5-15	6-8	25	20

a. Proposed for transit corridors, 0–500 ft. from a transit stop.
b. Per capita income figure for Sri Lanka.
c. Revised in 1990, and varies for parking zones.

Source: Herbert S. Levinson, "Zoning for Parking—A Global Perspective," *ITE Journal* (November 1984).

Table 3-4. Non-Concurrent Peak-Parking Demands

Daytime Peaks	*Evening Peaks*
Banks	Bowling alleys
Business offices	Dance halls
Professional offices	Theaters
Medical clinics	Restaurants–limited hours
Service stores	Bars
Retail stores (with limited hours)	Night clubs
	Auditoriums
Manufacturing/wholesaling (with limited hours)	

Source: Thomas P. Smith, *Flexible Parking Requirements*, Planning Advisory Series Report No. 377 (American Planning Association, August 1988).

be reduced by 33 to 50 percent from that in suburban settings to account for customers drawn from workers and other walk-ins; further reductions should be made to account for transit riders.

Downtown Seattle's parking requirements, shown in Table 3-7, set varying standards for long-term parking (at least 75 percent of parkers stay for 3 or more hours) according to the level of transit access. They also differentiate between short- and long-term parking requirements.

CBD Parking Zones and Limits. Cities with a high dependence on transit (especially cities with rail transit systems) may find it desirable to specify maximum amounts of parking for office buildings and other commercial uses within the city center. This leads to the "minimax" district zoning concept shown in Figure 3.1. This concept specifies *maximum* and *minimum* space require-

Table 3-5. Calculating Parking Requirements for Mixed-use Developments (Montgomery County, Maryland)

	Weekday		*Weekend*		*Nighttime*
(Percent Occupancy)	*Daytime (9 am-4 pm)*	*Evening (6 pm-midnight)*	*Daytime (9 am-4 pm)*	*Evening (6 pm-midnight)*	*(midnight-6 am)*
Office/Industrial	100%	10%	10%	5%	5%
Retail	60	90	100	70	5
Hotel	75	100	75	100	75
Restaurant	50	100	100	100	10
Entertainment/recreational	40	100	80	100	10

Source: "Parking Policies Study: Draft Proposals for Revising the Zoning Ordinance," Transportation Planning Division, Montgomery County Planning Department, July 1983.

(Individual Demand)

Example: Mixed-Use Development—Office, Retail, and Entertainment. The assumption is that the individual land uses would have the following parking space requirements:

Office	300 spaces
Retail	280 spaces
Entertainment	100 spaces
Total	680 spaces

	Weekday		*Weekend*		*Nighttime*
(Composite Demand)	*Daytime (9 am-4 pm)*	*Evening (6 pm-midnight)*	*Daytime (9 am-4 pm)*	*Evening (6 pm-midnight)*	*(midnight-6 am)*
Office	300	30	30	15	15
Retail	168	252	280	196	14
Hotel	---	---	---	---	---
Restaurant	---	---	---	---	---
Entertainment/recreational	40	100	80	100	10
Total	508	382	390	311	39

Solution to example problem: shared parking requirement, 508 spaces (shared parking allows a 25 percent savings.)

Source: Thomas P. Smith, *Flexible Parking Requirements* (Washington, DC: American Planning Association, 1983).

Table 3-6. Comparison of Downtown Parking in Selected North American Cities

City	Regional Population	Employment		CBD Office Space (sq ft)		Downtown Parking Supply					CBD Work Trip Mode Split (% transit)	Zoning Ordinance
		Regional	CBD	Total	Growth	Total	Surface On-street and Off-street	Structure	Long-Term	Short-Term		
Calgary	583,100	231,920	72,675	14,200,000	16,400,000 additional by 1982	41,212	24,419	16,793	15,295	21,175	45	Minimum of 1 stall/1,500 gross sq ft. If in the office core, 20 percent of requirement (or 50 stalls, whichever is greater) can be provided on site; balance will be provided by the city outside the office core by using developers' cash-in-lieu payments that are based on the minimum parking requirement
Denver	1,400,000	NA	93,000	33,000,000	11,000,000 additional by 1985	34,000 in CBD core; 60,000 in CBD core and fringe	36,000 in core and fringe	24,000 in core and fringe	NA	NA	24	No zoning bylaws govern parking except in an urban renewal area where 1 stall/1,000 gross sq ft is required
Edmonton	621,600	NA	54,000	NA	NA	20,100	NA	NA	6,400	13,700	NA	Minimum of 1 stall/1,000 gross sq ft. If direct access to pedway, 1 stall/2,000 gross sq ft; if direct access to light rail transit, 1 stall/2,500 gross sq ft. Parking must be provided within 400 ft
Ottawa	739,400	285,000	65,000	NA	None in the past 4 years	13,600 total off-street only; 7,700 of this figure available to the public	1,500 off-street only	12,100	NA	NA	66	No zoning bylaws govern parking for office development
Portland	1,200,000	575,000	80,000	13,500,000	1,000,000/year	33,000	NA	NA	23,000	15,000	35-40	Maximum of 1 stall/1,000 gross sq ft to 1 stall/1,429 gross sq ft, depending on proximity to transit spine
Seattle	2,400,000	400,000	115,000	19,000,000	4,500,000 additional by 1982	43,700	NA	NA	NA	NA	45	Maximum of 1 space/1,500 gross sq ft for buildings in which at least 80 percent of GFA is office space; 1 space/1,200 gross sq ft for buildings in which less than 80 percent of GFA is office space; principal-use parking structures and surface lots are prohibited
St. Paul	2,500,000	1,500,000	62,000	8,000,000	150,000/year	30,000	10,000	20,000	NA	NA	35	No zoning bylaws govern parking for office development Minimum of 1 stall/1,668 net sq ft; maximum of 1 stall/1,453 net sq ft
Toronto	2,900,000	NA	185,600	NA	NA	35,800	18,000	17,800	NA	NA	80	Maximum may not be required; if required, 1 stall/1,000 gross sq ft
Vancouver	1,200,000	NA	125,000	NA	NA	41,600	20,000	21,600	NA	NA	50	Maximum may not be required; if required, 1 stall/1,000 gross sq ft
Winnipeg	585,900	280,000	55,000	3,000,000	400,000/year	27,200	18,100	9,100	17,200	10,000	55	No zoning bylaws govern parking for office development in CBD

NA = not readily available.

Source: Raymond H. Ellis, John F. DiRenzo and Edward J. Barber "New Directions in Central Business District Parking Policies," *Transportation Research Record 845* (Washington, D.C.: Transportation Research Board, 1982).

Table 3-7. Downtown Seattle Parking Requirements (Expressed in parking spaces per 1,000 sq ft of GFA)

Use	*Long-term Parking Requirement*						*Short-term Parking Requirement in All Areas*
	Areas with High Transit Access			*Areas with Moderate Transit Access*			
	Unrestricted Long-Term	*Car-pool*	*Total*	*Unrestricted Long-Term*	*Car-pool*	*Total*	
Office	.54	.13	.67	.75	.19	.94	.1
Retail sales and service, except lodging	.32	.08	.40	.56	.14	.70	.5
Other non-residential	.16	.04	.20	.16	.04	.20	None
Lodging	1 space per 4 rooms (all areas)						None

Source: 1985 Seattle Parking Ordinance.

ments that vary throughout the CBD. Graduated zoning schedules should reflect development intensities and transit service availability. Table 3-8 shows how guidelines can be formulated.

Flexible Parking Requirements

The concept of flexible parking requirements has emerged since the 1970s, as an outgrowth of

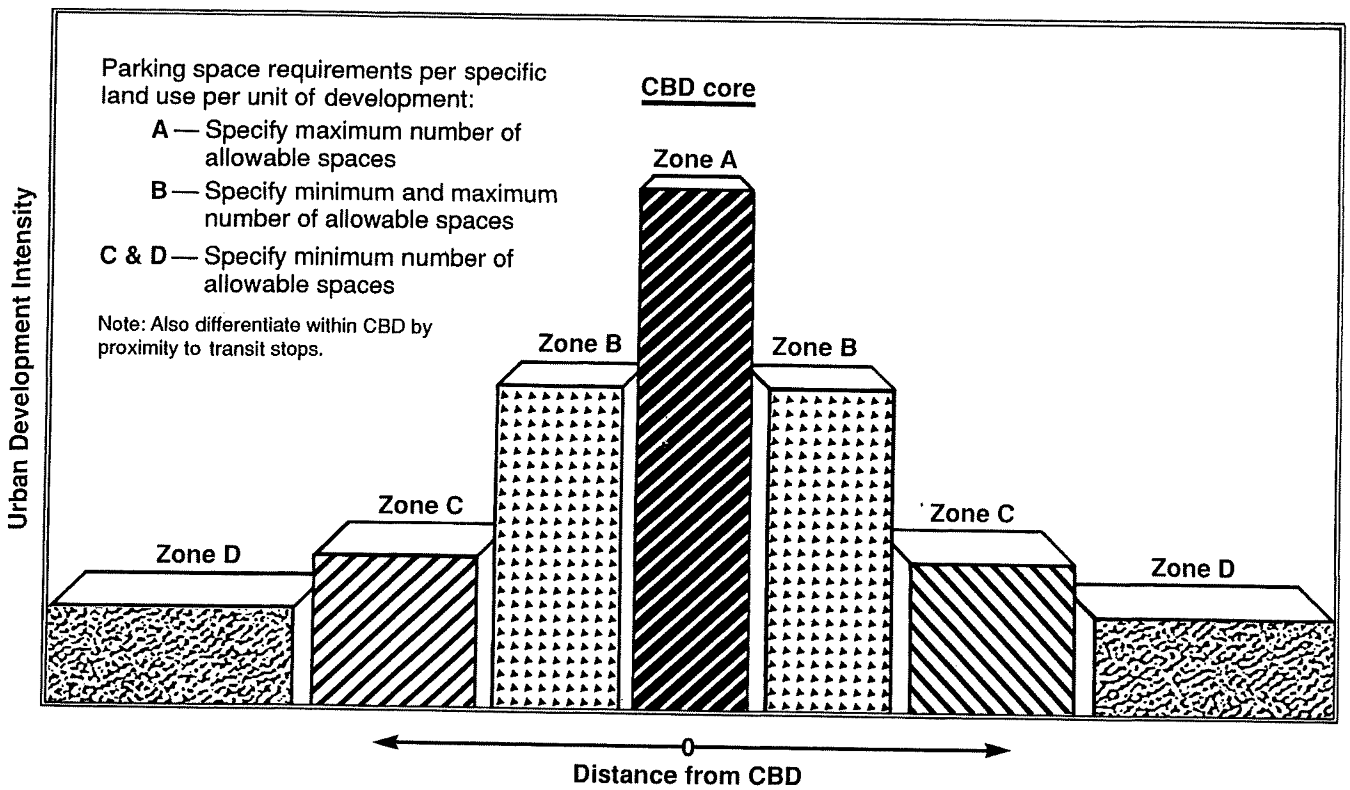

Figure 3.1. Zoning parking concept

Table 3-8. Illustrative Parking Guidelines for Major Transit Corridors

			Number of Spaces Per Unit by Distance from Transit Stop					
			0-500 Feet		500-1,000 Feet		1,000-1,500 Feet	
Land-Use	*Activity*	*Criterion Unit*	*Minimum Required*	*Maximum Allowable*	*Minimum Required*	*Maximum Allowable*	*Minimum Required*	*Maximum Allowable*
Residential	Single family	Housing unit	0.5	1.0	0.7	1.0	0.8	1.3
	Multi-family	Housing unit	0.4	1.0	0.6	1.0	0.8	1.3
Commercial	General office	GFA, 1,000 sq ft	—	2.0	1.0	2.0	1.7	2.9
	Medical-Dental office	GFA, 1,000 sq ft	—	3.3	1.7	3.3	2.5	4.0
	Retail	GFA, 1,000 sq ft	2.0	3.3	2.5	3.3	3.3	5.0
	Restaurant	Seats	—	0.17	0.17	0.25	0.17	0.25
	Hotel-Motel	Rental units	0.7	1.0	0.7	1.0	0.7	1.0
Industrial	Manufacturing, warehouse, wholesale	Employees	0.2	0.33	0.25	0.33	0.33	0.5
Institutional[a]	Auditorium	Seats	0.13	0.2	0.13	0.2	0.14	0.25
	Hospital	Beds	0.80	1.0	0.80	1.0	1.0	1.4
	Church	Seats	0.14	0.2	0.14	0.2	0.14	0.25
Educational	Elementary and junior high school	Classroom and office	0.7	1.0	0.8	1.0	0.8	1.0
	Senior high school	Classroom and office	0.7[b]	1.0[d]	0.8[b]	1.0[d]	0.8[c]	1.0[e]
	College and university	Classroom and office	0.7[b]	1.0[d]	0.8[b]	1.0[d]	0.8[c]	1.0[e]

a. Where public use of auditoria is likely, specific auditorium standards should apply.
b. Plus 1 space per 10-15 students, except where constrained by policy.
c. Plus 1 space per 8-10 students, except where constrained by policy.
d. Plus 1 space per 8-10 students, except where constrained by policy.
e. Plus 1 space per 5-8 students, except where constrained by policy.

Source: Estimated by Wilbur Smith and Associates for *An Access Oriented Parking Strategy for the Boston Metropolitan Area.* Final report prepared for Massachusetts Department of Public Works in cooperation with Federal Highway Administration (July 1974).

parking management actions. Flexible requirements relax the amount of off-street parking called for in local zoning codes in return for developer support of transit, ridesharing, or in-lieu payments to construct or support public parking.[7] They are designed to achieve specific land-use and/or traffic management objectives.

In-Lieu Fees. Table 3-9 summarizes experiences with in-lieu fees that support public parking. In-lieu fees have proven successful in Montgomery County, Maryland, where fees are a requirement for most types of new development, and relaxations of zoning requirements are not available. However, where cities delay providing parking (Calgary), inflation may make it difficult for the city to ultimately provide the desired parking. Or, where cities grant relaxations, means other than in-lieu fees may prove more attractive to developers, but difficult for the public agency to monitor and enforce over time. Appendix D provides examples of ordinances permitting fees in lieu of parking.

Transit and Ridesharing. Table 3-10 summarizes experiences with flexible parking requirements that relax parking requirements for developer/owner support of transit or ridesharing programs. Results appear to be most effective in large, transit-oriented cities, where parking is tight or expensive and development patterns are conducive to transit. They appear to be less successful in other settings — even where developers agree to provide ridesharing or transit actions—because there is often difficulty in assuring long-term incentives to attract adequate ridership levels. Appendices E and F provide examples of ordinances giving consideration to transit and ridesharing.

In general, developers enter into agreements that reduce parking requirements only if the required actions are easier and less costly to implement than providing the parking. Thus, flexible requirements must be selectively and carefully applied. And, there must be reasonable assurance that alternatives will remain effective over the life of the proposed improvement.

Design Requirements

Zoning ordinances normally include requirements that cover various functional design aspects of parking. Construction requirements normally are covered in building codes. Zoning standards typically stipulate minimum dimensions of stalls, driving aisles and access driveways, and details such as lighting, fencing and landscaping. Some communities provide design manuals that contain suggested layouts and landscaping plans. Maintenance, as well as design requirements are important and also should

[7] See Smith, *Flexible Parking Requirements;* and Thomas S. Higgins, *Flexible Parking Requirements for Office Development, New Support for Public Parking and Ridesharing in Transportation* (Amsterdam: Science Publishers, 1985); *Flexible Parking Requirements*, Urban Consortium Information Bulletin (Public Technology Inc., June 1982).

Table 3-9. In-lieu Fees that Support Public Parking

City	*Implications*
Calgary, Canada	In-lieu fees may not be utilized in timely fashion, or to the satisfaction of private developers
Davis, CA	Relatively high parking requirement (1 space per 400 ft of office) and tight sites for development can encourage payment of in-lieu fees
Evanston, IL	Little space for public parking and relaxations in requirements granted for simply locating downtown may make in-lieu fees for public parking infeasible
Montgomery County, MD	Public parking can be provided successfully via in-lieu fees, where relaxations in requirements are not readily available and where fees are supplemented with parking fees and fines

Source: Thomas Higgins, *Flexible Parking Requirements for Office Development; New Support for Public Parking and Ridesharing in Transportation* v. 12, n. 4 (Amsterdam: Elsevier Science Publishers 1985).

Table 3-10. Flexible Parking Requirements that Support Ridesharing and Transit

Jurisdiction	*Action*	*Result*
Bellevue, WA	City sets maximum requirement lower than actual demand, thereby allowing imposition of ridesharing as a mitigation measure	Several agreements made; developers generally take required action; increase in ridesharing at one site
Chicago, IL	10-15% relaxations for connecting to rail station entrances	Several agreements made; developers take required action; uncertain impact on transit usage
Palo Alto, CA	20% reduction possible for "alternatives to the auto"	No agreements for auto alternatives. Developers opt for other means of relaxations
Portland, OR	City sets maximum more than actual demand, and requires 15% of parking be set aside for carpoolers	Several agreements made; developers or institutions take required action; some increase in ridesharing at two sites
Sacramento, CA	5-60% relaxations for bicycle, ridesharing and transit actions	Few agreements made as of 1983
San Francisco, CA	City presupposes all major developments require ridesharing or transit mitigations	Several agreements with hospitals and colleges; agreements result in action; some ridesharing, transit use result
Seattle, WA	City negotiates variable reduction for ridesharing actions	15 developments with agreements as of 1982; 75% of developers comply; Few poolers in largest office with earliest agreement
Sunnyvale, CA	Ridesharing imposed as mitigation measure	One major agreement made; developer takes required action; no or little impact on bicycling, pooling or transit

Source: Higgins, *Flexible Parking Requirements.*

be included. (See Appendix G for a comparative analysis of design requirements in parking ordinances. A sample parking ordinance is given in Appendix H.)

Building height limitations, setback requirements, architectural treatment requirements, visual screening of parked cars, and landscape requirements used to improve land-use compatibility affect parking design and, in some instances, site selection.

General Criteria. The following parking requirements are generally typical of those incorporated into many zoning ordinances.

1. Zoning codes should specify reservoir capacities to preclude cars waiting to enter a parking facility from queuing out onto streets. The amount of reservoir space depends on the type of land use or method of parking control (entry gate, attendant park or free-flow entry).
2. Parking spaces should be at least 8'6" by 18'. However, where at least 75 percent of the daily users park more than 3 hours, an 8'3" minimum width may be acceptable.
3. Each parking stall should have appropriate access to a street or alley.
4. Maneuver and access aisle area should be sufficient to permit vehicles to enter and leave in a forward motion, except that residential and employee parkers may back in from alleys.
5. The full width of an alley, but no part of a public street, shoulder, or sidewalk, may be used in calculating the access aisle portion of a one-side parking module.
6. Parking layouts should be based on the dimensions given in references or specifications adopted by the local agency.
7. Lots that park five or more vehicles should be paved with a dustproof, all-weather

surface. Lots should be graded to drain as required by the city engineer.

8. All parking lot boundaries directly abutting public or other private property should have a landscaped setback of at least 4 to 8 feet or a suitable barrier to prevent vehicle encroachment beyond the property line. However, neither the required boundary nor any landscaping shall block the visibility of drivers exiting across a public sidewalk or entering a public street. If located closer than 8 feet to the nearest sidewalk line or 20 feet from the nearest roadway edge, any closed fence, wall, or hedge line should not exceed 24 inches in height along any side having a driveway exit to a street.
9. Parking facilities available for night use by customers of retail stores or patrons of theaters, restaurants, night clubs, and similar uses should be lighted.
10. Driveways should be paved and conform to the specifications adopted by the local agency, unless very high volumes or other special circumstances warrant variation.

Building Height Limitations. Local regulations may establish maximum allowable building heights for reasons of visual amenity and/or firefighting accessibility. Table 3-11 gives typical examples of building code regulations for aboveground open-wall parking structures. Of the 92 codes listed, 30 permit 6 tiers of floors, and 26 permit 9 tiers. Seven cities allow 85-foot structural heights. Additional examples follow.[8]

Table 3-11. Representative Allowable Heights and Areas for Parking Structures[a]

Allowable Height	*Number of Codes*
In tiers (floor levels)	
4	2
5	13
6	30
7	0
8	5
9	26
In feet	
40	1
55	5
60	1
75	1
85	7
No Limit	1
	92
Allowable Sq Ft/Tier	
30,000	92
Increases permitted (for access)	
Area	50
Height	—
Area & height	24
None	18
None	92

a. For ramp-type open automotive parking structures of unprotected noncombustible construction.

Source: U.S. Steel, *Technical Report on Steel Framed Structures.* Prepared by Alan M. Voorhees and Associates, Inc., and Lev Zetlin and Associates Inc (May 1971), Table 3 pp. 17-18. Includes 81 city codes, 6 state codes, and 4 "standard" building codes.

The Glendale, California, downtown urban design code, limits parking structures to 45 feet or 5 parking levels above grade. The design guidelines state that a parking structure's exterior should be "harmonious with the surrounding buildings and integral with the treatment of buildings they are built to serve."

Los Angeles' zoning code for the San Vincente Boulevard special district is similar to the Glendale code. Parking garages are limited to 45 feet in height along this heavily landscaped boulevard in the city's Brentwood area. The code requires that structures have staggered setbacks, landscaping at each level, and that the structure's facade be architecturally similar to the building it serves.

Architectural Standards. Some city zoning codes and urban design plans stress the importance of architectural compatibility in the parking structure design. The zoning codes of Orlando, Florida; Oak Brook, Illinois; and Irvine, Glendale, and Los Angeles, California; have architectural standards for parking structures. Urban design plans of Boulder, Colorado; Ann Arbor, Michigan; and Portland, Oregon; also stress compatibility in the appearance, size, scale, and bulk of parking structures with their surroundings.[9]

Irvine's code requires that the exterior elevations of parking structures be designed to minimize the use of blank concrete facades. The code

[8] A detailed discussion of environmental considerations is contained in Thomas Smith, "The Aesthetics of Parking", *Planning Advisory Service Report Number 411* (Chicago: American Planning Assocation, 1988).
[9] Ibid.

calls for the use of textured concrete, planters and trellises on each level, or other architectural treatments that improve the appearance of parking garages. Orlando's downtown development code requires that garages achieve "architectural unity" with the main building or principal use. Oak Brook's code requires that "all exterior walls ... visible from adjacent roadways, shall be finished with a material so as to maintain a common architectural character....with the principal building." Architectural character is defined in the ordinance as "the composite of aggregate characteristics of a structure-form, materials, function of a building" and its other details.

Boulder's urban design plan states that designers of parking garages should: (1) incorporate, at a minimum, an equal portion of vertical and horizontal architectural elements; (2) replicate the regular window pattern and other architectural elements of adjacent buildings; and (3) incorporate art into the structure's facade in order to maintain an active and interesting streetscape.

Landscaping Requirements. Most zoning codes do not include specific landscaping requirements for parking facilities. Generally, zoning ordinances mandate only that parking structures and lots comply with minimal setbacks and yard requirements. A few local codes, however, have specific landscaping requirements.

The Irvine, California, and Oak Brook, Illinois, zoning codes require that parking garages comply with street frontage and perimeter landscaping standards for surface parking lots. Irvine also requires the planting of at least one tree for every 20 feet of the structure's perimeter. The Fairfax County, Virginia, landscaping guide requires rooftop plantings for garages and encourages use of parapets for hanging vines. Orlando's code also requires that parking garages meet the perimeter landscaping requirements of surface parking lots — structures must have landscaped bufferyards, street trees, and other improvements.

IMPLEMENTATION

Methods of administering zoning ordinances depend on state enabling laws and type of local government. Enforcement of parking zoning provisions is usually the responsibility of the building inspector, building department, or other agency with comparable functions. A special zoning administrator or the planning department is responsible for parking ordinance enforcement in some cities. In a few cities, the city engineer and/or public works department carries out enforcement.

The job of defining the parking requirements in zoning ordinances should be the responsibility of the planning department. Reviewing submissions on off-street parking proposals should be a joint responsibility of the city engineer, as well as planning and inspection agencies. In most cities, the responsibility for granting variances is given to a board of appeal, which is normally separate from the agencies that promulgate and enforce regulations.

The sequence of steps that follows and the specific agencies involved vary from community to community. The essential considerations are objectivity, sensitivity, and broadness of the reviews.

Traffic Impact Analysis

Zoning approvals increasingly require a traffic impact study of a proposed development. It is essential to demonstrate that (1) the surrounding road and street system can accommodate the additional traffic, (2) an adequate number of parking spaces are provided, and (3) entrance and exit capacity is adequate. This approval may precede actual site plan review. Traffic engineers, planning agencies, and zoning commissions typically participate in this assessment.

Site and Building Plan Review

Most jurisdictions require that site development and building plans be submitted to one or more local government departments and agencies for review. In addition to the building department, review agencies normally include the fire department (for fire code compliance) and the engineering departments responsible for sewer, water and storm drainage. In some cases, a metropolitan planning agency and other regional interests, as well as the state may be involved in the review process. It also is desirable that site development, loading, driveway and parking plans be reviewed by both the city planner and traffic engineer. The school board may need to review plans for major residential developments.

A development permit is granted only after the plans are determined to conform with zoning requirements and respond to probable actual needs. Detailed building plans are prepared in accordance with the permit for review of conformance with the building code.

Inspections

Proper construction and development of a site should be verified by field inspections. The traffic engineer should make a final inspection of driveways, parking and loading facilities. Issuance of an occupancy permit should be conditioned upon completion of site improvements in substantial accordance with the approved plans.

What Site Plans Should Include

All site plans should include the north point, the scale, and the location and dimensions of all buildings, driveways, paved areas, parking and loading layouts, fences, and roof overhangs. The legal description and survey of the property is necessary, as are all critical dimensions. A topographic plan is desirable showing poles, signs, fire hydrants, trees, and other objects on public property along the site boundaries, plus existing street and sidewalk elevations.

Other details that should be shown include outside building dimensions, materials used for external wall finishes and roofing, lighting, drainage, and finished grades. Also attached should be statements of (1) use of the building, (2) ownership of the land and interest of the applicant, (3) estimated completion date, and (4) number of employees, if a commercial structure.

In some instances, drainage district approval must be received. Applications also must be accompanied by written approval of any utility company whose gas or power lines pass through the property.

Source: *Parking Principles*, Special Report 125 (Washington, D.C.: Transportation Research Board, 1971) pp. 45-46.

For existing development, checks of parking and loading facilities are often desirable prior to license approval. Some communities provide an annual fire and traffic inspection for compliance with regulations. Businesses sometimes use part of their legally required parking area for temporary storage or refuse containers. Such problems can be reduced with periodic checks by building inspectors. A few cities require a periodic structural inspection of parking garages.

Rezoning Applications

A rezoning application is necessary when a proposed use does not conform to existing zoning. This usually is submitted before any building plans are prepared. Applications normally are made for adjustment of the zoning to accommodate a new development; this means that all future buildings within the classification could be affected. The community or the developer normally makes that application to the Planning Commission (sometimes to the Zoning Appeals Board). The commission should have the authority to order special studies that will enable it to evaluate the application. These studies include traffic, parking, road, land-use density, and urban renewal considerations.

After review (which usually includes meeting with the applicant), a public hearing is held at which the planner, applicant, adjacent property owners, and other interested parties may testify. The commission approves or rejects the application. Approval may be conditioned with certain modifications and revisions, or the Planning Commission may suggest that an amended application be filed. In evaluating a rezoning application, the commission may apply the principle that the final development be no less desirable than under existing zoning.

The commission recommendation usually is sent to the elected local governing body. These political bodies may approve the zoning change, reject it, or refer it back for additional study and possible rehearing.

Special-Use Applications

A well-written zoning code contains provision for special-use or controlled-use applications that are not allowable as a general use because of problems that they might produce. Accordingly, each application should be considered separately on the basis of traffic generated, available parking, and whether or not the architectural treatment of buildings and land is compatible with that of the surrounding areas. The zoning code should permit only those special uses that do not substantially change the neighborhood.

A special-use permit may be processed like a rezoning request, and the opportunity exists to obtain additional improvements from the applicant such as special architectural treatment, roadway widenings, channelization, and traffic signal control of high-volume driveways.

Variances

Variation requests may be handled by the Planning Commission or by a separate Appeals Board. Variances typically involve reduced setbacks and parking supply. Theoretically, variances handle logical exceptions to the law. Review procedures are similar to those used for rezoning applications, and involvement of the traffic engineer is essential. Special-use and variance applications should not be approved in a wholesale fashion, otherwise the usefulness of the code will be lost.

Ownership Changes and Remodeling

The zoning code generally is applied to existing buildings only when there are substantial improvements or alterations proposed. Improvements that increase the assessed value of a structure more than 20 or 30 percent should subject the site to the parking requirements for new buildings.[10] Similar requirements may apply when use of the building changes and a significantly different parking generation rate occurs. Extensive property alteration may also subject the parking facility to the requirements of the Uniform Federal Accessibility Standard that requires provision of handicap parking spaces, among other accessibility measures. (See Chapters 8 and 9 for design details on providing parking for the handicapped.)

Court Appeal

When applications are denied at the local level, appeal may be made to the civil courts. Recourse to court action is necessary when elected officials take a stand contrary to their own administrative staff or the self-evident public good. The staff may find itself under subpoena and testifying against its employer when a zoning charge is rejected by the elected body. Professional integrity may produce this conflict, because in the court proceeding both sides must present factual testimony.

A court ruling may be appealed by either side and ultimately be taken to the state supreme court. Sometimes a principle is involved, while at other times local citizen pressures may be the deciding factor.

Revision of Zoning Ordinances

Changes in type and intensity of urban land use reflects the dynamics of economic, political and cultural forces. New programs and projects are constantly being developed, especially in a growing economy. Zoning ordinances are the basic tools of land-use policy implementation. They should be reviewed and revised every 5 to 7 years, depending on the nature of urban growth and change.

CONCLUSIONS

Parking requirements have come about because communities believed that private developers, left to their own initiatives, would not provide adequate off-street parking spaces. They were perceived as a means of bringing parking supply and demand into balance. Within the past decade, zoning has also been used as a parking management tool — as a means of managing the parking supply to achieve broader development and quality-of-life objectives.

Initially, zoning for parking was designed to alleviate street traffic congestion. Properly applied, zoning controls help to achieve this objective. Zoning requirements help to (1) avoid the

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[10] Highway Research Board, *Parking Principles*, Special Report 125 (Washington, D.C.: Transportation Research Board, 1971), p. 41.

nuisance and hazard of interference between adjoining properties; and (2) facilitate safe and efficient traffic movement. Zoning may be used in at least three other ways to benefit urban transportation. By regulating the location of major traffic generating activities, it can help protect costly transport facilities from becoming overloaded at critical points. Second, by helping to ensure that new urban development occurs in conformity with land-use plans, zoning helps assure that the environmental quality of the community is not lowered. Last, by regulating the location of unsightly activities and the design of facilities, it can help provide a more aesthetic and safer environment.

Zoning standards should be objectively set and tailored to each community's needs. And, they should be periodically updated. Equally important, is the need for coordinated action among the various agencies that have an interest in ordinance implementation. Above all, zoning policies must be coordinated with urban transportation and development policies. In this way, and perhaps only in this way, can the potential benefits of zoning ordinances be realized.

CHAPTER 1

Introduction and Overview

Automobiles, motorways, and parking facilities have dramatically changed the American landscape since World War II. Parking has become an integral part of the modern urban setting and an important land use. It is found wherever people live, work, shop or play — in the city center, in suburban employment and shopping areas, at universities and hospitals, at special events, theaters, and recreational attractions; at civic centers and community centers; and at airports and transit stations.

Metropolitan areas have expanded dramatically in the last several decades. As businesses followed residences to the suburbs, so did the demand for parking. Similarly, as air travel has grown, there has been an accompanying growth in parking demand at airports. Transit agencies — especially in large cities — also have become major parking providers. Today, the number of airport and transit parking spaces often exceed the downtown parking supply. In sum, parking problems and concerns are no longer confined to the city center; they extend throughout the urban region.

ISSUES AND CONCERNS

Parking is important to many people for many reasons. It influences the appearance of city and suburb; it adds to or reduces traffic congestion; and it is a vital component of the urban street and transit systems. The availability and perceptions of parking influence the choice of mode and route of travel, affecting the viability and competitive posture of commercial areas. Its adequacy influences the economic return on public and private investments, affecting property values and development opportunities. Parking space is indeed a major land use.

Parking is a crucial community concern. Cities want convenient, reasonably priced parking to make their established centers more competitive. Developers want parking to make their projects viable and to receive needed financing. Hospitals want parking for their doctors, staff, and visitors. Transit systems want parking to improve access to their express transit lines. Airports want parking to maximize the advantages of air travel. And, above all, the general public wants safe, convenient, and reasonably priced places to park.

Architect and urban planner, merchant and motorist, employee and employer usually desire convenient low-cost parking. Both the public sector and the private sector recognize the importance of parking. But this same community of interests has differing perspectives on how much parking should be provided, where it should be located, and who should pay for it.

These different perspectives reflect a broad range of concerns over the amount of parking provided, its cost, location, design and operation.

Some perceive parking as a public sector responsibility, while others believe that it should be developed by the private sector; some want parking to pay its way (recover costs) while others view it as an essential public service deserving public subsidy. Parking sometimes is viewed as posing energy, aesthetic and environmental problems; however, most people, recognize parking as an economic necessity. Some want enough downtown parking to meet all future demands; while others want to limit the downtown supply to conserve prime land for more intensive use, and to encourage transit and ridesharing.

MONOGRAPH PURPOSE AND SCOPE

This monograph on parking in North American cities attempts to place the issues and concerns in perspective. It addresses key questions commonly associated with parking:

- How much parking should be provided?
- Where should it be located?
- How should it be designed?
- What will it cost?
- Who will pay for it?
- How will it be managed and operated?

It will prove useful to administrators, developers, engineers, planners and others concerned with the regulation, provision and operation of parking.

It provides a benchmark for considering parking decisions and designs — for developing, financing, and implementing programs for the design of new facilities and the operation of existing ones. The purpose of this monograph is to show how the benefits of parking can be maximized and adverse effects minimized. For in a society where mobility depends upon the motor vehicle, parking is a necessity.

OVERVIEW AND PERSPECTIVE

This monograph describes the many dimensions and perspectives of parking. It discusses parking policy, finance, administration, planning, functional design and operations; and it shows how each of these aspects relates to the other in developing, designing and managing on- and off-street parking space.

One recurring theme emerges — parking is an important land use. It is a land use that makes other activities work because it provides the necessary access. Moreover, it is an integral part of the metropolitan transport system since it enables public transport to serve low density areas, and since it can reinforce ridesharing and other transportation management actions.

Thus, the role and value of parking must be viewed from a broader context than financial feasibility or traffic relief alone: parking must be assessed in terms of how well it interacts and complements other activities. It is in this sense that location and design become important. Parking must respect the *continuity* of development and pedestrian activity in the city center. And, it must be designed to blend with its surroundings. Sensitivity in planning, location and design is essential.

There is concern among many urban planners that parking contributes to urban disintegration. This indeed oversimplifies matters. Parking exists because lifestyles and preferences make public conveyances impractical for many trips. It exists in response to demographic and development patterns, consumer preferences, and market needs. The policy issue in most urban settings is *not* whether or not to park. Rather, it is *where* to park, and how best to make parking an integral part of the urban fabric.

Within the heart of the city center, depending on downtown size, form and reliance on public transport, parking may be counterproductive from both land-use and transport standpoints. Where most people come by transit, it usually is better to provide commuter parking at outlying places along express transit lines rather than within the central business district. Downtown parking space can be limited — especially for workers — through zoning ordinances that specify maximum allowable amounts of parking.

Should downtown parking facilities be removed to allow more productive use of land? The evidence suggests that this is precisely what happens with parking lots. And it takes place too — although more sparingly — with parking garages. Boston, Chicago, and Washington, D.C. are among the larger U.S. cities where garages have been replaced by more intensive land uses as a result of market conditions, development pressures, and environmental objectives.

In most downtown settings, however, parking is needed to sustain existing activities and to attract new development. To reduce parking supply, or to discourage additional parking may hurt the downtown economy and limit the opportunities to preserve or revitalize the city center.

Parking is essential in suburban settings where the automobile is the primary means of travel. Suburban parking can be improved by applying more realistic criteria, by better siting of activities, and by the consolidating and integrating specific development projects (although retro-fit may be difficult in many cases). New suburban developments, including their parking, should be carefully assessed in terms of access, economics and aesthetics, including how they relate to their surroundings.

How much parking space should be provided and who should provide it will depend on local precedent and specific circumstances. Parking generation rates, ability to make multi-purpose trips and the time separation of peak demands within a project are among factors influencing space requirements. Supply normally should be about 10 percent greater than demands to avoid congestion resulting from motorists searching for a parking space.

The private sector plays an important role in providing parking space that is ancillary to developments, in building and operating facilities for a profit, and in managing public parking space. The public sector plays a role in setting policy, planning and developing facilities, establishing programs, and monitoring transportation and development activities.

Financing off-street parking development becomes a challenge as costs of land, construction and operation rise. Many public agencies are unable to cover costs from parking revenues alone and must rely on other sources of revenues. The private sector is equally concerned about costs. Increasingly, both public and private sectors seek innovative means to finance parking and reduce costs of operation. Greater use of cooperative public-private efforts is the key to realizing economies in some cases.

There is no one "best" way to manage urban parking. Local precedents, values and resources will have important bearing on this decision. Parking authorities have merit but they are no panacea, especially when the authority must depend on financial help from the city. Managing parking, whether public or private, must attain a reasonable balance between public service and business requirements.

Land availability, costs and environmental factors normally dictate the type of parking. Surface lots are desirable when land is less expensive. Underground garages are appropriate when land is extremely expensive, or where environment conditions preclude above-grade parking garages.

On-street parking is convenient for people running errands, goods deliveries and activities where it is not practical to park off-street. But curb space is a valuable resource especially in established business areas, and it must be treated as such. Thus, priorities for curb space should favor (1) transit vehicles (2) moving traffic (3) goods and delivery (4) short-term parking, and (5) long-term parking.

The prohibition of on-street parking for traffic capacity or safety reasons is usually necessary all or part of the time especially along major arterial streets. Streets should favor vehicle movement over vehicle storage. This must be balanced against the curb access needs of adjacent activities, particularly where convenient off-street space is not available.

Regulation of curb parking is only as effective as how well it is enforced. Ticketing, towing, booting and adjudication procedures must be fair, timely, strict and consistent. They may prove painful at first. Yet, over a longer period, their reasonable application will provide accessibility, economic and environmental benefits.

Urbanization and motorization will continue to increase throughout the world. Cities will grow larger and more dispersed. Their car populations will increase; their transport problems will rise; and their parking problems will intensify. Whatever their form, economy, density, and public transport dependency, they will need more parking. There will be a need for carefully placed, sensitively designed and effectively financed parking. Parking will be especially important to North American cities, which for the most part, serve a motorized society. Parking will be essential for their urban vitality in the years ahead.

ORGANIZATION

This monograph is organized into two basic parts. Part I deals with policy and planning considerations. Part II covers facility design and operation.

Part I, "Policy and Planning" contains six chapters: Chapter 2 overviews public policy considerations and choices; Chapter 3 sets forth suggested zoning requirements; Chapter 4 covers administration and management; Chapter 5 discusses costs and financing; Chapter 6 describes parking characteristics and demands in the city center and outlying areas; and Chapter 7 provides site planning and location guidelines.

Part II, "Design and Operation" contains four chapters: Chapters 8 and 9 cover parking lot and garage design respectivity; Chapter 10 deals with parking operations; and Chapter 11 discusses on-street parking, including regulation and enforcement.

Appendices contain supporting information on zoning regulations and parking demand characteristics, and a checklist to help assure optimum parking structure design.

CHAPTER 2

Policies and Programs

Every community has parking policies that are stated or implied. Some policies cover the entire community, while others are limited to the city center or designated areas. Parking policies take the form of zoning ordinances, policy statements, administrative arrangements or specific actions. They normally govern how much parking should be provided, who should develop it, how it should be financed, where it should be placed and how it should be operated. Policies also set forth basic design requirements, often including aesthetic or appearance considerations.

Parking policies normally are an outgrowth of economic, political, and historical circumstances. They vary among cities and are influenced by each city's goals and objectives (development patterns, financial resources, and investment climate), by street traffic conditions, and by transit availability and use.

This chapter discusses public policy considerations — those affecting downtown parking in particular. It focuses on the basic questions of supply, price, financing, and management:

- When, where and how much parking should be provided?
- How can it complement other transport decisions?
- Who should provide and operate parking?
- How can needed parking be financed?

Answers to these questions vary, but in all cases, public policies should be clear, consistent, and compatible with local needs. They should reflect community objectives, financial feasibility and political reality.

ISSUES AND CONCERNS

Public policies affecting the quantity, location, cost, and availability of parking have been marked by changing attitudes over the last several decades. Parking is increasingly recognized as not only an essential part of the overall transport and land development system, but also as a means to help realize various community objectives. These objectives may include achieving ambient air quality objectives, reducing traffic congestion, reinforcing transit ridership, or attracting private investment.

Policies and regulations governing parking are hardly a new practice. For years, cities have regulated on-street parking. Zoning powers have been used since the early 1900s to define the amount of parking that must be provided in conjunction with new development to ensure that new development provides ample space to serve its own needs.

Until the mid-1970s public parking polices were primarily intended to enhance the use of private automobiles. It was often assumed that, when it comes to parking, more is better. This attitude has changed in most larger cities.

Reasons underlying this change include: the desire to reduce traffic congestion, the need to conserve spending, government mandates to meet air quality requirements and minimize air pollution, the concern over possible future energy shortages, and the obligation to protect public investments in transit systems and other infrastructure. Demands for preferential treatment by various user groups such as retail businesses, downtown employers, developers, and property owners have also influenced this change in attitude.

These concerns have encouraged local jurisdictions to think more systematically about their parking, especially in the city center. A number of cities have decided to limit the growth of their downtown parking supply, especially where express transit service is available. Some cities permit new development to provide less parking when acceptable transit access is within reasonable walking distance. Some encourage carpooling and vanpooling while discouraging single-occupant vehicle travel. Others give incentives for encouraging certain kinds of travel (i.e., shopper visits, tourists during off-peak traffic times) and provide special parking for other kinds of trips, such as all-day commuter parking at the central business district (CBD) fringes. More recently, cities have expanded their role to exert stronger controls over how parking can be used (availability of space to particular types of parkers, for instance), the maximum as well as the minimum amounts of parking that can be provided, and the charge for using parking space.

These broadening policies reflect a growing recognition that "parking management" and regulation can be valuable means in helping to realize broader community transport, development and quality-of-life objectives. Public attitudes, costs and community policy objectives will influence the appropriate response to specific parking questions.

Varying Perspectives

Parking decisions affect land use and development patterns, as well as travel behavior. Thus, parking is a complex policy issue involving many interests and viewpoints.

Community policies must reflect a broad range of urban parking perceptions. The average motorist wants to park as near as possible to the intended destination, while having complete assurance of safety — all at a minimum cost. In most locations, businesses and employers view parking as an economic necessity, especially those that depend on attracting customers (clients, patients, students, visitors, passengers, etc.) to their place of business. Without an adequate supply of convenient and affordable parking, most businesses also find it difficult to attract and retain professional staffs and employees.

Landowners and developers associate parking with helping to make a development more marketable. Parking provides access and lends an ingredient necessary for the success of most existing and proposed developments. Adequate and attractive parking makes favorable development financing more obtainable, as well as adding assurance for more attractive investment returns.

Urban residents often view parking with a degree of emotion. On-street space for parking is nearly always interpreted by residents as an implied right of residency. Emotions can flare when this space is usurped by others, or when otherwise legal curb parking is periodically prohibited to facilitate traffic movement or snow removal. In neighborhoods of predominately single-family homes with provision for off-street parking, residents can be provoked by "outsiders" parking along streets fronting residential properties. Spillover parking into residential neighborhoods from nearby commercial, institutional or recreational traffic generators is a problem of increasing concern around city centers and in mature suburban areas experiencing land-use changes and traffic growth.

From the pedestrian's standpoint, parking can be undesirable if it blocks walking paths or increases walking distances. Frequently unrecognized by the pedestrian, but potentially disastrous to the unaware, are the safety implications of parking. Illegally parked vehicles can block sight distance necessary for safe pedestrian and vehicular crossings. Improperly designed and/or controlled parking facilities can invite pedestrian accidents.

Among elected officials and government

agencies, parking is viewed with differing attitudes. Most recognize the necessity of providing some amount of publicly assisted parking, and are willing to exert and enforce their regulatory powers over public and commercial parking to varying extents to help accomplish community objectives. Within these broad areas of agreement, however, there is much room for divergent views and policy conflicts.

Over the last two decades a marked change has occurred in local government attitudes toward parking. Prompted by concerns for traffic congestion, air quality and financial resources, parking policies are increasingly used to help achieve a variety of community objectives. Local government, however, must be responsive to a multitude of special interest groups and organizations. Compounding the problem of satisfying this diverse constituency, is the fact that a community's parking policy actions are limited to the confines of its own jurisdictional boundaries. And, within these boundaries, much competition exists between the city center and outlying suburban areas.

Local government must carefully consider the ramifications of parking policies. For example, parking pricing policies intended to bolster needed revenues and increase transit patronage or ridesharing may make it difficult for downtown employers to attract lower paid clerical workers, many of whom perceive themselves as extremely auto-dependent. The ultimate result could be to drive CBD employers to suburban settings or other jurisdictions.

Policy Conflicts

Potential conflict exists between auto-oriented development and transit in large cities, and between publicly provided parking development and the capacity to afford such improvements in smaller cities. In all cities there is a need to provide enough parking to sustain existing activity and attract new development, but additional spaces should neither undercut transit ridership, nor the city's financial ability to meet other public needs and obligations. Achieving the proper balance between these differing objectives is essential.

Balancing the sometimes conflicting objectives calls for a careful assessment of the needs and consequences of providing parking — for clear understanding of both short- and long-range impacts. It is important to assure the economic vitality of the community while simultaneously complying with air quality requirements, reinforcing transit ridership, and protecting the city's bonding capacity.

Key Issues

Parking policy analysis should openly and objectively seek answers to questions such as the following:

1. What are the community development, transportation and environmental goals for downtown and surrounding areas?
2. What distribution of parking facilities is desired in regard to land-use intensity, demonstrated parking needs, existing or proposed transit services, and available and proposed roadway access capacity?
3. What are the individual worker, shopper and visitor parking requirements of subareas that might lead to a differentiated policy regarding the provision or prohibition of parking?
4. What opportunities exist for sharing parking between generators having non-concurrent parking demand timeframes?
5. How can parking serve as a catalyst for desired development?
6. What are the effects of parking on the location and design of transportation system improvements, both existing and proposed?
7. Should parking be provided for all people who want to drive into the CBD, or should it be rationed in some specified manner?
8. Who should develop, finance and operate parking facilities?
9. What public-private joint developments or working relationships are desirable in developing, financing and operating parking?
10. Should parking lead or follow new development?

Answers to these questions vary from city to city. They will reflect the rate and intensity of CBD development, reliance on public transit, limitations in street capacity, air quality requirements, fiscal resources, and community attitudes and antecedents. These factors also, influence parking programs and management actions used to implement policy.

Downtown Policy Choices

An issue facing the city center in larger communities today is whether "to park or not to park." More precisely stated, the basic question is *where* to park.

In most larger cities *commuter* work-trip parking represents the basic problem since it accounts for most of the space use, and represents the principal CBD trip purpose. It not only preempts parking space from people coming downtown for other types of trips, but it also adds to peak-hour traffic congestion on streets and expressways serving the city center.

The problem is compounded by continued growth of the urban core. Most downtown growth represents increases in office space and employment with relatively little increase in retail or recreational activities. There are exceptions, but the trend is clear. It implies an increase in demand for CBD parking and radial highway capacity if appropriate alternatives are not provided.

The challenge in most larger cities, therefore, is how best to serve commuter parking. In some cases, market forces will meet the challenge, but parking demand characteristics and land cost relationships limit the extent that private interests are willing to meet commuter parking needs. Implicit is strategic public intervention.

Downtown parking and express transit-related parking are complementary; an increase in one implies a decrease in the other. Commuter parking may be provided (1) in the CBD core where it could preempt short-term space and land available for higher use; (2) on the CBD perimeter where it could impact radial highway requirements; or (3) at outlying express transit stations (Figure 2.1).

The choice of parking options will depend on the nature of each community: the city center type and employment intensity; reliance on public transport; and the availability of meaningful access alternatives.

Three basic city center types can be identified:

1. *Extensively Transit-Oriented* — Over 60

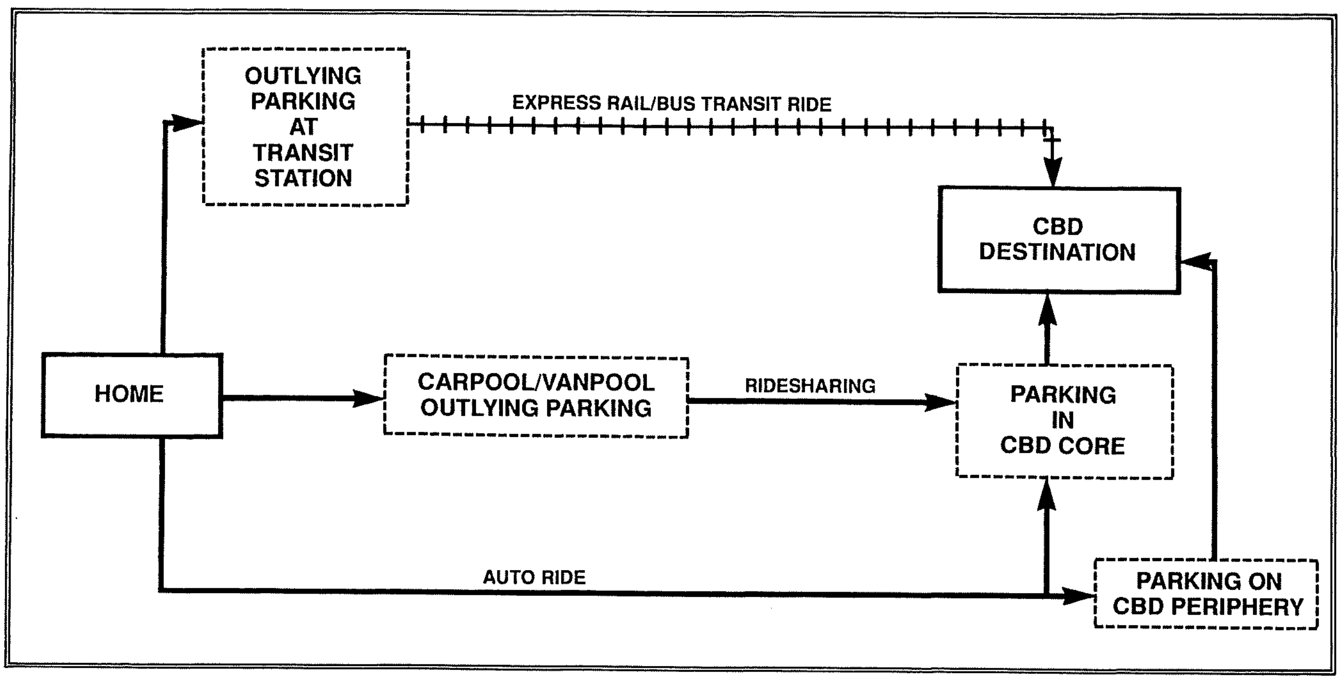


Figure 2.1. Commuter parking policy options

percent of peak-person accumulation by transit (i.e., Boston, Chicago);

2. *Intermediate Transit Use* — About 40 to 60 percent of peak-person accumulation by transit (i.e., Atlanta, St. Louis); and
3. *Predominantly Automobile Oriented* — Less than 35 percent of the peak-person accumulation by transit (i.e., Tucson; Columbia, South Carolina; Providence).

The extensively transit-oriented cities permit the option of transferring downtown parking to outlying express transit stations. Such a policy, however, would have limited applicability in auto-oriented city centers that are heavily reliant on auto travel and where transit service is not competitive with the automobile.

Development of meaningful downtown parking options for cities with intermediate transit reliance is not as clear-cut. Development of express bus and/or rail transit service is prerequisite to an outlying park-and-ride program. Implicit are the basic questions: How will the city center and its hinterland change? Will (or should) travel to the core become more (or less) transit-oriented?

POLICY AND PLANNING GUIDELINES

Parking policy should reflect mobility and development objectives within the fiscal resources of the community. Goals should be to improve access, and to support downtown development and to maintain viable attractions and amenities. Policies should view parking as an important land use and service that benefits users, businesses, developers, and the general community. Implicit throughout is the role of parking *both* as an economic necessity and an essential public service.

Policies, therefore, may have more than one objective. These objectives may include eliminating existing parking shortages, strengthening the city center, and attracting new development. They also may include actions to sustain public transport, to make more efficient use of available street capacity and land resources, and to encourage economic growth and activity.

Actions to control or manage parking often can be implemented quickly and inexpensively — attributes that make them attractive to local government. Since many of these actions only require modification of existing ordinances to implement, there has been a proliferation of regulations dealing with parking.

The potentially significant and highly localized nature of the impacts associated with many parking policy changes makes it extremely important that planning encourage the input of all concerned interests and use current and accurate data. Possible institutional conflicts should be recognized and accounted for in the planning, implementation and operation of new parking controls. Implementation of new parking policies should be coordinated with other aspects of the transportation system, including the parking enforcement program and public transport.

Most importantly, new or changed parking policies should be tailored to the needs of the individual community. Parking should complement other modes of travel in maintaining mobility and reinforcing the urban economy. Parking policies must avoid unfairly penalizing the CBD to obtain objectives that benefit a far wider spectrum of the community. Otherwise, problems of traffic congestion and air pollution are only shifted to other locations and the CBD problems of declining tax base, attracting affordable employees and maintaining or expanding economic activity are made more severe.

General Guidelines

The placement pattern and size of new public parking facilities should be planned to alleviate existing shortages, reinforce commercial activity, integrate with development projects, and serve anticipated growth — while not exceeding local economic realities. Policies and planning must recognize the city's needs and resources, and parking revenues and benefits derived from public provided parking should at least equal the public expenditure. Public parking investments should seek to leverage appropriate private sector responses. Within this context, the following planning and policy guidelines should be considered for local governments that have responsibility for developing new parking. They are described in greater detail in subsequent parts of this monograph.

Demands and Priorities. Parking space requirements should reflect actual needs, and not provide excess parking capacity on speculation. Zoning should consider factors such as floor space/employee ratios, car occupancies, transit service availability, and the interactions among downtown land uses. Parking requirements can vary throughout the city based on transit availability and development density. Excessive parking zoning requirements should be avoided. Parking for business, shopping, and entertainment activities (short-term parking) generally should be given priority over parking for commuters (long-term parking). In very large cities with extensive rail transit, it may be desirable to limit CBD parking space supply for all trip purposes. In these cities, zoning standards should specify both *minimum* and *maximum* requirements for each type of activity, based on proximity to transit stations, and development intensity. Commuter parking should be encouraged at outlying express transit stations.

In smaller cities (i.e., Providence, New Haven), about 75 percent of the long-term CBD parking demand should be met. If there are viable transit alternatives for workers, this proportion should be reduced as downtown size increases so that in large cities only short-term demands are met.

Parking fee schedules should encourage short-term parking and high parking space turnover in centrally located CBD parking facilities. This policy would provide maximum convenience for persons driving to or from the downtown on business or shopping trips.

Facility Coordination and Timing. New publicly provided parking should be coordinated with developments that are in process or in advanced planning. Publicly financed parking should not necessarily lead development as was often the case in the past. This is because many cities do not have sufficient financial resources for anticipatory or speculative parking developments.

Parking should be coordinated with the roadway and transit systems. It also should be coordinated with pedestrian circulation facilities. Parking should be designed to improve mobility while maximizing benefits of existing and future transportation investments.

Scale of New Parking Development. In communities where resources are limited, the goal should be to provide as little new publicly financed parking as necessary to attract or leverage private investment. New parking must be justified by measured needs. Cities should underprovide publicly financed parking relative to future demands because of the high costs to build and finance. This philosophy of "selective underproviding" has two benefits in addition to minimizing costs: (1) it helps to maximize use of existing parking, and (2) it helps to retain property on the tax rolls. This approach calls for effective parking enforcement measures and control strategies to ensure the best possible use of the existing parking supply.

Since the early 1970s change has occurred in the number of parking spaces needed for various land-use categories. Some categories have increased, such as at universities of certain types and at medical centers and hospitals offering outpatient services. However, some land uses now require fewer spaces. Among those needing fewer spaces per unit of measure are CBD activities, mixed-use developments and office buildings. Therefore, minimum parking requirements should be reviewed periodically and revised if found to reflect unreasonable levels for the times. Revision should consider allowing credits for special conditions such as transit service proximity and dedicated ridesharing programs.

Credits also should be considered for shared parking opportunities that might be available, at mixed-use developments. Reductions at such locations also recognize the fact that not all land uses have peak-parking accumulations at the same time.

Publicly financed and operated off-street parking facilities range widely in size. While public parking garages currently being planned and constructed typically are around 900 spaces, those found at major airports and transit stations sometimes exceed 2,000 spaces. Large parking facilities place greater demands on adjacent public roadways to accommodate vehicular access. The provision of small parking lots may be acceptable where access control is unimportant, and driveway entrance/exit points will not seriously interfere with street traffic movement or pedestrian circulation.

Facility Location and Design. Facilities should be located and designed for maximum value. Downtown parking should be rationally located in relation to land uses, demands, approach streets and pedestrian circulation. Parking facilities should be located within acceptable walking distances of the activities they are expected to serve, and their designs should not inhibit pedestrian access or safety. Walking distances generally should not exceed 500 feet for short-term parking and 1,000 feet for long-term parking. New parking should not be located where it must compete with underutilized existing facilities.

New parking structures should have a long service life; however many have experienced premature failure due to improper design and attention to construction details and/or deferred maintenance. Good design and construction supervision is extremely important to assure longevity of a structure. As a matter of policy, money for structural system maintenance should be budgeted beginning with the first year of operations. A qualified structural engineer, familiar with parking structures, should be retained to examine the structural system on at least a bi-annual basis and to recommend the most cost-effective method of problem prevention or correction.

Minimizing costs calls for avoiding complex designs, difficult sites, and elaborate architectural treatments. Parking dimensions should be matched to the anticipated usage. Dimensions that are too generous are a waste of resources; dimensions that are too tight also waste resources. The objective should be to use design standards that will remain adequate over the facility's projected useful life.

Parking lots and structures should be designed to blend with their surroundings. The goal is acceptable functional and visual integration. What is acceptable will depend on site-specific circumstances, including intended use of parking, existing or planned aesthetics of surrounding improvements, and what is financially practical to produce and maintain.

Building height and the potential for vehicle headlights and parking facility lighting to spill over onto adjacent properties often are major objections expressed by nearby property owners and tenants to new parking development proposals. Drainage, retaining walls and other features that are typically associated with parking facility development also can stir objections if they do not reflect consideration for adjacent properties. Traffic impacts, especially with large parking facilities, are usually the most critical concern of adjacent property users. The location and capacity of parking facility access points must seek to mitigate adverse traffic impacts.

Multiple-Use Development. The integration of parking with other land uses on the same site is desirable, especially in the city center where it improves the pedestrian environment and makes more intensive use of high-value land. Joint development of ground floor commercial space in parking structures should be encouraged except where it would preclude efficient garage design, or where there is no market demand for the commercial space.

Curb Space Management. Curb parking space represents a valuable resource, and it should be priced accordingly. Demands on curb space for pedestrian crossings, bus stops, delivery vehicles, and moving traffic generally should take precedence over on-street parking. Enforcement policies should help to assure that regulations are observed and the revenue potentials of on-street parking facilities are realized.

Commercial Parking Regulation. Local government should exercise control over commercially operated lots and garages with respect to location, design standards and operating practices.

Facility Development. New off-street public parking facilities may be developed by public agencies, by private groups, or through collaborative efforts. The goal should be to obtain needed parking in a timely manner and at minimal cost, subject to meeting desired design and operating parameters.

Systems Approach to Finance. Public agencies should consider a systems approach to parking improvement/program finance in which all parking related revenues are used to cover costs of existing and proposed improvements and actions.

PARKING MANAGEMENT

The concept of parking management has emerged in recent years as a means of better coordinating parking actions with overall transportation, development, and environmental policy. Parking management actions alter the supply or operation of a community's parking system to promote local transportation, economy, environmental and other actions.

The common types of parking management actions are shown in Table 2-1. They include actions related to on-street parking supply, off-street parking supply, fringe and corridor parking, pricing, enforcement and adjudication and marketing. Parking management actions are most effective where the public sector owns, operates, or controls a large portion of the total parking supply. U.S. and Canadian experience suggest that they generally require:

- fast, dependable, convenient, and reasonably priced alternative means of transportation (i.e., bus, subway, carpool); and
- ability to impose substantial price changes (price elasticities for parking are low — -0.15 to -0.30).

Parking management actions are most applicable in the city centers, outlying commercial centers, and high-density residential neighborhoods. Transit availability is essential where parking management actions call for constraining supply or price.

Policies to Reduce or Control Parking Supply

Policies to reduce or control parking supply are most evident in cities where there are viable alternatives to automobile commuting and high density employment centers. Some cities have placed a ceiling on parking supply in the CBD; others specify both minimum and maximum requirements aimed at balancing parking supply with street system capacity, controlling automobile emissions, and increasing transit's share of downtown travel.

New York City, Boston, London (England) Chicago, and Portland (Oregon) have limited the number of parking spaces in all or part of their central areas. Chicago prohibits non-accessory parking in the central parking district (approximately the loop). San Francisco allows parking only as an accessory use. Table 2-2 summarizes the various types of parking supply management actions and gives the reported effectiveness of each.

1. *Minimum and Maximum Parking Requirements.* When community objectives can be enhanced by constraining the parking supply, maximum parking requirements (build no more than) can be set at a low level. Alternatively, if the parking supply is inadequate for certain uses, minimum parking space requirements (build at least) can be set at a high level to promote additional supply.

- In San Francisco, where parking in the downtown can be provided only as an accessory use, the zoning ordinance limits to 7 percent the amount of gross floor area that may be allocated for parking. Any amount of parking proposed above this limit requires conditional use review by the City Planning Commission. Ultimately, San Francisco has established three downtown parking districts. In the first district, covering the heart of the CBD, new parking facilities are prohibited and existing parking is being converted to short-term use. In the second district, additional short-term facilities are permitted, and in the third district, on the periphery of the CBD, more long-term commuter parking will be developed.
- Toronto has set both minimum and maximum requirements on parking, enabling them to better control the amount of new parking developed in order to encourage transit usage among other intents. The minimum amount of parking required is one space per 1,668 net square feet, and the maximum is one space per 1,453 net square feet.

2. *Ceiling and Freezing Parking Restrictions.* A ceiling sets an upper limit in the parking supply within a designated area. The supply ceiling can be equal to, less than or larger than the existing parking supply. Conversely, a parking freeze limits future parking supply in a geographic area to the number of spaces

Table 2-1. Types of Parking Management Actions

On-Street Parking Supply	*Off-Street Parking Supply In Activity Centers*	*Fringe and Corridor Parking*	*Pricing*	*Enforcement and Adjudication*	*Marketing*
Add or remove spaces Change mix of short- and long-term Parking Parking restrictions Peak-period restrictions Off-peak restrictions Alternate side parking by time of day and/or day of week Permissible parking durations Prohibitions on parking before specified hours Residential parking permit programs Carpool/vanpool preferential parking Carpool/vanpool meters Carpool/vanpool stickers Loading zone regulations Bus Taxi Delivery Diplomat	Expand or restrict off-street supply in CBD and activity centers Zoning requirements Minimum requirements Maximum requirements Joint use Constrain normal growth in supply Maximum ceiling (i.e., freeze) on CBD spaces Reduced minimum parking requirements through HOV and transit incentives Restrict principal-use parking facilities Construct new lots and garages Change mix of short- and long-term parking Restrict parking before or during selected hours of the day Preferential Parking Carpool/vanpool parking Handicapped parking Small vehicle spaces	Fringe parking Park-and-ride parking Carpool/vanpool parking	Change parking rates Increase rates Parking price increase Parking rate structure revision Parking tax Parking surcharge Decrease rates Free parking in CBD Differential pricing programs Short-term vs. long-term rates Carpool/vanpool discounts Vehicle size discounts Georgraphically differentiated rates Monthly contract rates Merchant shopper discounts Stamp programs Token programs Employer parking subsidies Reduce subsidies Transit/HOV subsidies	Enforcement Non-police enforcement personnel Ticketing Towing Booting Adjudication Administrative Judicial	Advertising Brochures Maps Media Convenience programs (i.e., monthly contracts)

Source: John F. DiRenzo, Bart Cima and Edward Barber, *Parking Management Tactics* (Washington, DC: Federal Highway Administration), 1981.

Table 2-2. Characteristics of Selected Off-street Parking Management Supply Actions

Action	Jurisdiction	Agency	Area	Operating Characteristics	Compliance	Impacts
Zoning requirements						
Maximum and no minimum parking requirements	Portland, OR	Planning commission	CBD	No minimum required parking, maximum allowed parking for retail or office development is 1 space/1,000 sq. ft.	Development review process	This action in conjunction with other tactics has resulted in 1 space/1,350 sq. ft. being provided for new developments
	San Francisco	City planning commission	CBD	No minimum required parking, limits parking to 7 percent of the gross floor area	Development review process	Moderate growth in private off-street parking has occurred in contrast to high growth in downtown office and retail space
	Seattle	Department of buildings	CBD	No minimum required parking, depending on the zone and use; maximum allowed parking ranges from 1 space/1,000 sq. ft. to 1 space/2,000 sq. ft.	Environmental impact statement review	Parking supply is growing in areas farther from the retail core and decreasing closer in
Joint use	Los Angeles	Planning commission	Entire city	Would allow developments within 1,500 ft to share parking if demand patterns do not conflict	Land convenant and performance bond	Proposed action
	Montgomery County, MD	Division of parking	Suburban CBD	Spaces rented by local college for use by students	Parking patrol checks for valid stickers	Student parking impacts have been reduced
	Portland, OR	Planning commission	CBD	City has agreed to increase number of short-term spaces in city garage if developer reduces number of off-street spaces provided; code allows developers to share parking	Development review process	Development under construction
Constrain normal growth in supply	Palo Alto, CA	Department of planning and community environment	Entire city	Allows reductions of up to 20 percent for developers without conflicting demand patterns	Development review process	
Maximum ceiling (i.e., freeze) on CBD supply	Boston	Boston air pollution control commission	CBD	Limit on total number of allowable commercial spaces; freeze does not apply to free employee and customer parking	Development review process	Development has not been hindered
	Portland, OR	Planning commission	CBD	Limit on total number of allowable parking spaces by sector	Development review process	Ceiling has not been reached; tactic has encouraged parking in desired sectors; development has not been hindered
Reduced minimum parking requirements through HOV and transit incentives	Arlington, VA	Zoning administration	Entire county	Developers located near rail rapid transit station may provide approximately 70 percent of required parking	Development review process	Should reduce commuter parking impacts
	Chicago	Zoning administration	CBD	Required parking reduced if developer meets certain conditions concerning transit stations	Development review process	There are 1,000 fewer spaces in CBD since 1975; a 110-story building (Sears Tower) constructed with only 150 spaces

	Los Angeles	Planning commission	Entire city	Parking requirements would be reduced if developer provides HOV and transit incentives; developer would be allowed to substitute on-site spaces for off-site park-and-ride spaces; developer would be able to reduce required parking by 1.5 space for each space reserved for HOVs	Land covenant, development review process, developer would contribute money for park-and-ride facility development and transit shuttle services	Proposed actions
	Palo Alto, CA	Department of planning and community environment	Entire city	Allows up to 20 percent reduction in required parking if transit and HOV incentives are employed	Development review process, legal agreements	Several new developments have agreed to institute HOV incentives
Restrict principal-use parking facilities	Chicago	Zoning administration	CBD	Prohibits construction of principal-use parking facilities	Development review process	Number of parking spaces has decreased by 1,000 since 1975; number of long-term parkers has increased
	San Francisco	Planning commission	CBD	New principal-use parking facilities require conditional use review	Development review process	
	Seattle	Department of buildings	CBD	New parking lots prohibited; new parking structures prohibited in most of CBD	Development review process	No new principal-use facilities have been built since 1976, economics is major factor
Construct new municipally owned parking facilities						
CBD	Baltimore, MD	Baltimore City	CBD	New facilities for tourists and shoppers in capital improvement plan	NA	Facilities planned and under construction
	Montgomery County, MD	Division of parking	Suburban CBDs	New parking structures have been constructed to meet long-term and short-term demand	NA	Employers and shoppers are encouraged to work and shop in these suburban CBDs
	Portland, OR	Downtown development commission	Retail core of CBD	Recently completed 492-space garage with a 752-space garage under construction; designated for short-term use only; $0.60/h, merchant stamp program (1981	NA	Merchants pleased by increased supply of short-term parking
Neighborhood shopping districts	Los Angeles	City transportation department	Various neighborhoods	More than 7,000 spaces in more than 100 facilities have been provided	NA	Program has increased attractiveness of shopping districts
	San Francisco	Parking authority	Various neighborhoods	Began program to increase number of available short-term spaces	NA	Merchants are supportive; made less impact on surrounding neighborhoods
Carpool and vanpool preferential parking	Alexandria, VA	Alexandria	CBD	Reserved spaces for city employee carpools of 3 or more persons; city vehicles are also available to carpools	Applications are cross checked	15 pools in program
	Los Angeles	City of Los Angeles	City facilities	Free reserved spaces are proposed for city employees		Proposed action
	Montgomery County, MD	Division of parking	Suburban CBDs	55 spaces reserved for carpooling of 3 or more; cost is $16/month versus normal fee of $24/month (1981)	Vehicles must arrive with 3 or more occupants	48 pools in program
	San Francisco	California Department of Transportation	Fringe of CBD	40 percent of under freeway lots reserved for vanpools; fee is $10/month versus normal fee of $60/month (1981)	Vanpools are certified	Program just beginning
	Seattle	Commuter pool	CBD and fringe of CBD	219 spaces under free reserved for 3+ carpools at $5/month; 1,000 spaces in stadium lot available to poolers of 3+ for free (1981)	Carpools must be certified and are audited	Freeway lot is full; stadium lot has low utilization; 40 percent of carpoolers formerly used transit

NA = not applicable.

Source: Raymond Ellis, John F. DiRenzo and Edward J. Barber, "New Directions in Central Business District Parking Policies," *Transportation System Management and Parking, TRR 845* (Washington DC: Transportation Research Board), 1981.

available for use when the freeze is applied.

• Boston placed a ceiling on the total amount of new commercial parking that can be provided in its downtown core in 1972. The ceiling was part of the state's transport policy that favored transit development, and eliminated radial freeway construction. It was reflected by a downtown parking policy objective to: *Improve access to the core to achieve and serve desired levels of downtown development, and simultaneously minimize the role of the automobile.* A high-density, space-conserving city must rely on high-density, space conserving access.

• Portland, Oregon, has developed a city parking and circulation plan that places a cap on the total parking supply in its CBD. Unlike the Boston program, the Portland ceiling applies to employee and customer parking, as well as to commercial spaces. The various parking sectors are shown in Figure 2.2.

The Portland plan sets the maximum number of spaces permitted in the CBD at 40,055. The number is based on a 1973 survey of parking spaces that either were in use or were committed in that year, plus 1,985 spaces added in 1980 when the plan was updated. The CBD is subdivided into 11 sectors and allocations of spaces to the various sectors have been suggested. Development proposals that include parking are reviewed by the city's Planning Bureau to ensure that requested parking conforms with the city's overall parking policy goals. The program has significantly reduced the amount of parking being provided as part of new developments and has channelled new parking into those CBD sectors where it is most appropriate.

3. *Restrict Principal-Use Parking Facilities.* Chicago, San Francisco and Seattle restrict the development of principal-use (i.e., free-standing or stand alone) parking facilities in their central areas. In San Francisco, proposed new principal-use parking facilities must undergo a conditional use review. Chicago and Seattle prohibit the development of principal-use parking facilities in all or most of their downtown areas.

Alternatives to Parking Development. A number of cities have been considering policies that would permit private developers to opt for making a cash payment (to the public agency)

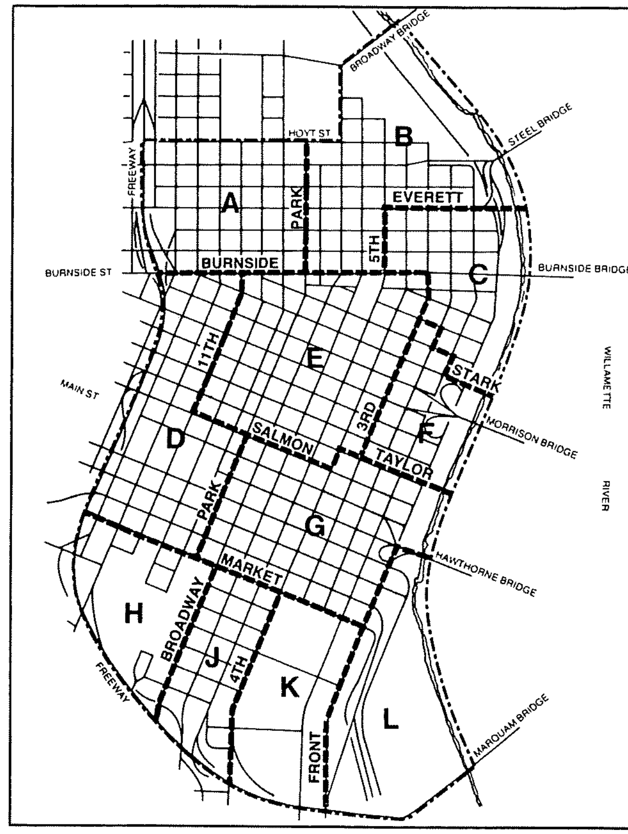


Figure 2.2. Map showing downtown Portland's 11 parking sectors. The Total number of parking spaces may not exceed 40,055. Sector parking space allocations were suggested to guide public and private action.

Source: Public Technology, *Innovations in Parking Management* (Washington, D.C.: Urban Mass Transportation Administration, 1982).

in lieu of providing parking. The public agency then uses the money to develop or support nearby parking that has the capacity to serve the new development. In some instances, this practice may be appropriate, especially with small projects, to avoid parking supply fragmentation and undesirable urban form.

• Calgary's first cash-in-lieu program was controversial, encountering strong opposition from developers. Under the city's original policies, developers had no control over the use of spaces built with their cash-in-lieu payments. The lack of on-site parking made lenders and developers concerned over marketing building space to prospective tenants. The city realized that policies that do not recognize developer's needs and perspectives are likely to be unsuccessful, and they have made adjustments to the initial program.

Calgary's downtown parking policy represents an innovative approach to solving automobile congestion and other problems that are exacerbated by rapid CBD office development. Their experience illustrates some of the difficulties that can be encountered when a new concept is implemented, particularly when some segments of the public feel the policy gives unfair advantage to competitors. Business opposition to changes in the zoning code and to growth restraints is an important obstacle that must be overcome in order to implement changes in parking policy.

• Los Angeles adopted policies to encourage a reduction in the supply of off-street parking by developers, employees, and businesses in exchange for their commitment to implement measures that will reduce single occupant automobile travel. The measures include promoting the use of carpools, vanpools, conventional transit, and subscription bus service. These measures are not intended to alter the intent of existing parking requirements but to create alternative ways by which those requirements can be met.

• Chicago created a Central Area Parking District wherein off-street parking is allowed only as an accessory use. Specific changes reduced the previously required number of parking spaces by 20 percent. Buildings with a floor area of 140,000 square feet or less require no parking. Buildings with a direct entrance to the underground transit system require 10 percent fewer parking spaces than the code specifies. These changes, like those being considered or implemented in other cities, were occasioned, among other reasons, by pressure from the federal government to improve air quality. Between 1975 and 1982 the supply of parking in the Chicago CBD decreased by 10 percent although there was a marked increase in new office construction in the downtown area during the same period.

• High Point, North Carolina, reduced the requirements for off-street parking in sections of its CBD to encourage the use of transit and because it lacked available land.

• Edmonton also linked transportation access to its parking policies. Their CBD ordinance requires developers to provide one space per 1,000 square feet, either in the building or within 400 feet of the building's entrance. However, if the building has direct access to a pedway, the requirement drops to one space per 2,000 gross square feet. If there is direct access to the light rail transit system, the requirement is reduced to one space per 2,500 gross square feet.

Residential Parking Policies. Four policies have attempted to restrict nonresident parking in residential neighborhoods. These are:

1. Curb-parking prohibitions in residential areas.
2. Restrictions on the number of consecutive hours parked.
3. Alternate-side parking requirements during mid-morning or mid-afternoon.
4. Nonresident parking prohibition (residential parking permits).

The residential parking permit program (RPP) is the most widely accepted method of discouraging nonresident parking in residential areas. It is designed to reduce the parking demands from people not living in a particular neighborhood, but parking their vehicle there for various purposes. Thus, it is intended to limit commuters parking on-street in residential neighborhoods.

There are several variations to the permit programs. Nonresidents are allowed to park for limited amounts of time; nonresidents are excluded at all times; and nonresidents are prohibited only during certain hours (typically 8 AM to 6 PM on weekdays). Parking permits are generally sold to residents of the area for a nominal fee sufficient to offset administrative costs. These permits are then displayed on the vehicle.

RPP programs can lead to the enhancement of a neighborhood's environment not only by reducing the number of nonresidents parking in the neighborhood, but also by reducing the number of vehicles moving through the neighborhood in search of parking spaces.

Major urban centers, including Boston, Cambridge, Denver, San Francisco and Washington, D.C. have established permit programs, as have smaller cities such as Lynchburg and Arlington, Virginia; Great Falls, Montana; and Winston-Salem, North Carolina. An RPP program may affect only a single neighborhood or

Lessons Learned From RPP Programs

Several lessons regarding implementation of residential parking programs have emerged.

1. *Involve citizens in the planning process.* Because an RPP program generally requires residents to purchase parking stickers or decals and because the program's impact on the neighborhood is more serious than traditional parking control measures, the neighborhood should be fully informed regarding all aspects of the program and should be encouraged to participate in program planning. Accordingly, many jurisdictions *require that a neighborhood initiate the request for an RPP designation* as the first step in the process.

2. *Provide effective enforcement.* Enforcement is an important key to the success of an RPP program. Lax enforcement of parking regulations in an RPP area will doom the program from the outset. Therefore, securing the cooperation of the enforcement agency, typically the police or traffic department, *before* program implementation is essential.

3. *Select a suitably sized area.* If the RPP area is small (four blockfaces or less), the displaced parkers will probably move to nearby blocks beyond the boundaries of the RPP. However, if the area covered is extensive, these drivers either will have to park at a considerable distance and walk to their destination, switch to a different transportation mode, or perhaps not make the trip at all.

With respect to the last point, an RPP program may have consequences that extend far beyond the boundaries of a particular designated neighborhood. If, for example, commuters to the CBD can no longer park in adjoining neighborhoods, they may choose to pay for parking, carpool or vanpool, or use public transit. If their numbers are significant and transit capacity at peak hours is not adequate to accommodate the increase, severe overcrowding may result. An RPP program must be understood in the context of its effect on the overall transportation system.

Source: Public Technology, Inc., *Innovations in Parking Management*, prepared for the Office of Budget and Policy, Urban Mass Transportation Administration in cooperation with Technology Sharing Program, Office of the Secretary of Transportation, 1982.

it may apply, as in Cambridge, Massachusetts, to the entire city. The adoption of an RPP program by a city does not imply that every neighborhood in the city is included in the program. Characteristics of selected programs are given in Table 2-3.

While there is no universally-employed procedure for implementing an RPP program, the request for designation typically requires a traffic survey as a precondition to designation. If a high percentage of the available on-street spaces are determined to be occupied during peak hours (for instance, 80 percent of the legal spaces are occupied when the count is made), the neighborhood can be designated an RPP area.

The enabling legislation in some jurisdictions (Baltimore, Chicago), gives a city department or agency the authority to designate an RPP neighborhood. Other cities, such as Washington, D.C., require action by the city council before approval is granted. In most cities, the traffic department or DOT is most likely to be responsible for planning the RPP program. Community groups and the police department also are frequently involved in program planning.

In most programs, residents purchase a residential parking permit that they affix to a designated window of their vehicle. Cars displaying this permit may park for any period of time on a street designated as part of an RPP area; those vehicles that do not display a permit are restricted from parking in an RPP designated area beyond a short period of time, generally 2 hours, during certain hours of the day.

Parking permits may be issued by one of a variety of city agencies and departments including the DOT, police, public works, finance, and the city manager's office. For most RPP programs, the permit is valid for one year. The permit typically costs from $5 to $10 a year to cover program implementation and operational expenses, including enforcement costs.

Parking Pricing Policies. Much evidence suggests that parking price can affect space use, choice of travel mode and trip making. This means that parking pricing can be used to help achieve such objectives as reduced traffic congestion, greater transit usage and rideshar-

Table 2-3. Characteristics of Selected Residential Parking Permit Programs

	Implementation			Operating Characteristics				
City	*Responsible Agencies*	*Activity Generating Impacts*	*Criteria*	*Hours*	*Geographic Area*	*Permit Fee*	*Non-resident Parking Privileges*	*Penalty for Parking Violations*
Alexandria, VA	Traffic	CBD	Park occupacy 75% Nonresident 25%	M - F 8 am - 5 pm	2 Districts	$2/yr	3 Hours Visitor permits	$15.00
Arlington, VA	Traffic Engineering	Employment center	Peak occupancy 75% Nonresident 25%	M - F 8 am - 5 pm	7 Districts Total of 100 blocks	None	Visitor permits	N.A.
Baltimore, MD	Transit and Traffic	Hospital	Peak occupancy 80% Nonresident 25%	M - F 24 hrs.	Neighborhood 20 Blockfaces	$10/yr.	Visitor permits	$7.00
Boston, MA	Traffic and Parking	CBD	Administrative discretion	24 hrs.	Citywide Neighborhood- (1 program)	None	2 Hour (citywide) 2 Spaces/block (neighborhood)	$5.00 (citywide) $10.00 (neighborhood)
Cambridge, MA	Traffic and Parking	University Transit stations Retail areas	Administrative discretion	M - F 24 hrs.	Citywide	$1/yr	Visitor permits	$15.00
Eugene, OR	Traffic	University	Administrative discretion	M - F 9 am -3 pm	33 blocks	$5/yr.	2-Hour parking	N.A.
Milwaukee, WI	Public Works	University Hospital Industrial area Retail area	Minimum 150 spaces Nonresident 20% Transit nearby	Except Sunday 8 am - 5 pm	Eleven districts	$6/yr.	2-Hour parking	$20 -$40 for falsification of application
Montgomery County, MD	Traffic Engineering	Hospital High school	Average occupancy 8 am- 5 pm>50% Non-resident 50%	M - F 9 am - 5 pm	2 Districts	$5/yr.	Visitor permits	$10
San Francisco, CA	Traffic Engineering	Transit stations CBD University	Peak occupancy 80% Nonresident 50%	M - F 8 am - 9 pm	3 separate districts	$5/yr.	2-Hour parking	$10
Vancouver, B.C.	City Engineering	Local generators	Petition from 213 residents	24 hrs.	150 - 200 RPDs Each RPS is generally 2 - 3 spaces	None	None	$25
Washington, DC	D.C. DOT	CBD Transit stations Other generators	Peak occupancy 70% Nonresident 10%	M - F 7 am - 6:30 pm	Multiple areas covering 12 - 15% of all residential streets	$5/yr.	2 Hours Visitor permit	$5

Source: John F. DiRenzo, Bart Cima, Edward Barber, *Parking Management Tactics* (Washington, DC: Federal Highway Administration), 1981.

ing, and compliance with clean air requirements. For one or more of these reasons, including economic gain, many cities, airports and institutions have significantly increased parking fees.

There are several ways to change an existing parking rate structure. Rate changes can be either general in nature, for instance, a 25-cent hourly increase in rates, or specifically directed at various classes of users. Examples of the latter include differential rates that favor carpools and vanpools, or a graduated rate structure that encourages short-term parking. A pricing technique that affects all parking, whether publicly or privately controlled, is the imposition of a citywide tax on parking. Table 2-4 gives examples of various pricing actions and their impacts.

1. *Encourage Short-term Parking.* Parking price changes directed at certain classes of users are intended to discourage all-day commuter parking in order to help strengthen retail and commercial areas.

• Honolulu's 1982 parking rates, for example, were increased from 20 to 40 cents per hour to discourage long-term parking. Lower demand, fringe parking rates were increased from 15 and 20 cents per hour to 25 cents. As a result, parking turnover in high demand areas increased by more than 11 percent between 7 AM and 3 PM. The number of available on-street spaces during the lunch hour increased by 41 percent; available off-street spaces increased by 58 percent.

• Montgomery County, Maryland, increased its parking rates for 10 to 25 cents per hour at most facilities. Average turnover in short-term spaces increased from 3.39 to 3.78 vehicles per space. Rates at selected off-street facilities were kept at 20 cents per hour to encourage use of underutilized spaces; however, a significant shift of parkers to these spaces did not materialize.

Denver, Portland, San Francisco and St. Paul, among other cities, have increased parking rates at publicly controlled facilities to encourage short-term parking. In San Francisco, the number of monthly parking permits at municipal garages was reduced to encourage more short-term parking.

The following example shows how the rate structure can be designed to discourage long-term parking: 1 hour, 30 cents; 2 hours, 65 cents (32.5 cents/hour); 6 hours, $3.10 (52 cent/hour); and 8 hours, $4.50 (56.5 cents/hour).

One important difference between changes in the parking rate structure and some of the other parking pricing strategies, is that rates can be modified fairly easily if unwanted consequences result. For example, if a city were to substantially increase its CBD short-term parking rates in public facilities, several outcomes are possible: drivers could continue to use the facilities and pay the higher rate; they could leave their cars at home and travel to the CBD by a different mode; they could park on the CBD periphery and walk to their destinations; or they could stop making discretionary trips to the CBD for shopping and personal business. If discretionary travel to the CBD declined dramatically, the city might decide that the benefits of the rate increase were outweighed by the damage to its business community and, accordingly, roll back the increase.

2. *Establish Surcharges.* Madison, Wisconsin, implemented a parking surcharge demonstration program during the morning peak period (7:00 to 9:30 AM) that increased the cost of parking in two city parking garages and two city lots by more than 50 percent. The principal goal of the surcharge program was to induce commuters who drive alone to switch to transit or carpools, thereby freeing up parking spaces for midday shoppers and visitors. As a result, the occupancy level at the facilities where the $1.00 surcharge was imposed dropped significantly during the morning peak period, but by midday the number of occupied spaces was comparable to the pre-demonstration level.

Parking rates for federal employees in Ottawa, Canada, increased from no charge to 70 percent of the prevailing commercial rate. Ottawa's experience reported a 23 percent reduction in federal employees driving to work alone. Automobile occupancy increased from 1.33 to 1.41 persons per vehicle and bus riders in the federal work force increased by 16 percent.

Like its Canadian counterpart, the U.S. government once provided free or inexpensive parking at government facilities. However, on November 1, 1979, federal agencies were directed by an executive order to charge their

Table 2-4. Selected Parking Pricing Actions and Impacts

Jursidiction	*Description of Pricing Tactic*	*Impact*
Honolulu, HI	Municipal parking rates increased to discourage long-term parking from 20¢ per hour to 40¢ per hour in high-demand areas from 15¢/20¢ per hour to 25¢ per hour in fringe	Number of cars parked between 7 am and 3 pm increased from: 4,645 to 4,847 off-street 6,265 to 6,735 on-street Number of available spaces at lunch hour increased from: 209 to 495 off-street 260 to 440 on-street Total revenue per month increased by 49,000 (36%)
Montgomery County, MD	Municipal parking rates increased from 10¢ per hour to 25¢ per hour at most facilities Rates at selected off-street facilities kept at 10¢ per hour to encourage use of underutilized facilities Carpool permits sold at $16/month vs standard permit of $24/month (also reserved carpool spaces) Merchant parking validation program is in effect	Average turnover in short-term spaces increased form 3.39 to 3.78 vehicles per space Shifts of parkers to underutilized facilities did not work Carpool spaces 74% occupied
Portland, OR	60¢ per hour on straight line basis for short-term parking Merchant parking validation program is in effect $15 per month carpool permit	288 Carpools use on-street carpool spaces (61% of carpools formed because of program)
San Francisco, CA	15% parking tax on patrons of for-hire parking facilities $10 per month charge for vanpools in CALTRANS lots vs standard $60 per month Long-term parking rates increased in municipal garages and number of monthly contracts reduced to encourage short-term parking	Tax generated $5.4 million in revenues in FY 77-78
Seattle, WA	$5 per month rate for HOV on-street parking permits vs standard $39 per month rate	193 Carpools certified to use 164 spaces. The number of carpools exceed the number of spaces to ensure high utilization
Washington, DC	12% parking tax on patrons of for-hire parking facilities	Tax generated $8.0 million in revenues in FY 1978
Ottawa	Parking rates for federal employees increased form no charge to 70% of commercial rate (approx. $20 - 24 per month)	23% Reduction in federal employees driving to work Auto occupancy estimated to have increased from 1.33 to 1.41 Bus riders in federal workforce increased by 16%
Pittsburgh, PA	20% parking tax on patrons of all public and private nonresidential facilities that charge for parking	Tax generated $4.8 million in revenues in 1978

Source: John F. DiRenzo, Bart Cima, Edward Barber, *Study of Parking Management Tactics* (Washington, DC: Federal Highway Administration), 1979.

employees one-half the commercial parking fee in areas where comparable commercial parking cost $10 a month or more. After 2 years, parking rates were to have been raised again to be comparable to fees charged by private operators. The executive order was intended to end the subsidy that free or below-market-rate parking represents and to encourage carpooling and the use of public transit for the journey to work.

In 1981, a federal judge ruled that the government had acted illegally when it began to charge federal employees for parking spaces because the program had been implemented by executive order, without the required approval of Congress.

3. *Increase Revenues.* Most communities have increased parking rates over the years. The reasons most frequently cited for overall price increases were inflation, raising additional revenue, debt service requirements, and keeping pace with the rates charged by private sector parking operators.

New Haven, Connecticut, doubled their metered parking rates in 1983. Parking fees at municipal off-street facilities in Wilmington, Delaware were increased an average of 23 percent between 1982 and 1983. Increased parking rates in Honolulu yielded that city a 39 percent increase in monthly parking revenues. Increasing demands for airport parking also are causing most airports to increase parking rates to provide reserves for needed new parking.

4. *Encourage Ridesharing.* A number of jurisdictions have implemented pricing changes to favor carpools and vanpools in publicly controlled spaces. Seattle's rate structure favors both short-term parking and carpools/vanpools as part of the city's overall policy of encouraging high occupancy vehicle travel. Carpools using designated metered on-street spaces can save approximately $35 per month in parking charges. Seattle and Portland have implemented on-street carpool/vanpool preferential parking programs. In both cities, spaces are located where long-term on-street parking will not impede traffic flow or use curb spaces that provided critical support for nearby commercial activities.

Sixty-one percent of Portland's carpools were formed because of the preferential parking program and over 288 carpools were using on-street spaces in 1982. In Seattle, 193 carpools were certified to use 164 spaces in 1982. The number of carpools exceed the number of spaces to ensure high utilization.

In Houston, carpools/vanpools are given discounts of 25 to 75 cents a day in several lots operated by the City Center Department. In Montgomery County, where carpool spaces are reportedly 74 percent occupied, carpool and vanpool parking permits are priced at about two-thirds the regular parking permit rate. CALTRANS' lots in San Francisco have a monthly charge that is less than 17 percent of the regular rate.

Parking Taxes. Some cities have parking taxes, including New York City, Pittsburgh, San Francisco and Washington D.C. (The tax rate in Washington is 12 percent.) The 15 percent parking tax in San Francisco resulted in parking elasticities ranging from -0.20 to -0.31.

Implementation Considerations

The effects of parking management programs are far-reaching and widespread. Programs impact:

- auto users;
- transit riders;
- the city center and adjacent residential neighborhoods;
- short-term parkers (shoppers and people on personal business);
- long-term parkers (generally commuters);
- downtown employers; and
- merchants.

In formulating a program, consideration must be given to its potential impact on downtown retail sales and professional services. Good strategies limit the use of parking for work trips, but encourage the use of available space by shoppers and other short-term parkers.

Implementation must consider the nature of the city center, its employment concentrations and reliance on public transport, the ownership patterns of the existing space supply, and the existence of competitive centers. It is essential to conserve the city center's vitality and economy.

One of the most difficult factors in implementing a parking management program is the mix of public and private space. The level of bond indebtedness, and taxing and land-use requirements and regulations are also significant. Ability and willingness to adhere to regulations and restrictions is another key factor.

PARKING DEVELOPMENT OPTIONS

Parking facilities are developed and managed by private enterprise and public agencies, both singly and together. The choice depends on the location and purpose of proposed facilities, cost and revenue implications, and the financial posture of the community.

Private Sector Role

Most parking spaces are developed and operated by the private sector to serve traffic generated by specific attractions or developments. Much of this parking is restricted to who can use it, and is not available to the general public. Many downtown lots and garages, open to the general public, are also developed by the private sector. Except for commercial parking, the private sector provides off-street parking in response to zoning requirements, as well as what the developer/owner/lender considers necessary to support the traffic-generating activity.

A major disadvantage of complete dependence on private enterprise can be its reluctance to provide enough properly located parking to satisfy community needs. The provision of commercial parking open to the general public naturally follows the law of supply and demand. Because private investors tend to be conservative, the commercial parking supply normally lags behind the demand. Developers, property owners, and business associations normally provide parking that benefits only their own traffic generating activity or business area.

Commercial Parking Operators. Some downtowns depend primarily on commercial enterprise to provide and operate the necessary public parking supply. In cities such as Atlanta, Dallas, Houston, Indianapolis, Los Angeles, Tulsa, and many others, the primary parking supply is found in commercial facilities.

Because commercial parking is operated for profit, owners necessarily favor the demand segment that produces the highest income/profit potential. Thus, commercial parking may not ensure a balanced supply of parking that is responsive to public parking needs. Commercially provided public parking lots can make no guarantee of continuing to supply parking into the future. In many cases, a parking lot operation represents an interim land use until the property can be used for a more profitable development. A competitive market, however, encourages strong commercial initiative in providing optimum location, pricing and operation of parking. The commercial operator can often operate parking at lower cost than public agencies. This is because labor costs generally are less. And, under private ownership, property and income remain taxable.

Business Associations. Retail associations or downtown parking corporations have been the prime movers of parking development in a number of communities. Business associations assume parking provision/operating responsibilities when they believe that they can provide parking more reasonably or more responsively than the local government or commercial providers. When business associations assume parking responsibilities, properties and revenues usually remain taxable.

Three basic elements are needed for the success of business associations in providing parking: (1) interest on the part of businesses, (2) financial support from businesses to establish the program and subsidize it if necessary, and (3) a willingness of business leaders to contribute time to the continuing affairs of the private corporation.

Special-Purpose Parking. Development of off-street parking by private interests also includes provision of customer, employee, and residential parking spaces by individual merchants, developers, or property owners. Although many such facilities have been built to conform with zoning requirements, most would have been built on the initiative of private interests, even if not required by ordinance. Business owners and developers understand the importance of adequate parking to their economic welfare.

Retail storeowners, particularly, are usually unwilling to accept anything less than what they consider an adequate parking supply. This is because they fear adverse customer or tenant perceptions and competition that may be providing more generous or convenient parking. Also, lending institutions are reluctant to finance any type of development that does not demonstrate the provision or availability of an adequate parking supply.

Public Role

Public agencies perform certain essential planning, administrative, and regulating services. They also may develop and operate parking facilities. Local government's concern and involvement stems from its fundamental responsibility for providing services and facilities that make the community a viable and attractive place to live and work. This includes actions to attract, leverage and retain economic development, while ensuring environmental quality and the viability of public investments.

Conceptually, government should assume responsibility for providing parking only when the private sector is unable or unwilling to do so to meet specific community needs. In theory, government's role should be limited to complementing rather than competing with private sector parking investments. In practice, this is not always attainable since parking is an *essential public service.*

Consequently, public and quasi-public agencies develop and manage parking space. They include departments of city, county, or metropolitan government; special-purpose parking authorities; transit authorities; airports; hospitals; and universities; redevelopment agencies; and non-profit corporations.

Parking at airports, transport terminals, and within the city center and outlying business centers is usually a public responsibility. Public sector participation is necessary to encourage commercial development and to assure an adequate off-street parking supply.

Cooperative Public-Private Development

Renewed interest in the rebirth of downtown retailing began during the 1970s in many cities throughout the United States. Over 100 major downtown retail projects were developed during this period. And, during the 1980s the downtown retail revitalization phenomenon gained momentum.

Although many factors have contributed to the surge in downtown development in recent years, many developers and research analysts believe that the most important factor has been the aggressiveness of the public sector in encouraging and participating in renewed downtown development activity. The public sector's role today in public-private cooperative arrangements or partnership ventures can take on wide-ranging characteristics. Public sector roles in assisting and/or participating in downtown projects may include:

- Planning and land assembly assistance, using powers of eminent domain;
- Political protection, which may include protection against pressure to scrap the project (particularly during the planning stages when no tangible product exists), as well as protection against pressure to spread city assistance to a number of competing projects;
- City support for nearby public projects, such as parking facilities or common areas that may be important to the success of a private development project;
- Access or other infrastructure improvements that enhance the usability of a site;
- Financial assistance, which may include tapping a variety of funding sources such as federal, state, and city grants; tax-exempt bonds; and public-private equity arrangements;
- Reorganization of the city bureaucracy to facilitate development, which may include establishing quasi-public development corporations, as well as streamlining the public review and approval process; and
- Design, construction, and/or management of various project components such as parking structures, pedestrian ways and exterior streetscapes.

Development of downtown projects through public-private cooperative ventures is frequently a complex and lengthy process requiring constant problem solving and coordination between the city and private developer. Working in partnership with the public sector can create certain drawbacks for private developers: they may have to add special staff to deal with the city; they may have to share information that they consider confidential; and they will have to operate on the city's schedule (which typically is different from the optimum schedule of developers). For its part, the city must often recognize that it cannot expect to share in the benefits or profits of downtown development unless it is also willing to share in the risks. The city's willingness to share in the risks is a major incentive for the private sector's joint participation.

The developer and the city will have different vantage points. The developer will evaluate the project in terms of the financial bottom line, while the city will likely consider the project in terms of the "political" bottom line (that is, whether or not the project can be justified and can be sold politically), and in terms of its economic impact.

These differences between the public and private sectors can be resolved through early consideration and, in fact, can frequently stimulate creative solutions that, in the final analysis, lead to better projects. Flexibility and an understanding of each participant's objectives are keys to resolving difficulties and making cooperative arrangements and partnerships work.

Privatization

Privatization offers a potential alternative for involving private source monies. Among other considerations, privatization of public parking may require a greater degree of public policy and regulatory interface. Under one type of privatization concept, private companies, backed by industrial bonds, are allowed to finance, own and operate public projects and services, with or without regard to tax advantages. And while this financing alternative is being applied mainly to wastewater treatment facilities, the same principles can be used for public parking development.

Another option is to sell publicly financed facilities to the private sector. In this situation, the public parking agency has a reduced, yet highly selective role in planning. Although designed to improve the city's financial picture, its application in regard to parking facilities has not been widespread. The City of Chicago has long contracted with private operations. In recent years, it has been trying to get out of the parking business by selling publicly owned garages and lots.

Comparison of Options

The strengths and weaknesses of the basic options for off-street parking development and operation are outlined below.

Private Development and Operation. This option enables the parking supply to rapidly respond to land-use changes and market demands. It avoids placing financial obligations on public agencies. However, the need to produce a profit may limit or result in an unacceptable undersupply of parking.

Public Development and Operation. This option gives government maximum control over parking development and management. It enables communities to respond to needs in a coordinated way — even where parking will not be financially viable. It takes advantage of the community's ability to assemble land. More significantly, it enables the community to secure lower interest rates with bond financing than available to the private sector, although it could impact the communities' bond rating. While parking revenues and real estate are normally not taxed, this disadvantage may be offset by benefits arising from public involvement.

Cooperative Public-Private Arrangements. This option works best when both parties are able to realize rewards. The public side may be able to offer bond financing, access to grants or credibility to attract other private funding and development commitments. The public side also can offer land assembly through eminent domain, protection from political and competitive pressures, a timely review process, or improved public infrastructure to facilitate development.

For its part, the private sector may offer specific development and/or operating expertise that enables greater efficiencies than possible through the public side. Considering the public side's input, the private side may be more willing and able to commit additional resources to complimentary private development. The private side's participation also may constitute a political or legal buffer, insulating the public agency from adverse impacts that might arise from parking development or operations. Private involvement may enable the public entity to avoid or reduce long-term expense commitments for payroll and structural maintenance associated with parking facility ownership and/or operation. Under some circumstances, private involvement assures that land and improvements used for parking, as well as revenues, remain taxable.

FINANCING OPPORTUNITIES

Opportunities and options for financing parking depend on who provides the facility, where it is located, and who it serves. This section identifies some of the ways that communities can achieve a better balance between parking costs and revenues. Detailed financing methods are discussed in Chapter 5.

Framework for System Finance

Parking facilities, like other transportation services, should rely on user charges for facility development and operation. The principle of *self-support* through parking fee revenues should be applied to the maximum extent possible. Where user charges are inadequate, or where direct user charges would not be appropriate, funding must be derived from other sources — ideally, from those who benefit from the parking's availability.

Costs for privately developed facilities — when not paid for by users — are absorbed in the rentals charged (i.e., a shopping center or office park).

Costs for publicly developed facilities frequently are paid in part by users. Shortfalls are covered by general revenues, or other parking-related revenues.

Benefit assessments enable the cost of publicly developed facilities to be shared with adjacent properties that benefit from the parking.

Addressing Economic Realities

For a combination of reasons, many public agencies find it difficult, if not impossible, to finance new parking development from parking revenues alone. The financing of new facilities and major rehabilitation of existing parking facilities frequently requires additional support beyond revenues obtained from parkers.

The problems of providing parking and "making it pay" confront most cities. They are most acute in older communities suffering low downtown growth and a declining tax base. Larger cities with rail transit and high CBD employment may limit the CBD parking supply; the high demands and limited space supply in these city centers result in high parking rates and, paradoxically, new parking facilities usually can be financially attractive if permitted in these areas. Cities with growing downtown areas and strong private sector inputs are able to require developers to share in costs, often through zoning requirements. Most other cities are faced with a major economic problem relative to their city centers in general, and particularly CBD parking. They are reluctant to require the private sector to pay for parking for fear of discouraging new development; their bonding capacity may be limited, and their parking is unable to pay its way from user revenues.

Many public parking systems barely cover operating costs from parking fees, leaving little revenue reserve for debt service. The widening gap between revenues and costs is apparent from the comparative performance of parking systems operated in eight New England and Middle Atlantic cities summarized in Table 2-5.

Annual net operating income ranged from $3 to $467 per space, averaging $169 per space in 1983-84. Variations among agencies reflect differing mixes of lot and garage spaces, hours of operation, rates, and management practices.

Existing revenue experience is especially significant since it indicates: (1) the likely financial performance of new parking space; and (2) a lack of coverage potential from funds available for debt service or system expansion. Annual debt service of $1,000 or more for each garage space is typical.

At 1989-90 cost levels, municipally developed garage costs, including land, construc-

Table 2-5. Comparative Financial Performance of Parking Systems in New England and Middle Atlantic Cities

City	Spaces in System (rounded)	Annual Revenues per Space	Annual Maintenance & Operating Costs/Space	Annual Net Income per Space
1[a]	9,300	$858	$391[b]	$467
2	4,100	446	443	3
3	3,600	349	205	144
4	2,300	580	293	287
5	1,900	214	160	54
6	1,300	323	180	143
7	1,200	474	271	203
8	1,200	240	190	50
Mean	3,112	386	267	169
Standard Deviation	2,732	251	104	151

a. Data for CBD spaces only.
b. Metered operation, excludes depreciation.

Source: Parking Agency Annual Reports (1983-4) from New Haven, Stamford, Waterbury, Connecticut; Wilmington, Delaware; Worcester, Massachusetts; Paterson, Trenton, New Jersey; and White Plains, New York (1986).

tion, engineering, legal, financing and contingency costs, ranged from about $10,000 to $16,000 per space. This translates into an annual debt service of approximately $1,000 to $1,600 per space. Net operating incomes in small- and medium-sized cities are generally under $500 annually per space. Under these conditions, revenue bond financing is not feasible, and cities cannot finance new garages from user revenues alone.

Many cities cannot rely on new parking to pay its own way through parking revenues. This poses at least two policy questions: How can user charges be augmented? and Who should pay? It suggests a financing policy that (1) maximizes operating efficiency of existing facilities, (2) effectively controls and licenses commercial parking space, (3) shares costs between the community and benefited groups, and (4) adopts a systems approach to parking finance.

Curb parking meter revenue rates should reflect the true commercial value of on-street parking. Ticketing, booting, and towing of illegal parkers should be maintained at a high level (subject to political and community acceptance). And, ideally, all parking-related revenues should be deposited into a single fund that can be used to help finance parking facility expenses, including structural maintenance and eventual replacement.

Improving Fiscal Management

Parking agencies should be fiscally accountable for their actions and businesslike in their operations. They should exercise careful cost controls over all aspects of their operation, and they should be sensitive to the balance sheet.

Parking Rate Adjustments. Parking rates should be set as high as competitively possible to maximize revenues, commensurate with other costs. Revenue derived from parking generally should exceed current operating costs. Depending on specific circumstances and the amount of other parking-related revenues dedicated to the parking fund, revenues should exceed operating costs by at least 25 percent. Revenue security is essential.

Parking rates should be reviewed annually. They should be adjusted for inflation and to match commercial market rates. Key considerations include:

- Revenue needed to offset operating and maintenance costs, including some portion of debt service requirements;
- Rates charged by competitive facilities; and
- Rates necessary to attract or maintain desired type and level of use.

Greater Operating Efficiency. Operating and administrative costs should be kept to a minimum. Performance audits should be made periodically to identify ways to control or reduce costs. Typical areas for possible operating cost reduction include:

- Reducing hours of operation and/or modifying methods of operation;
- Trimming operating personnel and administrative staff;
- Insuring on outstanding debt, rather than on full replacement value;
- Reducing utility costs with improved lighting fixture retrofits;
- Consolidating or relinquishing small facilities; and
- Contracting for private operation through competitive bidding.

To help anticipate and identify costs, a 3- to 5-year financial plan should be prepared and updated annually. Additionally, accounting procedures and reporting systems should provide a consolidated financial statement in addition to statements for individual parking facilities.

Control and Licensing of Private Commercial Facilities. Municipalities should exercise regulatory control over private commercial parking facilities relative to design features and operating practices. Requirements should be set for new facilities with licensing contingent on compliance.

Controls on commercial parking facilities normally include the following key elements.

1. Use should be limited to parking the type of vehicle for which the facility is designed and approved to accommodate.
2. A minimum amount of area (excluding access driveways and driving aisles) should be established for each space.
3. Each parking space should have safe access to a street, acceptable to the regulating body.
4. Parking spaces should be surfaced and maintained with dustless, all-weather material.
5. Parking facilities should be screened from adjacent properties if deemed appropriate by the governing body. Alternative screening methods should be allowed, but minimum performance standards should be specified.
6. Adequate illumination should be required to a specified minimum, but should not exceed a specified maximum when measured near adjoining property uses where spillover lighting could have a negative impact.
7. A minimum setback should be required for any side of parking that faces an open street. Width of setback should be adequate to develop effective screening.
8. New parking facilities should not be permitted where they replace architecturally or historically significant structures.
9. License fees for commercial parking should be levied on a per space basis. Funds so derived should be earmarked for the parking fund, and all costs associated with the collection of license fees should be paid from the parking fund.

Intensified Enforcement. Communities should enforce their parking regulations as effectively as possible. This often poses problems of resource allocation priorities if police departments must use regular police officers to perform parking enforcement duties. Some local governments find it more cost effective to use civilian enforcement agents, releasing sworn officers for other assignments.

Effective enforcement of on-street regulations is essential for several basic reasons.

1. *Public Protection.* The prohibition of parking is necessary near fire hydrants, in emergency vehicle easements providing access to areas where the streets are not dedicated, at

intersections when vision may be impaired by parked vehicles, and at or adjacent to construction sites.

2. *Traffic Flow Improvement.* The prohibition of parking is necessary where and when it is desirable to use the curb lane for moving vehicles and at bus stops and loading zones.

3. *Parking Management.* Enforcing parking restrictions that are designed to cause faster parking turnover is necessary to give preference to short-term parkers who are visiting commercial establishments and offices. It is also necessary to enforce parking prohibitions designed to implement parking management policies or to reinforce other transportation management strategies.

4. *Parking Revenues.* Effective enforcement can generate substantial revenues that can be applied to parking programs.

There is substantial evidence that parking policies in many cities are skewed toward revenue objectives. However, emphasis on managing parking to generate revenues for public coffers may conflict with the principal objectives for public provision of parking.

Techniques for enforcement of parking regulations are well-established and straightforward. The greatest deterrents to an adequate enforcement program are: (1) a lack of resources to employ the persons needed to detect, record, and adjudicate infractions; and (2) a perception that priority for any increased police resources should go to combating street crime. Many jurisdictions are addressing these problems by using civilian enforcement agents, moving to administrative adjudication, adopting a strict parking enforcement policy, improving data systems, and by systematically collecting fines from scofflaws who try to evade payment (see Chapter 11).

Sharing Parking Costs

Public parking facilities benefit users, adjacent developments, the downtown community and the community at large. It is logical, therefore, that each group contribute to development costs.

The concept of cost sharing implies that development costs should be shared among users, the municipality and/or public parking agency, and benefited parking generators/owners. Parking fees from users should cover operating and maintenance costs plus a specified minimum portion of development costs (debt service). The remaining costs should be distributed among the community at-large and others who benefit directly from the parking's availability.

Table 2-6 shows how new parking development costs could be shared among various beneficiaries. It assumes that parking revenues will cover all operating costs plus a specified share of development costs. The remaining development costs would be divided equally among other beneficiaries. Thus, it would cost the city or parking authority $315 per space annually, the downtown community (i.e., benefit assessment) $315, and the benefitted devel-

Table 2-6. The Concept of Cost Sharing Applied to Parking Garage Development

Item	*Capital per Space*	*Operations and Maintenance per Space*	*Total per Space*	*Percent of Annual Costs*
Annual costs	$1,050	$350	$1,400	100
Parking revenues	- 105	- 350	- 455	32.5
Non-user costs	945	0	945	67.5
City/authority	315	0	315	22.5
Benefited properties	315	0	315	22.5
CBD-community	315	0	315	22.5

Note: Annual costs to build based on $10,000/space/year with 10% interest and 30 years debt service rounded to $1,050.

opers $315 per space per year.

The cost sharing concept recognizes that parking is a public service offering many benefits. Therefore, it is reasonable to expect each group benefitted to share in the costs of parking space development. It is an application of the well-established public finance principle of cost recovery that has been applied to many public works and transport developments. It is actually similar to the benefit-assessment procedures used in communities such as Garden City, New York, nearly 40 years ago.

Cost sharing is correct in principle, but it may prove difficult in practice. Many public parking agencies do not have the financial reserves necessary for their outstanding portions of the debt service. City government limitations on debt service obligations may make it difficult for general fund contributions. Moreover, some cities already have assumed their maximum debt service obligation allowed under state law. Benefit assessments may require state enabling legislation.

A Financial System Approach

A systems approach to parking's financial needs can and, perhaps, should be adopted for all aspects of parking facility development, operation and maintenance, including enforcement of parking regulations. This approach should reflect sound business and public finance principles, enhance the financial integrity of the public agency having parking responsibilities, and reduce reliance on general municipal funding for public parking needs.

The first step to realizing a systems approach is to dedicate all or a portion of all parking-related revenues to a single parking fund. Contributing sources of this fund normally include: municipal lot and garage revenues, curb parking meter revenues, license fees charged to commercial parking operators, and parking fine revenues. It should include additional revenues from rate increases, more intensified enforcement and improved ticket adjudication procedures.

These funds should be used to cover costs of enforcement, operation, and to the extent possible, debt service. Cross subsidies between the local government and parking agency or authority — common in some cities — should be minimized. This will enable better accountability of expenditures and encourage greater operating efficiency.

If the fund is not adequate to cover all costs, expenditure priorities should be established. Generally, priority usage of these funds should be to cover costs of enforcement, operation and, to the extent possible, existing debt service. Surplus revenues should be used to establish a reserve fund for major structural maintenance and new development.

While this represents a businesslike and financially accountable approach, it may not be able to provide adequate funding by itself. And, it could be difficult to persuade city officials to relinquish parking-related revenues traditionally placed in the city's general fund. Thus, implementing a systems approach of dedicated funding probably would require other actions to make the reorganization more financially attractive and economically viable.

The flow of parking-related revenues is shown in Figure 2.3a for a hypothetical parking authority. This illustrative cash-flow is not city-specific. It is based on a 4,000-space system (owned and operated by a parking authority) with gross revenues of $390 per space, or $1.56 million annually. It assumes that curb meter and parking fine revenues are placed in the city's general fund. In addition, the parking authority pays $100,000 annually to the city. In turn, the city pays $700,000 annually in outstanding debt service for the authority. The parking authority is unable to produce sufficient revenues to meet debt service and to establish a reserve account for preventative and corrective maintenance on its parking structures, which are in a state of deterioration. The parking authority has been attempting to obtain financial help from the city to make needed deck repairs over the next several years. The city is balking at making such a financial commitment because surplus parking revenues in the general fund have already been earmarked for other purposes.

Adding to the dilemma, the city has embarked on an aggressive economic development program that will depend, in part, on the city's participation in providing additional parking. However, neither the city nor the parking

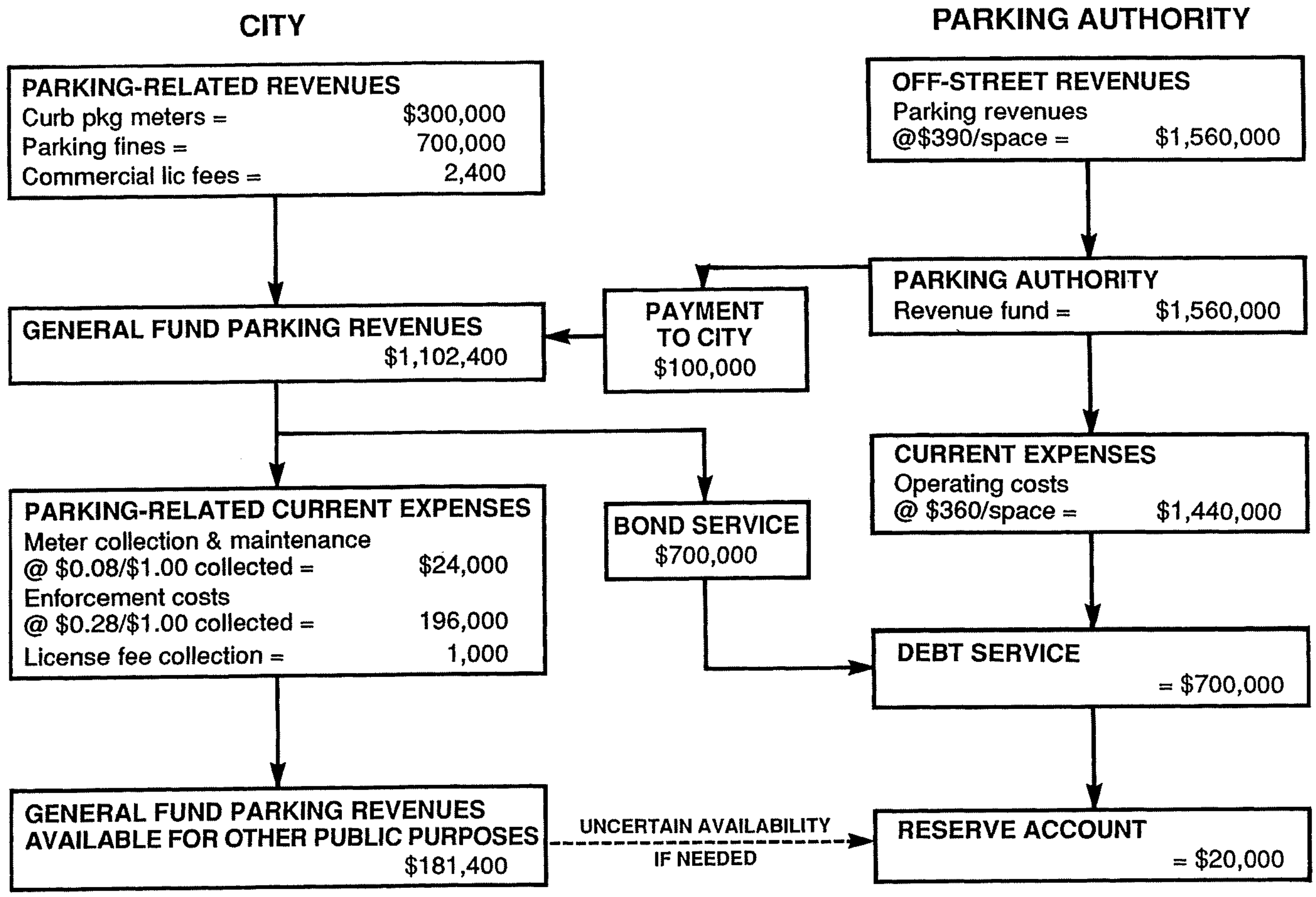


Figure 2.3a. Existing flow of parking-related revenues and costs for a hypothetical parking authority

authority will be financially able to participate in new parking under present circumstances.

To effectively address these problems, the city agreed to funnel all parking meter revenues, commercial parking license fees, and 25 percent of existing (base year) parking fine revenues plus 75 percent of the parking fine amount collected in excess of the given base year into the authority's parking revenue fund. In exchange, the parking authority would become responsible for collecting on-street meter revenues and maintaining the meters. Parking enforcement had been performed with regular police personnel and while reasonably effective, there was room for improvement. The city transferred the primary responsibility for parking enforcement to civilian personnel, supplemented by regular police. In addition, an administrative adjudication system was instituted.

The resulting flow of parking-related revenues for the financial system reorganization is shown in Figure 2.3b. This flow pools a larger portion of parking revenues, and minimizes the need for cross subsidy between city and parking authority. Parking rates were increased to better reflect market rates, and operating costs were reduced. Annual revenues increased to $450 per off-street space. License fees paid by private operators were doubled, but the total cost remained modest at $2 per space annually. More effective enforcement and adjudication helped to ensure better use of parking spaces and was responsible for some of the revenue increase in both on- and off-street spaces. Better enforcement also in-

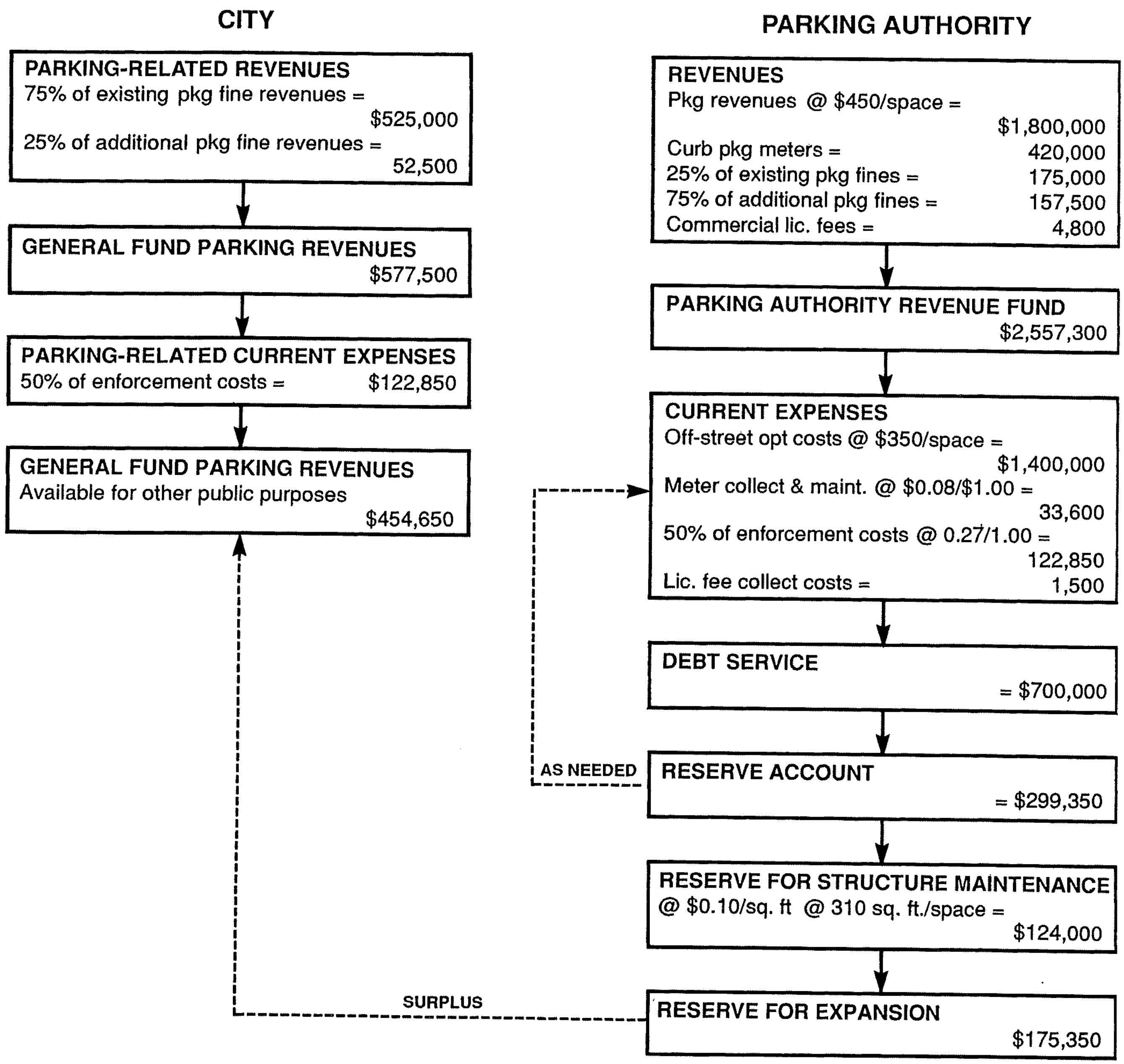


Figure 2.3b. Improved flow of parking related revenues and costs, using a financial system approach.

creased parking fine revenues, and even though the amount spent for enforcement increased, the unit cost per dollar of fines collected decreased slightly from 28 to 27 cents.

These policies produced gross annual revenues to the parking authority of over $2.5 million, enabling the authority to assume full responsibility for the $700,000 annual debt service. A $299,350 annual reserve remains for major maintenance and systems expansion, with any surplus returned to the city's general fund.

SUMMARY

Parking policy charts the directions for both public and private parking developments. It calls for a careful *balance* of *public service* and *business* aspects: parking programs should recognize parking as an important public service that benefits users, businesses, and the general community; but they also must apply some business principles. They should recognize each city's parking problems, development prospects and financial realities, and strive for greater public-private cost sharing.

This chapter has set forth the concepts and principles that underlie parking policies and programs. The chapters that follow cover key aspects of these policies in greater detail.

CHAPTER 4

Public Parking Administration

The organization and management of parking activities varies from city to city. Specific responsibilities and arrangements reflect local circumstances and needs. Major variables include who the parking is for, amount and location of parking involved, community size and resources, state enabling legislation, and local precedents and attitudes.

There is no one best way to administer and manage public parking activities. There is a role for both the public and private sectors. Both roles continue to change with evolving needs and priorities.

This chapter explains some of the more common approaches to public parking organization and administration. It cites their strengths and weaknesses, and provides examples of each.

ROLES AND RESPONSIBILITIES

Most parking space in North America is provided and operated by the private sector. This parking mainly serves as an ancillary to specific developments. Examples include shopping centers, office buildings and banks. The private sector also builds and operates parking as commercial business ventures.

Public involvement in parking activities reflect government's responsibility to protect the health, safety and welfare of its citizens. Within this context, government's role is to:

- Establish parking program goals and objectives;
- Develop policies and plans;
- Establish program standards and performance criteria;
- Establish zoning requirements for parking;
- Regulate commercial parking;
- Provide parking for specific public uses (i.e., schools, parks, transit stations)
- Manage and regulate on-street parking and loading; and
- Enforce laws, regulations and codes concerning parking, and adjudicate offenses.

In addition, government develops and operates parking facilities when the private sector is not able or willing to do so.

Role of Government

Public agencies perform certain essential planning, administrative and regulatory, enforcement and adjudication services, regardless of who has assumed the primary responsibility for developing and operating parking. This is necessary to assure that parking needs are properly addressed and that parking activities are coordinated with community objectives and goals.

Changing Role. The role of local government has evolved over time. In the early years, parking regulations and enforcement activities typically were assigned to police departments. In larger communities, parking facility development often became the responsibility of public works departments.

With growing concern over parking issues, many communities created special government or quasi-government agencies to handle parking matters. Parking bureaus or departments were established, and in the years following World War II, parking authorities were formed to allow more flexibility in developing and financing parking.

In recent years, many municipal governments have been confronted with a broad array of socio-economic concerns, increasing the burden on public resources. This posed problems for parking authorities that relied on financial aid from the city. And, because of diminishing federal and state financial assistance during the 1980s, some communities sought greater private sector involvement in parking development. This created new challenges for parking managers.

Responsibilities. The role and responsibilities of the public sector continue to change in many communities. The public sector's role in parking may involve planning a park-and-ride facility, building and operating a downtown garage; or merely setting guidelines for the private sector. Implicit is its responsibility to provide essential community services and to plan for the community's future.

Local government must establish community goals and objectives, and develop policies and plans necessary for the community's existence and improvement. To effectively provide vehicle parking, local government should continually acquire, maintain and disseminate current data on transportation, including inventories of land use, economic trends, traffic data, and parking supply and use characteristics. Factual and current information is essential to both private and public interests as a basis for establishing parking needs and for determining the most appropriate and cost-effective way of providing for the need.

Local government has responsibility for regulating the provision and use of parking space. Accordingly, most communities establish and enforce zoning ordinances, subdivision regulations, and building codes that help assure acceptable quantity and quality of off-street parking. Parking facilities operated as commercial ventures are regulated further through licensing or operating certification, and increasingly are required to submit to periodic safety and structural inspections.

Regulation of on-street parking and loading is an important governmental activity. These regulations must be an integral part of each community's overall traffic management activities.

Parking enforcement is another area of local government responsibility. Whether it is performed by the police department, a special civilian agency, or a private contractor or combination, it varies by local jurisdiction. The trend, particularly for larger cities, is to assign the enforcement responsibility to civilian departments of government — usually the department having overall responsibility for street traffic and parking.

Administrative adjudication for parking scofflaws increasingly is being substituted for the traditional criminal court process. Para-legal hearing examiners, who work under the department charged with parking enforcement, are used to replace criminal court judges in hearings of contested parking violations.

The extent of government participation in off-street parking varies among communities and reflects attitudes, needs, precedence, and the ability of private enterprise to get the job done. Government should play a complementary role, to the private sector's provision of parking, consistent with overall public mandates.

The Pittsburgh Parking Authority, for example, once stated that its function is to supplement private garage operation, not to supersede it, and that the facilities shall be operated by experienced private operators under a lease agreement or management contract. The rationale was that experienced private management can attain better efficiency over the long run.

Sources of Local Government Powers

The amount of public responsibility that can be assumed for provision and operation of parking is related to the legal authority allowed local government by state law. The right of a municipality or local government unit to establish parking facilities and to perform other functions necessary to parking may be provided through home-rule powers, through powers delegated by state enabling legislation, or by means of implied powers — those not specifically delegated but considered to be covered by some broadly assigned authority.

Five general types of laws delegate authority for parking actions to local government: (1) general laws, authorizing all municipalities or designated class thereof within a given state, to provide parking facilities; (2) local laws, authorizing specified cities to deal with their parking problems in a more or less comprehensive manner; (3) special laws, authorizing the use of a specified piece of property for parking or the provision of parking facilities in connection with a single development or establishment; (4) laws applicable to state properties; and (5) laws applicable to private businesses, authorizing the provision of parking facilities in connection with localized business areas or specified types of private business.

Fundamental powers required by public entities to enable them to deal with parking problems (exclusive of private-sector initiative) are the ability to (1) plan and design facilities, (2) finance, (3) assemble land, (4) construct parking facilities, and (5) operate and maintain facilities.

The power to acquire land for lease has been included in many state and local laws. Most of these laws merely enumerate leasing as one of the permissible methods for acquiring parking sites. In a few, however, there are limitations on the leasing privilege.

In a number of instances, private interests have been allowed to build parking facilities on public property, and then to operate them under a lease arrangement. This matter has been given specific attention in many parking laws and appears to be implied in a number of other statutes. Usually, local government retains some contractual control over leased parking facilities to assure equitable parking rates and proper use of the facilities.

New laws or special authority may be needed for local government to institute a particular type of parking action. Decisionmakers should determine the adequacy of existing powers with respect to the nature of proposed actions. If there is a lack of any necessary authority, immediate steps should be taken to obtain some. If it appears that the desired legislative action will be very difficult to secure or that it will require considerable time, it may be best to alter the nature of the proposed parking action.

A broad and legally enforceable state parking law can enable local government to institute and implement their parking programs without recourse to special legislation or court decisions. Otherwise, when parking action is required, a program may be seriously delayed pending the convening of the state legislature and adoption of measures delegating the essential authority.

ORGANIZATIONAL ARRANGEMENTS

Administration of parking activities within local government can take many forms, depending on community needs. Responsibilities may be vested in a traditional city department (i.e., public works), in a department of traffic and parking, or within a special parking department. They may be vested in a parking utility or a more autonomous parking authority.

Organizational arrangement and powers should be carefully matched to local conditions and needs. It should take into account the legal authority, political pressures, financial resources, character and magnitude of needs. It should strive to achieve managerial efficiency, operating and financing autonomy, and accountability.

Different public (and private) organizational arrangements have been used to successfully implement and manage parking. No absolute principles or formulas exist for achieving the ideal form or model of structure to manage parking activities. Many factors that vary from community to community must be considered. There are advantages and disadvantages to every organizational form and, though the form is important, it is management's capability and the processes and systems used that enable the parking program objectives to be realized.

Local Government Department

The parking function can be delegated to an existing department within the city government or it can be assigned to a separate parking department or utility. The parking department or division should have responsibility for: (1) planning parking and loading facilities; (2) regulating the location, construction, and operation of municipal facilities; (3) setting rates for municipal facilities; and (4) developing and operating municipal facilities as required.

Existing Department. Placing parking responsibilities in an existing municipal department is the simplest way to establish a parking program. This is a common means of dealing with parking in smaller cities. The Department of Public Works or Police Department is the logical place to assign parking activities in communities where there is no traffic or transportation department (often with communities of under 100,000 people). However, parking needs may not receive the necessary attention where such an arrangement is used in larger cities.

Combined Department. A combined department of traffic and parking has merit, since it enables all street traffic related activities to be brought into one agency. The parking agency also could form a major unit in an overall department of transportation. Such a department could result from a coalition of existing agencies. However, it could pose problems of manageability in very large cities.

Separate Department. Parking responsibilities can be placed in a separate department that is primarily devoted to parking. This gives parking activities equal status with other departments. A separate department enables direct lines of authority, and its duties and responsibilities can be clearly defined. In addition, capable management personnel can be more easily attracted by the prestige, salary and authority of a city department head. A full-time staff experienced in parking can give the parking program the attention and expertise required. This arrangement calls for close coordination between departments, such as between the parking department and the traffic engineering or transportation department.

Parking Utility. Some states (i.e., Wisconsin) allow formation of a parking utility. The utility operates basically as any other municipal agency, but with a separate corporate structure. It is a legal entity of local government with power to make contracts and to exercise responsibility for its own activities. Utilities remain under the direct control of local government. Madison, Wisconsin, and Buffalo, New York, provide parking utilities. Figure 4.1 shows Madison's organization for parking.

Strengths and Weaknesses. Each of these options offers an administrative form directly controllable by local government and is consequently responsive to public demands. Income from parking revenues are returned to local government's budget, and funds for improvements, maintenance and operation can be raised by taxation and other sources normally available to government.

Placing the responsibility for off-street parking in a municipal or county department (separate or combined) has the potential advantages of: (1) coordinating the community's parking system actions, including on-street spaces; (2) facilitating proper integration of parking with street and other transportation access elements; (3) permitting maximum use of the municipality's powers, equipment and personnel; (4) keeping parking fees lower because no taxes or profits need be reflected; and (5) facilitating regulation and enforcement of parking operations, fees and usage patterns. Figure 4.2 illustrates a division of parking organized within a department of transportaion.

Perhaps the greatest disadvantage of administering parking through a city department is that funds for major capital expenditures must come from local government's budget. Therefore, parking must compete for funding with other community needs. At the same time, parking expenditures add to local government's total indebtedness, which is limited by law. Moreover, changes in political leadership can disrupt the continuity of management and the efficiency of parking program administration. And, political influence is more apt to override objectivity than with more autonomous arrangements.

Parking Boards or Commissions

A slight departure from direct control of municipal parking by local government is the parking board or commission that oversees the parking program and operation. This type of arrangement is under local government auspices. The mayor and council, for example, form the board by appointing a group of interested businesspeople and community leaders who are cog-

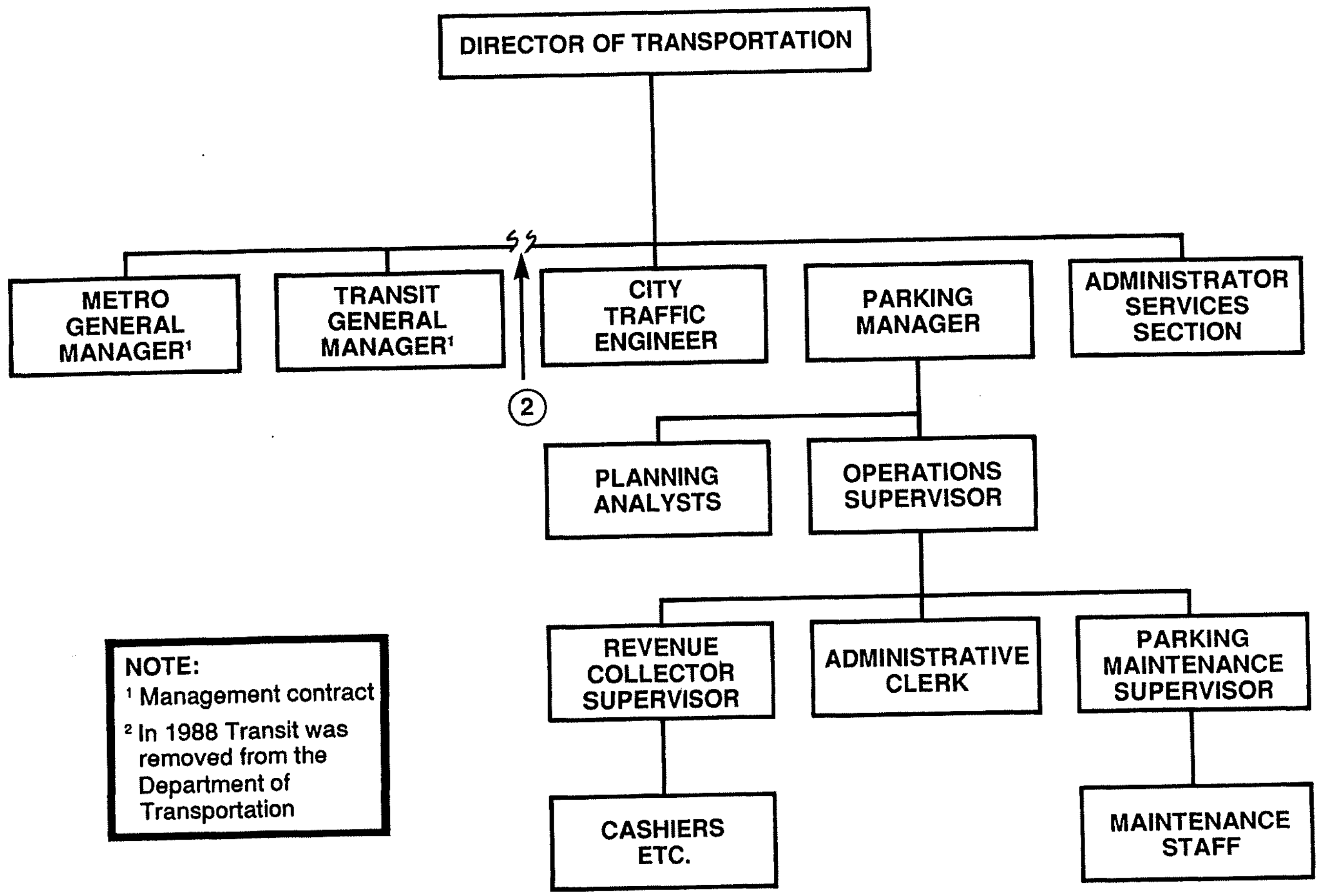


Figure 4.1. Parking organization for Madison, Wisconsin

nizant of parking needs. This group has the power to employ outside services to operate and maintain the parking facilities.

Basic ingredients for the success of this approach include:

- Escrow financial support of bonds by business community;
- City financing of parking investment;
- Strong control of parking program by Board of Parking;
- Careful planning of additional parking facilities by specialists;
- Sound operation of facilities by specialists;
- Energetic support of new plans, maintenance and improvements; and
- Unilateral board decisions with no political influence.

Members of most parking boards or commissions serve without pay. Their role is primarily an advisory and policy-setting one. This type of organization gives a voice to representative members of local groups interested in improving parking conditions.

Boards are helpful in the formative stages of a parking program in obtaining public support and in setting initial policies. A weakness is the limitation of powers to act, since in most cases, financial support and the final authority rests with the elected officials. In addition, the decision-making process of a large group can become cumbersome and time consuming. Interaction and communication with professional and technical staff within city departments could pose problems.

Parking Authority

Parking authorities are established as autonomous parking agencies. However, the degree of actual autonomy varies from place to place. The

City Department Parking Administration

The Madison Parking Utility, created in 1947, was the first municipality-operated parking system in the United States. It was originally administered by a 5-member Board of Parking Commissioners. This number was increased to 11 in 1966. In 1973, the Board was superseded by the City Transportation Commission with an advisory Parking Committee.

The organization of parking activities in Madison, Wisconsin, illustrates: (1) diffusion of functions within various agencies; and (2) organization of a parking division within the Department of Transportation (DOT).

Paid city parking is operated as a *unified system* administered by a parking utility. Parking in central Madison is provided by state, county, city and private sectors. The city has review and approval of public and private parking supply but has limited control over management and usage of private parking and that provided by other governmental units.

Eight different city and county agencies and committees share city parking management responsibilities. These include the Parking Division of the Madison DOT, the Parking Utility Committee, the Transportation Commission, the Police Department, the Data Processing Department, the City Treasurer in the Department of Administration, the City Attorney, and the Dane County Court. The city operates a total of 8,100 parking spaces in the central areas. Approximately 3,700 off-street parking spaces are located in six garages and five lots. The remaining 4,400 spaces are located on-street.

The Parking Division within the Madison DOT includes a staff of about 60 full- and part-time persons who oversee, regulate, manage, and perform the day-to-day operations of the major types of public parking. Residential permit parking, attended/metered parking ramps and lots, 2-hour free parking, on-street metered parking, and loading zones are included. The Division also coordinates establishment of on-street parking regulations with the Traffic Engineering and Transit Division. Figure 4.1 shows how the parking division functions within the city DOT.

The Transportation Commission functions as the parking utility for the operation of the Parking Utility System pursuant to Sections 66.066 and 66.079 of the Wisconsin statutes. It advises the Common Council on parking policy. The commission has complete jurisdiction over off-street parking time limits and rates. (Common Council approval is not required, however, the council does retain veto power.) On-street parking is regulated by ordinances adopted by the Common Council.

A six-member Parking Committee functions as an advisory body to the Transportation Commission and the Parking Committee chair is a member of the Commission. The committee supervises the assets and operation of the Parking Utility System.

Operation of the Parking Utility is financed completely by parking revenue. The utility receives no subsidies or tax money from the city of Madison, nor does it receive any parking fines collected from tickets issued for parking violations. Moreover, the utility is required to make a payment in lieu of taxes to the city's general fund each year, and it pays the salaries of five parking monitors to enforce parking at the meters.

The Police Department also shares in parking management responsibilities. It enforces parking regulations with the help of a 17-person civilian ticket writing force of parking monitors. The Police Department pays the Data Processing Department an annual fee to process parking tickets. The City Treasurer (in the Department of Administration) collects parking ticket payments and counts parking facility revenues. The Dane County Court adjudicates parking tickets. Finally, the City Attorney writes parking ordinances and writes opinions on the implementation of ordinances and statutes.

parking authority is a special purpose corporation that is a legal entity with board members under most state statutes. The authority can function independently of other local government departments and is normally responsible for administration, planning, financing, development and operation of an off-street parking program. It has the power to: acquire property through use of eminent domain; purchase, construct, improve, and operate parking facilities; borrow money and issue necessary revenue-supported bonds; regulate use of parking facilities; establish parking rates; consummate contracts; and execute all instruments necessary to conduct its business. It does not have the power to tax, nor police power to enforce traffic and parking laws.

Members of the authority board, usually five members, are appointed by the mayor (subject to approval of the local legislative body) to serve in unsalaried positions normally for staggered 5-

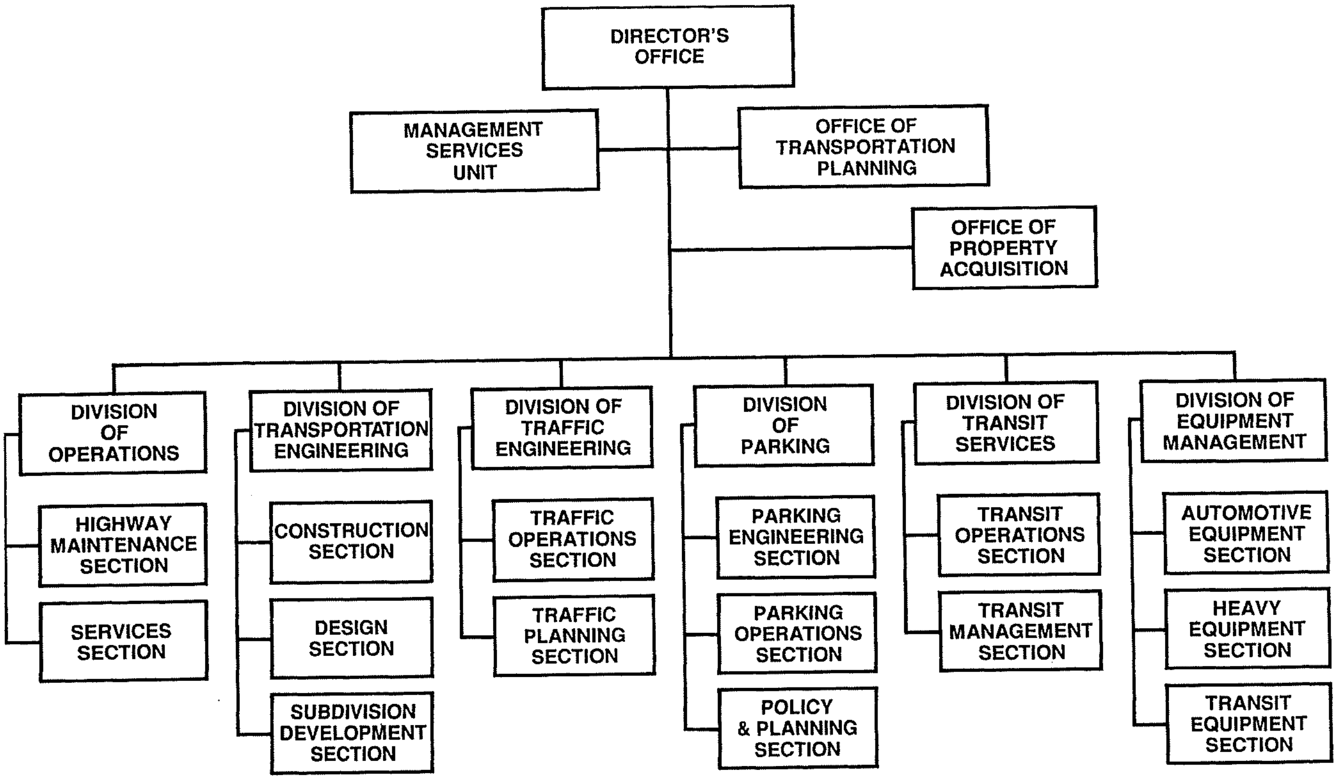


Figure 4.2 Organizational chart for the Department of Transportation in Montgomery County, Maryland, showing the relative position of the Divisions of Parking

year terms, ensuring membership continuity through elections. This continuity is an important consideration to the financial community when evaluating the authority's bond rating. Members can be removed during a term by the mayor and council only if just cause is demonstrated.

The authority establishes its own organization and hires a staff. It can contract for management, accounting, planning, engineering, maintenance and other services. Careful coordination with other agencies and private businesses is necessary to ensure that the parking program fits community needs. To fulfill its responsibilities to its bondholders, the parking authority normally requires separate auditing of its bond indentures and independent fiscal and legal counseling, and consulting engineering services.

Functions. Parking authority staff normally have responsibility for planning, financial, and supervisory functions (Figure 4.3). Some authorities have an engineering function as well, but this is not essential. The goal should be to provide necessary management resources without excessively increasing administrative costs — to adopt a businesslike approach to planning, development and operations of off-street parking.

Strengths and Weaknesses. The primary advantage of an authority is that it can provide an agency, staff capabilities and legal authority nec-

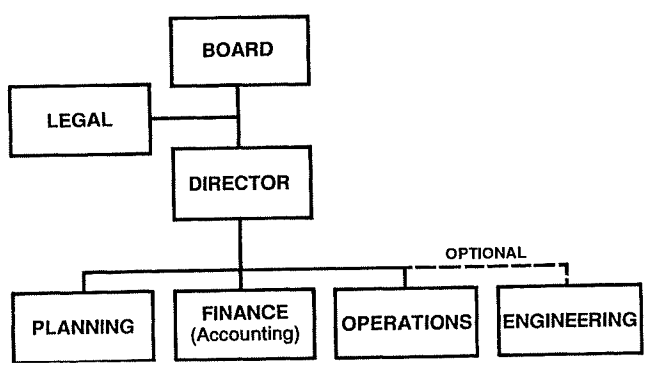


Figure 4.3. Typical parking authority organization

County Department Parking Administration

In 1945, the Montgomery County government and the private business sector both recognized the vital role that off-street parking would play in the economic development and welfare of the county. As a result, legislation was enacted authorizing creation of a comprehensive program to provide parking needs for the unincorporated business communities within the county area. The program was initiated with the Silver Spring Parking Lot District in 1945, followed in 1950 with Bethesda and in 1951 with the Wheaton and Montgomery Hills Districts.

Within each district, the program is totally self-sufficient, generating its own operating and capital funds without burdening the county's General Fund. Funding is accomplished through direct contributions by property owners in the form of special ad valorem parking lot district taxes, parking receipts from users based on a nominal rate structure, enforcement income, income from investments, and proceeds from bond entity unto itself for funding purposes. The current level of operation and service, including debt service on capital projects, is paid in total from operating revenues with surplus funds available for future programs and capital projects.

The basic purpose of the public parking program is to support the comprehensive development of the central business districts (CBD) of Silver Spring, Bethesda, Wheaton and Montgomery Hills by providing, operating and maintaining economically self-sufficient parking facilities that keep pace with the needs generated by growth in these districts. To this end, emphasis is directed toward planning and defining the future role of parking as it relates to a comprehensive, multi-use transportation system and master plans for the affected business districts.

Montgomery County's public parking program has grown to a system of nearly 13,000 parking spaces, both on and off-street. Off-street facilities number 11 multi-level garages and 37 surface lots. Parking needs of each parking district are based primarily on master/sector plans for that area, together with a knowledge of the development patterns that have actually taken place.

The county's parking policy is twofold. First, the public parking program must promote the economic welfare of the CBD by supplying a sufficient number of parking spaces to accommodate that segment of public demand that is not provided for by developers or is not served by alternate travel modes.

Second, it must promote and complement a total transportation system through careful balance of rates and supply to encourage use of the most efficient and economical transportation modes available.

The program is administered through the Division of Parking within the county's Department of Transportation. As shown in Figure 4.2, the division is one of six divisions within the department. It contains sections in: (1) engineering, (2) operations and policy planning. Collectively, it has 46 full-time positions. One reason for the program's success has been the cooperative and excellent working relationship between the Chambers of Commerce and the Department of Transportation.

essary to deal with the scope of parking problems. Its powers are normally broad and flexible and it can plan and initiate a parking program suitable to overall community needs. Other advantages include: (1) centralization of extensive authority and responsibility for the parking program in a single agency; (2) relative freedom from political pressures; (3) avoidance of certain governmental processes and other delays; and (4) payment of costs, as a rule, from user revenues, possibly without affecting the regular municipal budget or tax program. In addition, it can issue non-taxable revenue bonds to finance parking developments.

The authority form also has weaknesses. Authorities may bypass city legal debt limits and issue their own revenue bonds. This ability is not considered a blessing by some financial analysts since debt to the community can be increased beyond the amount considered financially sound. The interest rate on the authority's revenue bonds is high, and the debt greater than if the city finances the undertaking with general obligation bonds. Coordination of parking programs with other city activities relating to planning and transportation and traffic may be reduced (at least potentially) by the autonomous character of an authority. The authority also may duplicate the work or even conflict with development plans of city departments.

Board of Parking Administration

Buffalo, New York, has a seven-person Board of Parking. The Buffalo plan for development and operation of parking garages has been in existence since 1954; it resulted from the cooperation of the downtown merchants, the Board of Parking and the officials of the city of Buffalo through the office of the Mayor, the Common Council and the office of the Comptroller.

The city of Buffalo, by the issuance of general city obligation bonds (interest at the going market rate) finances the land acquisition and construction of the parking garages ($30 million to date). Downtown merchants, through a private not-for-profit corporation, the Buffalo Civic Auto Ramps, Inc., lease the ramps for the term of 30 to 40 years as reflected in the bond life, with ownership remaining with the city. Rent is set at a figure that provides a yearly rental in an amount sufficient to retire the bonds, with interest, over the 30- to 40-year period. All profits over and above rental and operating costs are paid to the city in lieu of property taxes. Buffalo has constructed 12 parking ramps and one surface parking lot in the downtown core. It received over $4 million from operation of the facilities between 1954 and 1985.

The Buffalo plan of public development and private operation of garages is somewhat unique. It used the city's credit to acquire sites and construct garages at the lowest possible cost. The garages then were turned over to a private corporation comprised of downtown merchants and bankers to operate on a non-profit basis.

Ideally, a parking authority can combine the public responsibility of government with the potential efficiency of private enterprise. An authority that is financially independent is likely to be most effective. In actual practice, however, parking authority financial independence varies. Some agencies are totally independent from their local government's resources. Yet, some parking authorities are obliged to share resources with local government, often in exchange for certain public services. In other cases, municipalities may finance all or part of the authority's development costs.

During periods when interest rates are particularly high, there are sometimes public moves to shut down parking authorities, and transfer (often through purchase) facilities to the municipality itself. When this occurs, the parking authority experiences economic hardship and does not have the legal ability to generate non-parking revenues to help support the existing parking program and/or develop new parking.

The parking authority adds another entity to the local government structure. This could pose problems of government responsiveness and coordination where a large member of such agencies exist outside of the formal local government structure.

Parking Authority Examples. Examples of several parking authorities follow.

• *New Haven Parking Authority.* The New Haven Parking Authority was created in 1951 in response to growing community concerns over the availability of downtown public parking and the perceived inability of the private sector to adequately serve the needs of the downtown business community and its patrons. The charge was led by the Chamber of Commerce and brought to vote by New Haven residents in a public referendum, provided for by the terms of enabling legislation approved by the Connecticut General Assembly.

The authority, a quasi-independent municipal agency, was created to acquire, construct, reconstruct, improve, operate and maintain off-street parking facilities. Its autonomy is mainly geared towards financial matters, such as providing a vehicle to finance revenue bonds. It has its own independent operating budget and largely subsists on user fees. Aside from certain capital agreements, it is not part of the city's General Fund. Subject to authorization and approval of the Board of Aldermen, it has power to acquire real property, including use of the power of eminent domain; enter into contracts for construction, reconstruction and improvement of parking facilities; lease facilities to individuals, firms and corporations; and establish and collect off-street parking fees.

The ties to the city, particularly in the past, have been very close. For example, the mayor appoints the Parking Authority Board members and the mayor is an ex-officio board member.

Board of Aldermen approval is required for developing and financing the authority's parking facilities. The City Traffic Engineer, until 1987, also served as part-time executive director to assure coordination of traffic and parking activities. The Parking Authority is part of the development team that includes various city departments engaged in development matters. It has been an integral component of major urban renewal and development projects.

The New Haven Parking Authority owns and/or operates 10,000 parking spaces, including seven garage structures and 26 surface parking lots, serving retailing, commercial, banking, professional offices, government offices, entertainment facilities, and other uses with hourly, daily and monthly parking. Although its main emphasis is downtown parking, it operates several parking facilities that serve two major medical centers, and several neighborhood business and residential areas. It also operates the Union Station Transportation Center (railroad station building and 900-space garage). It controls over $60 million worth of parking facility investments; its 1989 operating budget was approximately $6 million. It makes no tax or in-lieu payment to the city. The authority's administrative staff was substantially enlarged when its first full-time director was appointed in 1987. An organization chart of the New Haven Authority is shown in Figure 4.4.

• *White Plains Parking Authority.* The White Plains Parking Authority, established in 1941 was the first such agency created by the New York State Legislature. It contains seven members, named by the mayor; the chairman always has been a member of the City Counsel.

The authority has power to acquire land by purchase and lease. It has the power to construct and operate off-street facilities, to issue bonds, and to pledge revenue for their amortization. It was established as a separate entity on the premise that "parking could pay for itself." Revenues traditionally have covered debt service, operating, and maintenance costs. Because of this constraint, no new garages have been constructed

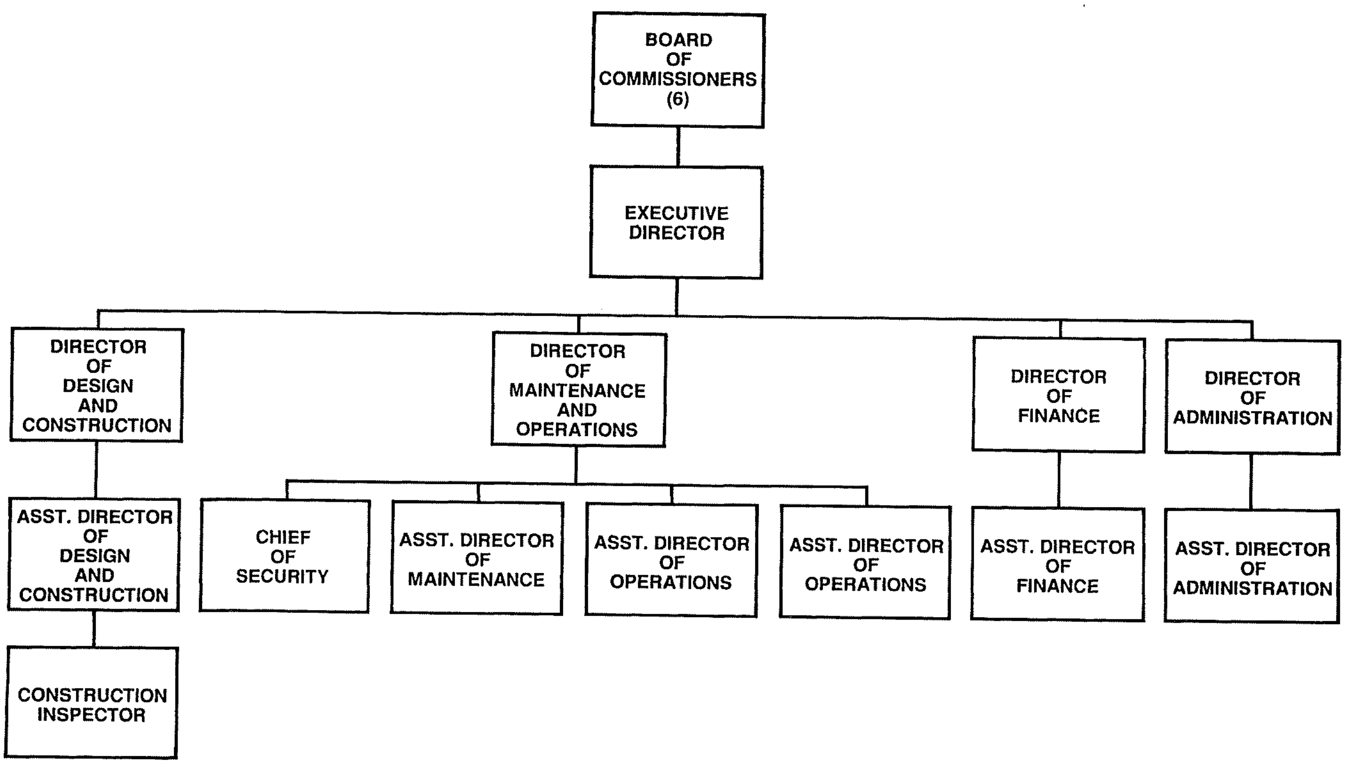


Figure 4.4 New Haven, Connecticut Parking Authority organization

recently, except a public-private cooperative venture at the Metro North train station. The authority is constantly looking for arrangements with the private sector where it would provide the land and let the private sector build the parking.

The authority operates more than 11,000 metered parking spaces in its many lots and garages, and it has both conventional meters and centralized parking fee payment boxes. Its parking facilities have been an important catalyst for the economic resurgence of White Plains since World War II.

Parking rates are approved by the City Council. The council also must approve expenditures of over $10,000. Parking meter fine revenues are paid to the authority regardless of who collects them. The authority pays no taxes; however it makes a small payment to the city for administrative services rendered.

The authority draws upon city agencies for support services, thereby enabling it to function with minimum administrative staff. The city's Law Department negotiates purchases; the Department of Public Works provides engineering services, and the Finance Department handles payroll functions. Cash collection and processing — once handled by the Police and Finance Department — are now handled by the authority.

The White Plains' administrative structure is shown in Figure 4.5. The authority is in the process of taking over the operation of the Parking Violations Bureau run by New York State. Accordingly, it is expanding its staff and computer facilities to provide this service.

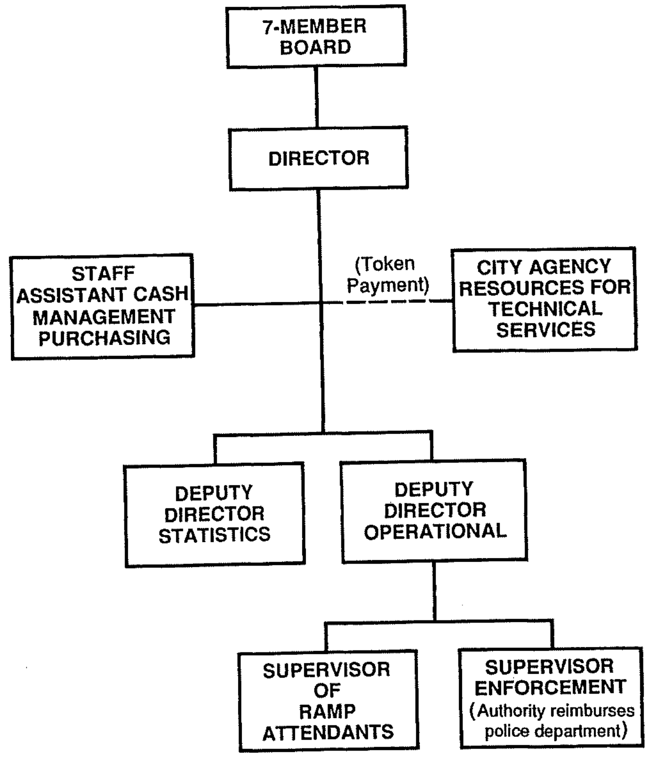


Figure 4.5. White Plains, New York Parking Authority organization

Other Agencies

Public transport agencies in many communities have developed extensive park-and-ride programs. Facility planning, location, design and, in some cases, operation, is the responsibility of the transit agency.

A few states have assumed responsibility for parking development. The Connecticut DOT, for example, has developed a statewide program of park-and-ride facilities for both transit riders and carpools.

Finally, special public activities, such as airport authorities, hospitals and universities develop and/or operate their own parking. Often, these activities have the ability to finance the parking developments from user (parking) fees they collect.

CONCLUSIONS

Since parking is important to the local economy, its administration calls for concerted actions by both public and private sectors. In each community, appropriate groups or agencies must take the initiative to get programs started and to keep them functioning. Responsibility must be assigned and resources must be made available.

Local officials should be aware of their parking problems and remedy them. They should assume a key role in assuring adequate parking space. Government leadership is essential, even where local government does not build and operate parking facilities.

Administrative arrangements are varied. The key is an efficient, responsive and responsible structure. The job is large enough and important enough to warrant coordination and continuous attention of regular municipal departments or concentrated efforts of an autonomous body.

There is no substitute for competent personnel. Parking administrators must have vision, understand traffic and parking problems, comprehend business management principles and possess an intimate knowledge of public administration. They must have the freedom to act within the guidelines established by the community.

CHAPTER 5

Costs and Financing

Financing parking facilities is the most challenging and difficult aspect of parking development. It depends on an array of factors that influence costs, revenues, and financial feasibility. These factors include who develops the facilities — public, private, or joint — the costs to build and operate, interest rates, credit worthiness and bonding capabilities and, above all, likely revenues and/or other tangible benefits.

Parking facility financing, whether private or public, is not a simple procedure to be attempted without professional assistance. It calls for careful studies of financial feasibility, and ways to obtain or produce needed funds to cover development, debt service and operation. Because most parking developments or improvements require borrowing money, financing methods and repayment capabilities assume major importance.

This chapter provides an overview of the factors involved in financing parking facilities. It describes and assesses various methods of financing, outlines steps in analyzing financial feasibility, presents pertinent data on parking costs, and sets forth illustrative feasibility calculations.

FINANCING METHODS

Financing parking facilities from user revenues alone has become increasingly difficult. High development costs and limited funds have caused local governments, institutions and private developers to closely consider alternative sources and means of financing proposed parking. The high cost of borrowed money has further intensified the search for innovative methods of financing, including cooperative public-private ventures.

Financing arrangements vary. Specific financing programs are commonly an outgrowth of a variety of professionals, working together as part of a multi-disciplined team. Required disciplines include legal and financial advisors, traffic and parking specialists, architects, and civil engineers. A team of such professionals, with parking project experience, provides maximum assurance that the project will be realized with efficiency and at the lowest cost of borrowing consistent with the borrower's credit and prevailing market rates.

Private Financing

Most parking structures and lots are financed with private funds. Financing may cover an entire development project that includes parking, or it may be only for parking facility development or improvement. Financing sources include life insurance companies, commercial banks, savings and loan associations, pension funds, and real estate investment trusts and syndications.

Life insurance companies have been a major source of permanent financing for downtown developments. Development mortgages interest life insurance companies because of their attractive yields, the flow of amortization payments, opportunity to spread investments over geographical areas, and the investment flexibility offered. Life insurance companies have sometimes purchased existing properties proposed for multi-use redevelopment or entered joint ventures with developers. Joint ventures usually provide the insurance company with a share of project ownership in return for equity capital invested. Insurance companies also have formed real estate development subsidiaries to invest funds for project ownership or equity participation. Typically, ownership or equity positions in mixed-use or multiple-use projects are preferred over a single-purpose parking project.

Commercial banks are primarily interested in short- to intermediate-term lending, usually not exceeding 5 years. This has helped to make commercial banks the largest source of construction or interim financing. Banks are attracted to short-term construction mortgage loans because they are a reasonably secure investment, especially when backed by a permanent financing commitment from other sources. The bank fills the financial gap during the construction period, assuming the greater risk, at a higher interest rate but for a shorter term than required of the permanent source.

Savings and loan associations and mutual savings banks, similar to commercial banks, can be sources of short-term financing. Compared to commercial banks, the size of loan that can be handled by savings institutions is typically smaller.

Pension funds are a more recent source of property development financing. Usually, pension funds invest in real estate that already is producing income and has a proven history of income and expenses. Joint venturing with banks and insurance companies has enabled pension funds to invest more aggressively in real estate.

Real estate investment trusts (REITs) are financial intermediaries that specialize in real estate investment. Some REITs are strictly equity or property-owning trusts; others specialize in either short- or long-term mortgage loans, while others represent both mortgage and ownership trusts.

Foreign sources of financing for U.S. real estate developments have been assuming an increasingly larger role. Foreign investors have typically been willing to pay a higher price and accept a lower yield than many American investors in exchange for the security of American investments.

Institutional and individual investors recognize real estate equity as a legitimate investment option. This has given rise to a large syndication market that effectively separates the raising of equity capital from the entrepreneurial requirements of real estate equity investment. This mutually beneficial arrangement has made real estate equity syndication a long-term part of the capital markets available to private-sector financing. Use of syndicated equity financing rather than the more traditional debt-financing approach is most attractive to developers when prevailing interest rates are high.

Characteristics of Private Financing. A mortgage commitment for a parking project is made before construction, but the final closing of the permanent mortgage does not take place until the project is complete and operational. Hence, construction financing is necessary during this interim period. While the construction loan is of relatively short term (typically 12 to 18 months, but sometimes ranging to 36 months or more), the cost of interim financing is normally more expensive per dollar borrowed than the permanent financing. Figure 5.1 shows the continuum of a private investment project.

Unless the owner is contracting under a design/build arrangement with a guaranteed maximum project price, the monthly construction payment must be estimated. This normally requires an assumed construction timetable in order to estimate the amount and cost of money borrowed during construction. Assumptions most often used to estimate construction loans are

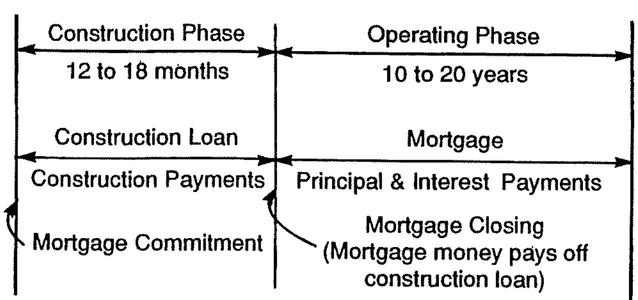


Figure 5.1. There are two financing arrangements necessary for a parking project developed with private funding — construction phase and operating phase or permanent mortgage.

either straightline (equal monthly payments) or the simplified calculation of one-half the total construction cost over the term of construction. Recent studies suggest that both these traditional methods significantly underestimate the cost of construction finance borrowing or overestimate the amount of investment earnings from construction capital, depending on financing method.

Characteristics of permanent mortgage finance vary widely. Permanent financing is usually based on a maximum percent (usually no higher than 75 percent) of the appraised value of the completed project. This means the developer and/or other investors usually must assume a 25 percent or larger equity position. The various forms of mortgage instruments also typically exhibit other common characteristics.

1. Most permanent mortgages are for 10 to 20 years, sometimes with renegotiation of terms and rates every 5 years or more frequently.

2. All have redemption features, usually at a premium, to permit early retirement or refunding.

3. All have severe restrictions on additional debt for the mortgaged property, and some loans will restrict use of cash flow and payment of company dividends.

4. Mortgage loans can be fully amortized from regular sinking fund deposits or partially amortized to a maturity date, with a balloon maturity at the end — necessitating a larger-than-usual cash payment or refinancing of the remaining amount. Most mortgage loans or corporate bond issues include either specific principal retirements each year or the accumulation of a sinking fund to accomplish the retirement of the obligation at some future date. Some loans, however, have been written to require a smaller-than-necessary amortization annually, with the intent of refinancing the unamortized principal at the end of the loan period.

5. Mortgage agreements seldom require maintenance of reserves for debt payments, but sometimes require the borrower to maintain a reserve for extraordinary maintenance and repair of improvements included under the mortgage.

6. Under generally accepted accounting principles, interest payments on a mortgage loan are an operating expense, and payable before taxes or dividends (payments toward principal come after the payment of taxes).

Mortgages may include one or more financing means: variable, indexed and renegotiable rate loans; blend mortgages; shared appreciation mortgages; percent-of-cash flow or presale by developer deals; and joint ventures. Sometimes, combinations of these methods will include syndications and sales/leaseback agreements. Most tax-exempt funding possibilities were eliminated by 1984-1986 and subsequent tax law amendments.

With some longer term private financing of multi-use development, convertible mortgage loans have gained interest. This type of financing arrangement permits purchase or development of an income-producing property where the investor can offer a project's developer/owner a mortgage loan at below-market rates. The investor/lender, however, receives an option to acquire the property in the future, at an agreed price. Thus, debt financing can be exchanged for an equity position. This arrangement can be an investor's means of ultimately acquiring a property that might not otherwise come on the market with acceptable terms, in exchange for providing lower cost financing for the project. If the investor does not exercise the option when the time comes, the loan is allowed to mature and is payable by the borrower on the original terms.

Project Credit Worthiness. The willingness of mortgage lenders and other investors to financially back development is influenced by a number of factors. These include project location, market conditions, tenant interest (measured by leasing commitments), financial appraisal of the project, quality and reputation of the developer and general contractor, project design, and the rate, term, size and coverage ratios of the loan required.

Size of the mortgage loan amount is based on a maximum percentage of the appraised value of the completed project. Value is primarily a function of a project's net income-producing ability. Project cost is a factor, but usually secondary to net income valuation. Projected income is best supported by leasing commitments. Projected expenses are best supported by the developer's record on previous projects. Both income and expense projections are documented by financial feasibility studies performed by qualified and reputable analysts.

Shorter term construction financing also is predicated on financial feasibility. The construction loan lender will consider the same factors as the permanent mortgage lender. Additionally, the construction lender will be influenced by the commitment, terms and conditions imposed by the permanent mortgage lender.

Table 5-1 gives an illustrative example of private financing for a 600-car parking garage with 20,000 square feet of commercial space on the ground level. This example assumes a 30 percent equity position, requiring a first mortgage to cover 70 percent of project costs.

Public Financing

Most political jurisdictions in the United States have the legislative power to issue municipal bonds to finance publicly owned parking developments. The type of government entity or agency determines the sources of taxes or revenues available to secure tax-exempt bonds issued. In addition to general revenues, sources may include limited property or benefit assessment tax levies, in lieu of payments, lease rental payments, parking revenues from one or more off-street parking facilities and on-street meters, or pledging a combination of these sources to secure bond payments.

Bonds issued by a municipality can provide 100 percent of the aggregate costs involved in planning, designing, constructing and opening a parking facility, plus all costs of financing, reserves and capitalized interest. A bond issue can provide that portion of these same costs not being paid for by federal grants, state grants or loans, impact fees, exactions, public-private equity arrangements or municipal general fund contributions, if any.

Municipal Bond Security. Security backing bonds used for parking purposes can be on the basis of any one or a combination of the following bond forms.

1. *General Obligation Bonds.* These bonds are payable in part or in whole from net revenues of the parking project or from net revenues of a community-wide parking system, or from tax revenues. This type of bond financing is ultimately secured by a pledge of the taxing power of the public issuing agency. Such bonds in some states require voter approval.

General obligation bonds are backed by the full faith and credit of the agency, since they carry a pledge of the borrower to levy an ad valorem tax for payment without limit as to rate or amount. Because of the relatively low risk involved, they have a lower interest rate than revenue bonds. A debt service coverage factor (ratio of annual net revenue to debt service costs) of 1.10 to 1.30 generally is considered adequate.

Specific advantages of general obligation bonds include: (1) reasonable flexibility in structuring a bond issue for a given maturity date (typically, up to 20 years); (2) ability to be combined with other city general purpose financing into a single bond issue; (3) lowest bonding costs for a comparable debt service period; (4) minimal bond issuance costs since a debt service reserve is not required; and (5) eligibility for municipal bond insurance.

General obligation bonds, however, have become an endangered means of public financing since they reduce the borrowing power of the city by the bond issue amount. The indebtedness normally is included in calculations of a city's debt margin, regardless of the analytical procedures used by rating agencies in calculating the net debt.

Many jurisdictions face debt limits or declining

Table 5-1. Illustrative Project Costs for Private Financing of 600-Car Garage

Item Projected Costs	*Unit*	*Unit Cost*	*Total*
Land cost	36,000 sq ft	$25/sq ft	$ 900,000
Construction cost garage	600 cars @ 350 sq ft per space	$27	5,670,000
Construction cost commercial space	20,000 sq ft	$30	600,000
	Subtotal		7,170,000
Fees and contigencies (±15%)			1,075,000
	Total project cost		$8,245,000
Method of finance:			
	Equity money (30%)		$2,473,500
	First morgage (70%)		$5,771,500

Source: Estimated.

credit ratings as the need for traditional "public purpose" improvement and renewal projects increase. This suggests that general obligation bonds may be less available for parking development purposes that are not perceived as a high priority public need when compared to other community needs.

Table 5-2 gives a generalized cash flow analysis for general obligation bond financing. The example assumes that all parking revenues are pooled into a single fund, and then applied to the system. This results in a 1.2 debt coverage ratio.

2. *Parking Revenue Bonds.* These bonds are payable from the net revenues of the parking development for which they are issued or, on a parity with other outstanding parking revenue indebtedness, from net revenues of the community-wide parking system. Thus, they do not affect the borrowing power of the public agency in respect to state regulations limiting outstanding municipal debt.

Advantages of revenue bonds relative to general obligation bonds are: (1) greater structuring flexibility (typically, up to a 30-year maximum term, instead of 20 years); and (2) a more definitive degree of project accountability from revenues produced by a single parking project or by systemwide parking.

Because revenue bond repayment is from a single revenue source (parking revenues), interest rates are usually higher than for general obligation bonds. Debt coverage ratio (annual net income over annual debt service) of 1.3 or greater is usually necessary.

Table 5-2. Illustrative Cash Flow for General Obligation Bond Financing

Operating revenues	
Street meters	$100,000
Surface lots	250,000
Parking structure	340,000
Total operating revenues	$690,000
Operating expenses	
Street meters	$ 25,000
Surface lots	80,000
Parking structure	153,000
Total operating expenses	$258,000
Operating surplus	$432,000
Bond payment–parking structure	$260,000
Bond payment–meter & lots	100,000
	$360,000

$$\text{Bond coverage} = \frac{432,000}{\$360,000} = 1.20$$

Revenue bonds, especially if they are issued as self-supporting from a single parking facility, are difficult to market, and they usually represent the most expensive method of financing in terms of borrowing costs. Not only are interest rates higher, but a debt service reserve is required as part of the bond issue. Specific disadvantages include: (1) an interest cost of 0.5 percent or more, higher than for general obligation bonds; (2) the probability of higher parking rates, not only in the financed parking project but also systemwide, to provide revenue required; (3) municipal bond insurance may not be available at a feasible cost; (4) higher bond issuance costs; (5) inclusion of a debt service reserve, adding to the amount of bond financing; and (6) less flexibility to include design enhancements or amenities due to the effect on project financial feasibility.

Table 5-3 gives a generalized cash flow analysis for revenue bond financing. In this example, the debt service coverage ratio equals 1.5.

3. *Guaranteed Revenue Bonds.* These bonds pledge the security of a municipality's general taxing power to support a parking revenue bond issue. This improves marketability and reduces the cost of borrowing from that necessitated by pure parking revenue bonds. The required debt service ratio approximates those for general obligation bonds.

4. *Special Assessment Bonds.* These bonds may be issued by certain types of government (but usually not authorities), payable from a special assessment on property within the boundaries of a specially created taxing district. Benefit assessment districts are arrangements where properties within the business area of

Table 5-3. Illustrative Cash Flow for Revenue Bond Financing[a]

Operating revenues	$465,000
Operating expenses	75,000
Operating surplus	390,000
Bond payment–principal + interest	260,000
Cash flow surplus	$130,000

$$\text{Bond coverage} = \frac{390,000}{260,000} = 1.50$$

a. While this illustration yields what might be considered an adequate debt (bond) coverage ratio for revenue bond financing, many contemporary parking projects are unable to show this high of a coverage ratio.

proposed parking facilities are assessed in accordance with the benefits they derive from new parking. Money used to underwrite improvement is generated through extra fees collected in addition to regular jurisdiction-wide property, sales or income taxes. In most states, such bonds, by law, are also general obligations of the local government entity and in the event the special assessment collections are inadequate to meet the annual debt service, the deficit is paid out of general funds.

This method of financing frequently is used when the parking project provides free parking or if the financial feasibility is insufficient. Creation of special assessment districts is subject to some form of prior approval by district property owners — a simple majority of owners, or agreement by owners who control a majority of the land area, or owners responsible for a majority of the fees assessed. Principal disadvantages are that objectors may slow the process with costly court suits or that there is a perception that some properties will incur a competitive disadvantage. Occasionally, the procedure or formula used to spread the assessment comes under fire. Assessments may be spread through use of simplified or highly sophisticated procedures that include distance from the proposed facility, parking generation attributable to the benefited property, assessed valuation, street frontage length, and credit for the number of parking spaces that may already be provided by the property being assessed.

Table 5-4 provides a generalized cash flow analysis for special assessment financing. In this example, the debt service coverage ratio is 1.38.

5. *Tax Increment Bonding.* Tax increment bonding is a form of special assessment district financing that pledges the incremental increase in regularly-assessed taxes resulting from new or redevelopment within specific districts to the retirement of debt incurred to finance public infrastructure in those areas. This type of bonding is permitted only in some states. This method is used mainly in redevelopment areas. For bond issue payment, it pledges the future property tax revenues generated by the increased assessed valuation of a redevelopment project, above a predetermined base year assessed valuation, usually the year before initial construction. The tax rate is left free to fluctuate according to municipal budgets, but the tax base is frozen, with base revenues flowing to the municipal general fund and increase in revenues due to the development project used to pay the bond financing.

This financing technique is complex, and the marketability of such bonds is highly dependent on developer commitments to complete the overall redevelopment project on schedule. Table 5-5 illustrates tax increment financing yielding a debt service coverage ratio of 1.50.

6. *Excise Tax Bonds.* These bonds may be issued by a municipality (or a municipality may pledge excise taxes to a parking authority revenue bond issue), and are payable primarily from project net revenues and, if needed, from the municipality's receipts from cigarette, utility, fuel taxes, and/or sales taxes. Consequently, the amount and availability of such non-property taxes may improve the project's financial feasibility. Excise taxes serve as security for the debt.

7. *Lease Revenue Bonds.* These bonds are

Table 5-4. Illustrative Cash Flow for Special Assessment District Financing

Operating revenues	$175,000
Operating expenses	75,000
Operating surplus	$100,000
Special assessment tax	260,000
Funds available for bond payment	360,000
Bond payment	260,000
Cash flow surplus	$100,000

Bond coverage = $\frac{360,000}{260,000}$ = 1.38

Table 5-5. Illustrative Example of Tax Increment Financing

Old tax base =	$100,000
New tax base =	300,000
Tax increment	$200,000

Operating revenues	$265,000
Operating expenses	75,000
Operating surplus	$190,000
Tax increment funds	$200,000
Funds available for bond payment	$390,000
Bond payment	$260,000
Cash flow surplus	$130,000

Bond coverage = $\frac{390,000}{260,000}$ = 1.50

payable from lease rental payments made by a government, hospital, university or similar non-profit entity. In the case of municipal ownership and financing through use of a net lease to a nonprofit entity, the municipality becomes a financial vehicle only, subject to the assumption of operation only in the event of a default by the nonprofit entity. Terms of the lease agreement between the municipality and nonprofit entity constitute the basic security behind the bond issue.

Pursuant to the lease agreement, the nonprofit entity would assume full responsibility for operation and maintenance of the parking facility and payment to the municipality of a lease rental equal to the annual principal and interest charges of the bonds issued. To provide a marketable security for the municipality, the nonprofit entity would be required to place its general credit behind the obligations assumed under the lease agreement and not limit payment of the lease rental to the availability of revenues from the parking project.

The obligations issued by the municipality to finance the leased parking project can take the form of any one of the previously mentioned bond security alternatives.

8. *Industrial Revenue Bonds.* These bonds are payable from lease rental payments. Their use is limited, depending on type of development and other circumstances. Limitations vary among the states that have approved such bonds, and are influenced by federal tax law amendments.

Construction Phase Interim Financing. In most public ownership cases, a municipality will fully fund new parking project costs before construction begins, either with long-term bonds or an amount of short-term bond anticipation notes (BANs) sufficient to meet all estimated costs.

As shown in Figure 5.2, bonds are sold before construction is commenced. Money from the bonds is invested to earn interest during the construction period. Payments of principal and interest may be delayed after the facility is open until sufficient revenue is generated to pay these sums. However, debt service payments normally begin during the first year of operation. Table 5-6, illustrates a typical bond issue debt retirement with a 3-year period with interest-only payments on the bonds, and then finally the principal and interest payments planned to commence as the revenues build up from the facility.

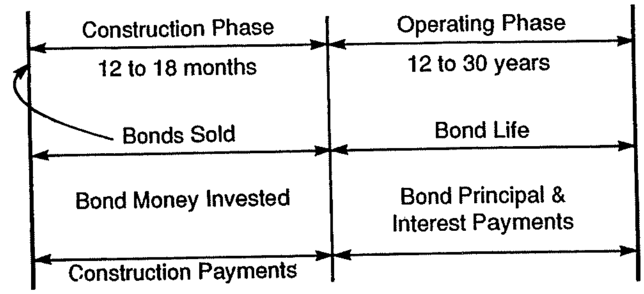


Figure 5.2. For publicly financed facilities, bonds, covering total project costs, are sold before construction begins.

Municipalities and parking authorities have the option of issuing bond anticipation notes, with no arbitrage restrictions during the construction period, to finance a new project temporarily. However, when there is sufficient interest differential between one-year BANs and U.S. government obligations of like maturity (BAN rates lower than interest paid by U.S. government obligations), it can be advantageous to include the entire project cost plus BAN interest at maturity in the total amount of such BANs to be issued. Another advantage of such interim financing is built-in flexibility to arrive at a more

Table 5-6. Typical Bond Issue Debt Retirement Schedule

Year	*Principal[a] Payments*	*Interest*	*Principal & Interest*	*Principal Balance*
1	$ 000	$138,000	$138,000	$2,300,000
2	000	138,000	138,000	2,300,000
3	000	138,000	138,000	2,300,000
4	50,000	138,000	188,000	2,250,000
5	75,000	135,000	210,000	2,175,000
6	100,000	130,500	230,500	2,075,000
7	100,000	124,500	224,500	1,975,000
8	125,000	118,500	243,500	1,850,000
9	125,000	111,000	236,000	1,725,000
10	150,000	103,500	253,500	1,575,000
11	150,000	94,500	244,500	1,425,000
12	150,000	85,500	235,500	1,275,000
13	150,000	76,500	226,500	1,125,000
14	150,000	67,500	217,500	975,000
15	150,000	58,500	208,500	825,000
16	150,000	49,500	199,500	675,000
17	150,000	40,500	190,500	525,000
18	150,000	31,500	181,500	375,000
19	175,000	22,500	197,500	200,000
20	200,000	12,000	212,000	000,000

a. No principal payments until the 4th year.

Source: E. Carlton Heeseler, Parking Finance Consultant exact cost of the completed project for permanent financing.

Purchasers of BANs must be reasonably assured of a "take-out" at the maturity of the notes. For a short period of time, not to exceed a year or so after project completion, BANs can be "rolled over" (reissued in the same amount for another year). Eventually, however, permanent financing must be issued and sold to retire the BANs. In the case of a general obligation BAN, in the event market conditions are such that long-term bonds cannot be sold for whatever reason, the municipality is charged with the burden of placing the full amount of the BAN issue in its current budget and raising sufficient taxes to provide the money for BAN retirement at maturity. In the case of a revenue BAN, the issuing government agency may not have this taxing capability and is completely dependent on the availability of the marketplace to sell permanent bonds. This is why investors generally do not look with favor on BANs that are not general obligations of a municipality or backed by the municipality's full faith and credit.

Municipal Bond Rates. Interest rate levels for tax-exempt municipal bonds move more in concert with U.S. government bonds than any other form of obligation. Even so, there will appear from time to time, aberrations solely attributable to the market for municipal bonds, which cause the level of interest rates for municipals to veer away from the course of government bond rates. Similarly, an over abundance of Treasury financing, usually for deficit funding in recent years, has caused a widening of the spread or difference between long-term government bond yields and composite municipal bond yields.

Additionally, the yield curves for various maturities of municipal bonds and other types of obligations generally show increasing yields or rates of interest with each added year of maturity. There is a distinct flattening of the curve beyond 25 to 30 years. This is because as time to maturity increases, the risk to the investor increases and the investor demands more compensation for that increased risk.

Costs of Issuing Municipal Bonds. Bond issues are not designed and sold in the marketplace for free. Usually a number of professional people are involved in addition to those needed for project planning and engineering. Attorneys are needed, both local and special bond counsel, to prepare legal documentation and proper authorizations and opinions for the bond issue. Sometimes a financial advisor may be needed to prepare the official statement or prospectus used to market the bonds to investors. Both Moody's and Standard & Poor's charge for their ratings. In addition, there is a cost for printing the negotiable bonds, as well as the prospectus. Finally, there are usually some costs incurred at the closing, signing and delivery of the bonds to the primary purchaser. The aggregate of these costs vary widely and depend on size of the financing and its complexity.

Another cost borne by the issuer is cost of marketing the bonds. It can be direct or indirect and is the compensation demanded by the dealer or bank acting as the primary investor or underwriter of the bond issue. The underwriter must be compensated for the risk, sales commissions, underwriter's legal counsel, and actual costs of processing and handling the bonds and paperwork connected with sales to investors.

Fees for services rendered by an underwriter of variable rate demand bonds range between 0.75 and 1.25 percent, depending on size and degree of financing difficulty. The bank providing the liquidity facility has a fee that ranges from 0.25 to 1.0 percent per year on the amount of bonds outstanding. This is in addition to the costs of issuing bonds.

Depending on state laws or local ordinances, bonds may be sold to an underwriter at a discount (less than the par value) or at or above par. Assuming the gross "spread" determined by the underwriter will be $20.00 per $1,000 or 2 percent of the total bond issue, it might be broken down as follows: sales commission, $12.50 per $1,000; underwriting profit (risk), $5.00 per $1,000; and legal and processing expenses, $2.50 per $1,000. Unit costs will vary depending on the quality (rating) of the bond issue. The lower the quality, the harder to sell, requiring a higher sales commission. Unit costs could be increased by perhaps $2.50 per $1,000 if a negotiated sale is consummated, as opposed to a public competitive bid, because of the underwriter's development work prior to the actual sale. Usually, in a negotiated sale the issuer does not employ a financial advisor, so the increased spread is offset to some degree. Unit costs normally are not influenced by whether the underwriter purchases the bond issue alone or in syndication with other underwriters.

When a discount bid is permitted, the underwriter may offer to buy the bond issue at a price of say $980 per $1,000 per value, using the assumed $20 spread mentioned previously. The issuer must compensate for this 2 percent loss in bond proceeds available for the construction of a new project by increasing the overall size of the bond issue by a like amount. In this case, the municipality is paying the underwriting spread directly, while the underwriter offers bonds to the public at par.

Public-Private Venturing

From the public viewpoint, there are several reasons for considering public venturing with the private sector. The most common reason for public involvement is to increase the local tax base or revenues. Other reasons include: improving the urban environment, treating blight and decay, increasing transit ridership, and integrating public uses in private development. Secondary reasons include creating jobs, expanding the community's commercial and/or residential base, and participating in profits of the development.

Private participation in parking facilities open to the general public can be active or passive. Active participation includes direct private investment and administration of public parking. This is typical of private commercially provided parking intended to generate revenues in excess of costs solely from parking fees charged.

There are several potential means of passive private participation in the provision of public parking. One approach is for private developers or new entrants to contribute in-lieu payments in exchange for contractually defined rights to use publicly provided parking.

In another type of passive private participation, investors "own" a parking facility through their purchase of certificates of participation. Certificates of participation are financial instruments backed by physical assets. The parking facility itself is held by a trustee as collateral, and the user makes lease payments that, in turn, are used to pay debt service.

Unlike general obligation bonds, certificates do not require voter approval. This can be partially important when required funding is small compared to costs of voter approval and bond issuance. Moreover, some quasi-public entities (parking improvement districts, for example) cannot issue bonds but may be able to issue certificates backed by real property or equipment. Certificates can be issued only to finance physical property and/or equipment that is suitable as collateral; and only in jurisdictions where local authorities are allowed to negotiate long-term leases.

Public equity or equity-like involvement in private developments may be possible in many jurisdictions but has not been a common practice. This approach involves assigning the public participant a portion of the gross or net revenues from a private venture as payment for government property sold or public services rendered to the venture. Government thus becomes a partner in the private project in return for its aid in establishing the project.

The advantage to the public is in being relieved of some portion of the infrastructure costs and responsibilities, and a potentially enhanced tax base that may otherwise not have occurred. The private venture gains because repayment to the public depends on future profitability, eliminating some of the entrepreneurial risk. One disadvantage of this approach is uncertainty concerning a revenue stream that cannot be controlled or altered by the local public entity.

The public sector can provide a number of incentives to encourage or leverage private investment and development. These normally include zoning incentives, land assembly, tax abatements and land value writedowns, and the provision of public infrastructure and project components, as well as favorable financing. Publicly provided incentives can make proposed private development more attractive, without violating or circumventing prudent government management practices and responsibilities.

In theory, public expenditures and financial support for private development should be directly tied to a commitment of much larger private investment — public expenditure should leverage greater private investment. By requiring public funds be used as leverage, public agencies can be more assured that public investment generates predictable and measurable benefits for both public and private interests. Using public monies to joint venture in this way tends to preclude highly speculative and costly public investments that are unable to result in significant private investment or public return.

There is growing recognition that different market and development conditions call for different kinds of public assistance. In the past, public entities have used traditional public assistance approaches — land acquisition and writedown, tax abatement, and public infrastructure improvements — regardless of the particular problem restricting or discouraging private development. Increasingly, the public sector is recognizing that the same development objectives often can be achieved more effectively by tailoring public assistance to the specific problem. Thus, it may be better to provide a publicly backed construction loan, below-market loans funded by tax exempt bonds, or public funding of front-end costs (such as underwriting of initial feasibility studies) to leverage private investment.

Cooperative public-private development arrangements are desirable when it is impractical for either the public or private sector to attempt the parking improvement or development alone. There are many ways that this cooperation can work, depending on circumstances. Cities, for example, may make land available for private development. Conversely, the city or public agency may develop parking on land provided by the private sector. Cities can provide "air rights" over streets or other public property for private development. Or, they can provide space for commercial development within an otherwise public parking development. Cities also can provide financing (with or without regard to tax-exempt implications) for any portion of the development process. Under some circumstances, it may be more desirable for the private sector to finance parking development and lease the facility to a public agency, possibly with a purchase agreement. The following sections discuss these possibilities and examine actual examples.

Public Development on Private Land. Charleston, South Carolina, used private land behind existing commercial and older multi-family residential buildings to develop public parking. A 140-space parking lot was developed to the rear of five adjacent properties at a 1978 cost of $106,000 ($757/space). Key to this development was the negotiation and structure of the joint public-private venture, involving the city leasing the private lands. About two-thirds of the spaces are reserved for short-term parkers; the balance are in all-day contract parking with priority given to parking for landowners who leased their property for the project.

To realize this parking, the city agreed to construct a 140-space parking lot on the leased property, providing asphalt paving, curbs, landscaping, lighting and parking control equipment. The city further agreed to maintain and operate the lot, including provision of utility service, attendants and/or parking meters, at the city's discretion as may be required. Parking fee rates were set by the city's Committee of Public Safety and Traffic, subject to City Council modification. The city also agreed that the creation and operation of the lot would not be allowed to obstruct rear entrances to buildings backing the parking lot.

After deducting operating and maintenance expenses, income generated by the lot is returned to the property owners. Each owner's share is based on the percentage of square footage owned compared to total lot area. At the start of each lease term, the city projects probable income and expenses, giving the pro forma analysis to the property owners. The city agreed that after the first 2 years of operation at least 50 percent of the income projected for each lease term would be paid to the owners.

The first lease term was 2 years plus construction time (construction required 4 months). The city retains an option (dependent on the city paying at least 50 percent of the projected net income) to extend the lease in 5-year periods for 40 years. Lot operation may be discontinued by the city upon 60-day notice if the lot revenues will not achieve at least the 50 percent level projected. Upon termination of the agreement, the city is responsible for removing from the lot any parking meters or other revenue collection devices that it installed.

A separate accounting system was established for the lot. Payments are made quarterly by the city to the property owners along with a certified accounting of lot costs and revenues. Property taxes on the lot continue to be paid by the property owners. Costs for insuring the lot against all liability is borne by the city.

Public Land for Private Development. Kansas City, Missouri, participated with local business leaders to develop the 1,150-space Baltimore-Wyndote Garage. The city purchased the necessary land and paid for demolition of existing structures. A group of local business leaders acquired conventional private financing to construct the garage, and contracted for its operation with a private operator. Return of the city's investment is being realized through property taxes and reduced need to provide and operate additional downtown parking.

New Haven, Connecticut, and Bath, Maine, are among other cities that have provided publicly acquired lands for private development of public parking. New Haven's objective is to add public parking without adding to the city's bond indebtness. Additional parking is being realized through privately financed development on a combination of publicly and privately provided lands.

Bath participated in a similar approach. Both cities have purchase agreement options that can be exercised at future dates. Bath is placing tax revenues from its parking facility in a special fund for the eventual purchase of the parking improvement.

Public Air Rights Development. Des Moines, Iowa, has been successful in using air rights above parking structures to encourage private development of residential and commercial uses. A tower apartment, opened in March 1988, was built on top of a city parking garage. At another downtown location, the city plans to purchase land to be resold at discount for private development of parking with several stipulations. Among these stipulations, the new parking structure must be developed so that ten stories of future use can be constructed above it. The city retains ownership of the airspace above the garage to determine future development.

Leasing Space for Commercial Use. Birmingham, Alabama, completed two parking garages, where street levels provide space for commercial lease. The objective is to add downtown vitality and help pay costs of providing the parking. Because of restricting state law, the city is not allowed to use public monies to finance the interior finishing of the commercial space. It has leased the commercial space to local realty companies, who are completing construction of the commercial areas and will find tenants.

Direct Public Financing Assistance. The Gallery and Harbor Park garages in Baltimore, Maryland, are being financed with tax-exempt revenue bonds. Payment of full real property taxes is deferred until the parking facilities can generate cash flow in excess of operating expenses and debt service. For its patience in collecting taxes, the city is entitled to varying shares of surplus revenues generated by the Gallery and Harbor Park improvements or refinancing proceeds when the projects become well established.

Tax-Exempt Financing Considerations. Under current federal tax laws, private side gains from possible tax-exempt financing in joint public-private ventures may be difficult to achieve. Where tax-exempt financing is possible, tax saving incentives may add to the overall attractiveness of public-private venturing, but other advantages of public-private cooperative arrangements normally will be far more significant.

If joint public-private venturing is to result in tax-exempt financing, tax law requires the venture to meet the following criteria:

1. Not less than 90 percent of the available spaces in the financed project must be available to the general public on a daily, monthly or yearly basis, exclusive of governmental or non-profit institutional users;
2. Not less than 95 percent of the total proceeds of the financing must be spent solely for construction of the public parking spaces, including related soft costs;
3. Not more than 10 percent of the annual debt service of the financing may be paid for or guaranteed by a corporate or non-public entity on a long-term contractual basis; and
4. Any management agreement for operation of the parking facility may not exceed 5 years duration, must provide for either a periodic flat fee or a fixed percentage of gross revenues, and must give the owner of the parking facility the option to cancel at the end of any 2-year period.

Since federal and local tax laws are periodically amended, current tax-exempt requirements should be reviewed. Complexities of financing usually require special expertise from experienced legal and financial council.

FINANCIAL FEASIBILITY

Financial feasibility deals with direct costs and revenues that are easily assigned monetary values. It differs from economic feasibility, which considers a broader value picture that compares costs and benefits.

The financial feasibility of a proposed parking facility denotes the extent that net income exceeds the costs of providing and operating the facility. Net income is total income minus operating and administrative costs and, when required, sinking or reserve fund payments. Cost of financing the facility (debt service) is the mortgage principal and interest payment, and may include payment to return investment on equity positions. The ratio of net income to debt service is termed "debt service coverage ratio." This ratio is normally calculated on an annual basis. Potential project investors and lenders look at the projected debt service coverage ratio as a prime indicator of probable financial performance.

Parking is not the dominant use of most private developments. In such cases, the costs of parking space are offset, at least in part, by revenues from activities the parking serves. Consequently, the profitability of the parking is usually not the primary determinant of project feasibility.

It is usually necessary or advisable to determine the financial feasibility of proposed parking development, even when the development is not intended to generate a direct monetary return. The financial feasibility assessment will help to refine preliminary cost estimates and pro forma analyses to better identify funding needs and sources. It will indicate the degree of subsidy needed to cover operating costs and debt service. The analysis may also suggest ways to reduce costs, thereby lowering possible subsidy requirements. The financial feasibility determination will enable project costs, equity and debt requirements, and financing arrangements to be calculated with some degree of confidence.

A financial feasibility determination is essential where the major value of the proposed development or improvement will be parking, and where parking development represents the primary basis for securing investor interest and financing. To obtain financing, a financial feasibility determination must be performed before commitments for land, final plan engineering and construction. Prospective investors and lenders will examine the financial feasibility analysis to help them determine the desirability and degree of their financial involvement. Even though the developer/owner initiates a financial feasibility analysis for purposes of soliciting investor/lender interest and refining project plans, the interested investor/lender may also conduct a similar analysis for purposes of confirmation and to explore alternatives in more detail.

A few private-side investors may be willing to finance a project with a relatively low debt service ratio — if tax consequences and/or other, often proprietary or speculative, considerations offer to make the deal acceptable. The required debt service coverage ratio deemed acceptable to an institutional lender or private investor can be highly variable, depending on the lender's/investor's financial objectives. These objectives might be to create higher real estate values; to create long-term cash flows; to maximize an ownership share while minimizing the investor's cash contribution; to realize tax writeoffs; and/or to earn development fee income. In nearly all cases, however, the parking project that offers to be financially self-supporting from its own operations, and is able to project reasonable assurance for generating an acceptable profit margin, attracts more interest and the best financing terms.

Public financing offers less flexibility and tolerance for risk than private investor financing might offer. Public forms of financing are closely governed by law and must adhere to prescribed criteria that set forth minimum risk levels for public financing. Depending on state and local requirements, this typically means that the debt service coverage ratio must equal or exceed 1.30 to 1.50 for revenue bond financing, and 1.10 to 1.30 for general obligation bond financing. Where costs and revenues for a proposed parking project cannot be projected to yield the required debt service coverage ratio, other additional sources of revenue or a guarantee for financial support must be promised to obtain a favorable financing commitment.

Financial Feasibility Analysis

Once the parking project or overall development program is sufficiently well-defined to prepare preliminary cost estimates, a financial feasibility analysis can be prepared. Key steps are outlined in Figure 5.3. It may be necessary to refine the initial analysis one or more times during the course of project planning and design to reflect changes in original assumptions and plans. Some change normally occurs to accommodate circumstances not considered earlier and to optimize the project financially.

The primary value of the financial feasibility analysis is to assess the prospects of financial success or failure with reasonable accuracy, thus determining whether or not to proceed and how to pay for the project. The financial analysis can range from a simple pro forma analysis (a statement for the project, showing estimated capital costs, operating revenues and expenses, and return on investment for a single year at stabilized operation) to a complex analysis of cash flows, internal rates of return and after-tax positions (frequently performed for extended periods covering 5 to 15 years).

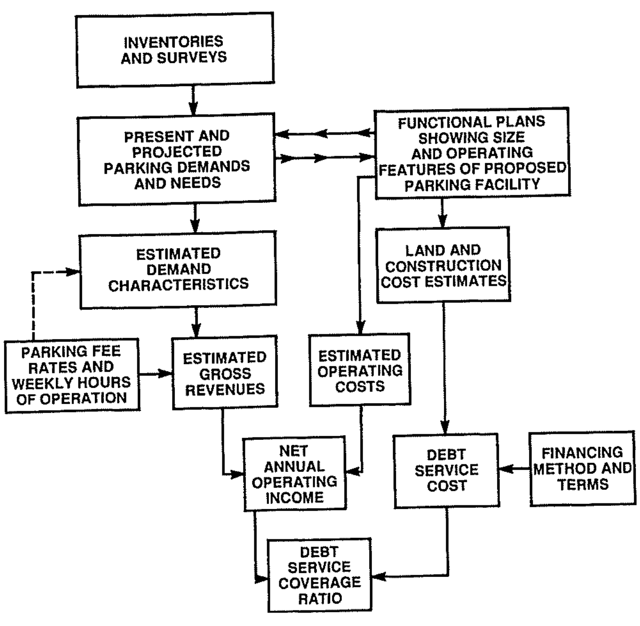


Figure 5.3. Key steps in financial feasibility analysis

In performing a financial feasibility analysis it is essential to make assumptions relevant to costs, revenues, financing methods and associated costs. For purposes of analysis, it is sometimes convenient or necessary to differentiate between "hard" and "soft" costs. Hard costs are generally measured in terms of costs per square foot and consist of all other costs not described in the following for soft costs. Soft costs are those for architectural and engineering, developer's fee, legal and accounting professional services, taxes and insurance (all as a percentage of hard costs); financing fee (as a percentage of amount financed); and construction loan interest (as a percentage of amount financed times the construction period). Soft costs also may include an amount for contingencies (percentage of hard costs), working capital marketing/preopening costs (variable basis but usually percentage of hard costs), and leasing fees and commissions if project is to contain commercial space (highly variable basis but often derived as a percentage of first several years' rent times net square feet of the commercial area). Representative cost assumptions are discussed in the following sections.

Land Costs. Availability and costs of land can be significant factors to preliminary project planning, as well as financial analysis. Land availability and costs help determine development site and type of parking facility (surface lot or parking structure). In the financial analysis, land expense is based on site-specific knowledge.

In many cases the costs of land are not included in the financial analysis. This may occur when the site is already owned by the public or private developer. Whether the property is mortgaged or not may have little influence on its cost in the development project's financial analysis. The owner's wishes and circumstance determine its inclusion in the analysis.

Where land and/or its associated on- and off-site pre-development costs are to be included in the financial analysis, several areas of costs are considered. In addition to land acquisition cost, these may include: clearing and demolition of existing improvements; removal, modification or improvement of public infrastructure (utility and sewer services, access easements and facilities, including surface drainage facilities). It also may be necessary to consider the cost of temporary construction easements (to facilitate existing structure demolition and/or new structure erection), space for construction staging, and costs of handling traffic or parking during construction. These costs of acquiring and being able to use the site for the proposed development can easily influence choice of site. Each cost center associated with the land expense can be highly variable, reflecting site-specific circumstances and market timing.

Construction Costs. Costs of construction reflect type of facility and construction complexity, modified by factors of location and timing. Construction costs include costs for excavation, foundations, access driveways and surface paving, and superstructure. In some cases, some of the associated costs of making the site developable are included as construction costs rather than as land costs. Parking facility construction costs also normally include costs of fixtures and access/revenue control equipment. They may or may not include improvement costs associated with finishing, furnishing or equipping common use or commercial areas provided in conjunction with parking space construction.

Construction costs are most often expressed in terms of cost per square foot of constructed area. While many construction items are initially estimated as lump sum expenses, such as purchase and placement of fixtures and equipment, their costs are normally included as part of the estimated cost per square foot in financial analyses. The cost per parking space depends on the design space efficiency of the parking facility. Space efficiency is measured in terms of the amount of total constructed area (including driving aisles, ramps and pedestrian circulation facilities, as well as the actual parking space area) prorated to each parking space.

Representative ranges in construction costs (1989) are shown in Table 5-7. Costs are given on a square foot basis. The cost per space can be computed for specific parking arrangements, once the area is determined. For comparative purposes, costs also are given on a per space basis that assumes 320 square feet per parking space.

Surface parking lot construction costs typically range from $3 to $7 per square foot, including paving and drainage, lighting, landscaping and basic assess/revenue control equipment. A construction cost of $5 per square foot represents about $1,600 per space.

Table 5-7. Ranges in Construction Costs (1989 Conditions)

Type of Facility	*Range in Costs (per sq ft)*	*Representative Costs (per sq ft)*	*(per 320 sq ft space)*[a]
Parking lot	$ 3-$ 7	$ 5	$ 1,600
Garage-one or two supported levels	$20-$25	$ 22	$ 7,040
Garage-three or more levels	$22-$34	$ 28	$ 8,960
Garage in multiple-use building	$24-$40	$ 30	$ 9,600
Underground	$30-$60	$506	$16,000

Note: Costs exclude contingencies/engineering (±15%), and finance.

a. Cost per space will vary depending on the space efficiency of the specific design.

Parking structures of one to two supported levels exhibit typical construction costs ranging between $20 and $25 per square foot. This cost range generally does not include passenger elevators for interfloor travel. At a representative cost of $22 per square foot, the cost per parking space approximates $7,000.

Parking structures of three or more supported levels typically cost between $22 and $34 per square foot to construct. This range reflects regional differences in cost, variations in architectural and aesthetic treatments, and characteristics of specific sites. A representative cost of $28 per square foot results in approximately $9,000 per parking space.

Parking within the same structure that houses another use typically costs between $24 and $40 per square foot to construct. Per space construction costs typically exceed $10,000.

Underground or below-grade parking construction can range from $30 to $60 per square foot. Construction costs of over $15,000 per space are common. Cost considerations include site excavation, ventilation, special waterproofing and drainage provisions, and (usually) fire sprinkling systems in addition to most other costs of above-grade construction.

Operating Costs and Revenues. Operating expenses and revenues in a financial analysis

Key Steps of Financial Feasibility Analysis

A typical parking feasibility study includes a description of the proposed project along with its estimated costs and revenues. More specifically, it involves analysis of existing and projected parking supply and demand in its influence areas; proposed rate schedules and estimates of development and financing costs, gross revenues, operating expenses, and net income; and proforma statements of income and expenses based on the methods of financing.

1. The project description should include a location map, and illustrative financial plans. These plans should clearly show how the facility will work, its estimated capacity, and orientation to the traffic generator.

2. The influence area should be identified along with major parking generators and competing parking facilities.

3. Existing and future parking space supply, demands, and needs should be estimated. Future needs should reflect proposed developments in the influence area, and any changes in the available space supply.

4. Rate schedules should be set, and gross parking revenues should be estimated. Rates should be competitive with other facilities in the area, taking into account proximity to the development served. Revenues resulting from leasing ground floor commercial space should be identified. Parking revenues associated with a facility for a development (such as a hospital or office building) should be based on the *average* peak generation rates. This will produce a more conservative estimate of likely incomes than *design* rates.

5. Operating and maintenance expenses generally include salaries, wages, and fringe benefits; for operating and administrative staffs, utilities, taxes, insurance, supplies, general housekeeping and minor repairs. Ideally, a sinking fund should be established for preventative structural maintenance and major repairs.

6. Land, construction, development and financing costs should be estimated. These costs should be annualized to show the average annual debt service costs.

7. Financial proforma statements should be prepared that compare net annual income with average annual debt service, and identify the debt service coverage ratio. It is usually desirable to develop such statements for each of the first 5 years, and then produce average values for succeeding years.

(a) *Bond issue* costs will depend on the prevailing interest rate, length of the borrowing period, amount of time required for construction and the terms of financing. The annual debt service cost should be obtained.

(b) *Net* income should be computed by deducting the annual operating expenses from the annual gross revenues. This often is done for the average of the first 5 years, and for the remaining life of the project to (1) allow for revenue growth and (2) indicate debt service requirements during the initial years of operation.

(c) The *debt service* coverage ratio is computed by comparing the average annual net income to the average annual debt service. It may be desirable to provide annual cash flow projections. Such projections are important where additional funds come on-stream during the life of the project. The overall financial program may consist of more than one form of funding. It may include revenue surpluses from existing facilities, subsidies, funds obtained from special assessments or other sources.

8. Finally, the feasibility study should contain a summary of conclusions and recommendations. This summary should acquaint prospective lenders with key aspects of the project.

must be projected on an annual basis for future years. If the parking facility contains non-parking commercial space, operating costs and revenues for the commercial area component are projected separately from the parking operation. Results depend on the assumptions made about supply and demand, type of operation and controls, operating hours, personnel requirements, chargeable parking fees and/or subsidy support, mix of parkers (short-term, long-term transient and contract parkers), inflation and economic trends — especially those likely to affect the traffic generator to be served by the parking. The key to performance projections is the reliability of the assumptions used to project costs and revenues.

The best information source is a similar operation in the same market area. The proposed facility, however, probably will have peculiarities affecting operating costs and revenues. In very general terms, annual non-personnel operating costs for a parking garage will typically range from \$1.32 to \$1.54 per space times weekly hours of operation (1989); for parking lots the annual non-personnel operating costs typically range from $0.44 to $0.88 per space times weekly hours of operation (1989). These costs exclude payroll, personnel benefits, administrative costs and real estate, income and payroll taxes. They include utilities, routine maintenance and housekeeping, insurance and miscellaneous expenses.

It may be desirable to include some amount for major maintenance and rehabilitation of the parking facility. For a parking structure the major maintenance/rehabilitation reserve expense amount may range from $0.12 to $0.35 per square foot annually (1989) or more depending on quality of design and construction, environmental and operating factors. No substitute exists for local market data and site-specific cost estimates, and the values presented here should be used only for relative comparison rather than average or typical costs.

Estimated revenues should reflect prevailing competitive parking rate schedules and likely usage patterns for expected periods of parking facility operation. The estimate basis and revenue projections should reflect allowance for any unique, speculative or emanating circumstances that could affect revenue/subsidy sources and/or the project's ability to sustain projected levels of revenue generation.

Preliminary Pro Forma Analyses. A detailed pro forma analysis must be done when a preferred design and development program has been selected. Cost estimates projected in the preliminary pro forma analysis should be within 10 percent of the final cost figures. This pro forma analysis is refined during the design stage, after more detailed cost estimates are prepared and basic assignments of responsibilities for construction and operation have been agreed upon.

The pro forma analysis listing of costs and revenues provides a checklist of financing factors for participants. It explicitly states all preliminary assumptions (interest rates, financing terms, profit percentages, rental income, parking revenues and operating costs). It also states how, if any, income items will be shared between participants and those benefited by the parking. The analysis may indicate the need for program changes and/or greater subsidy contributions. The pro forma analysis illustrates the projected financial feasibility of the project and its components to potential investors, tenants, and parking operators or owners.

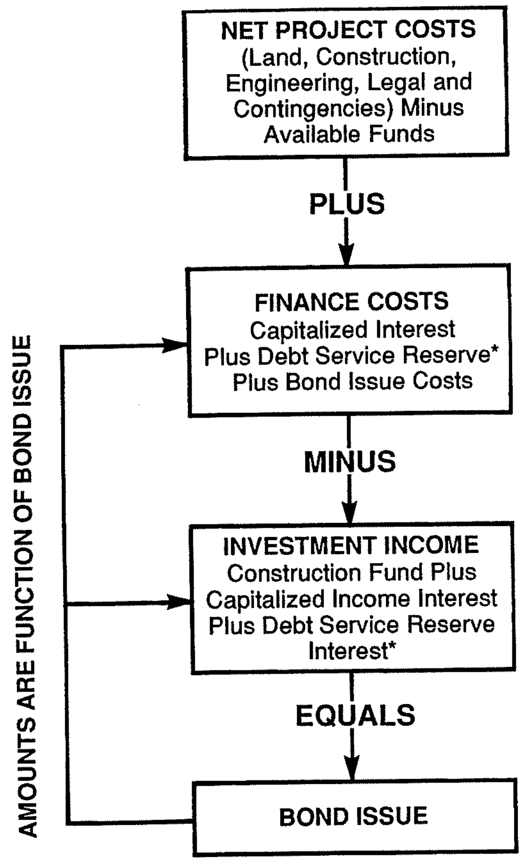
Financing Assumptions. Using the preliminary pro forma analysis and estimated costs as an indication of financial feasibility, potential financing sources can be identified. Assumptions made about the conditions in the financial marketplace and structuring of the financing are critical.

The developer's preferences (regardless of whether the developer is public and/or private) affect project financing. Private developers may want to proceed with the project only if they have a commitment for the permanent loan in place (this also helps to attract construction lenders and more favorable loan terms). Public-side financing must consider existing bond indebtedness and limitations, as well as the suitability (politically and financially) of other financing options. Specific requirements and financial realities of the proposed parking project shape the financing package.

Financial structuring is the process of matching funding needs of the project and the developer with the financial alternatives in marketplace. Key questions involve the mix between debt and equity financing, use of construction and permanent financing, and number of financing sources that must be involved. These questions are considered at every stage of the financing process, including funding of front-end costs to carry the project from conception through detailed planning and public review, construction and the initial period of achieving normal operations.

Financing abilities and requirements can change significantly as economic conditions, the money market, government policy, and the investment objectives of individuals and institutions change. The ability to fund a new parking project successfully varies, depending on capabilities and financial qualifications of the private developer or the public entity, and other circumstances. Thus, timing and continuing financial assessment are paramount concerns.

Calculations for estimating the costs and necessary cash flows for various private financing arrangements are very project-specific and beyond the scope of this text. Figure 5.4 shows key steps in computing typical bond issues.



*Normally applies only to revenue bonds

Figure 5.4. Determining the bond issue

Bond Issue Calculations

Computing the size of the bond issue is straightforward. The goal is to obtain an order of magnitude estimate of the total project cost, including financing, from which the annual average debt service can be obtained and compared with the net annual income to determine financial feasibility.

The size of the bond issue depends on (1) the net project costs or capital required, (2) the additional financing costs and (3) the income obtained from funds reinvested during the construction period. The added financing costs include (1) cost of bond issuance (including bond counsel, printing, and closing costs), (2) interest paid during the construction period, and (3) one year's debt service reserve for revenue bonds.

Factors influencing the bond issue will include the project construction and total costs, available up-front money to receive size of the loan required, length of the construction and bond retirement periods, type of financing, prevailing interest rates, and how the capitalized interest income, debt service reserve, and construction funds are reinvested during the construction period.

Usually, the amount of a revenue bond issue is about 25 percent more than the hard costs; however, more refined estimates are more desirable, whenever possible. The amount of the bond issue should be rounded upward to the nearest $5,000.

Analysis Steps. Steps in computing a typical bond issue are:

1. Project costs are estimated first, from which any available funds can be deducted to determine the amount to be financed.
2. Financing costs are then estimated. These include capitalized interest, costs of bond issuance, and, for revenue bond financing, one year's debt service reserve.
3. Investment income during the construction period is estimated and subtracted from the project and finance costs to estimate the bond issue amount. Interest is usually attained on the construction fund and capitalized income fund, while income obtained from investing the debt service reserve applies only to revenue bond issues. The interest rates for (1) bond financing and (2) investment incomes may or may not be the same. The methods of obtaining income will vary from project to project.

Assumptions and Formulas. Many of the finance costs and investment incomes are a function of the bond issue. This enables the amount of the bond issue to be estimated by formula, once the assumptions are specified. The following formula can be used to compute the estimated size of a bond issue. The *exact* amount of the bond issue usually will be done by financial consultants as part of a bond prospectus. The bond issue equals:

$$\frac{\text{Net Project Costs} \quad - \quad \text{Construction Income}}{\text{1 minus sum of finance cost factors related to bond issue} \quad + \quad \text{sum of investment income factors related to bond issue}}$$

This formula can be expressed as:

$$B = \frac{P - y_o C}{1-(x_1 + x_2 + x_3) + (y_1 + y_2)}$$

Table 5-8. Factors, Assumptions and Notations Associated with Bond Issue Calculations

Factor	*Notation in formula*	*Representative Assumptions*
A. Project costs		
1. Land cost	L	Actual
2. Construction cost	C	Actual
3. Subtotal	L + C	
4. Engineering, architecture, contingencies	p (L + C)	p = 15% of land & construction costs
5. Project costs (total, lines 3 + 4)	P	
B. Finance costs (function of bond issue, B, method of finance, interest rate, i, construction period, n)		
6. Capitalized interest	x_1 B	Compounded annually during construction period
7. Debt service reserve	x_2 B	1 year's reserve
8. Bond issue costs	x_3 b	usually 3% of bond issue
9. Finance costs total (lines 6, 7, 8)	F	
C. Investment income (funtion of bond issue, B, method of finance, interest rate, construction period, n)		
10. Construction fund income	y_0 C	Construction funds invested assuming a monthly draw down during construction period. Interest at given annual rate for 30-day periods
11. Capitalized interest income	y_1 C	Quarterly payment of capitalized interest quarterly investment. Periods based on annual interest rate
12. Debt service investment income	y_2 C	Debt service interest income compounded annually (revenue bonds only)
13. Total investment income (lines 10-12)	I	
14. Total bond issue (lines 5 + 9 - 13)	B	Sum of project costs, finance costs reduced by investment income—rounded up to nearest $5,000

Source: Derived from information furnished by Donald P. Ingold, Wilbur Smith Associates.

Table 5-8 defines the relevant terms associated with bond issue computations, gives their notation for use in the formula, and sets forth representative assumptions. These assumptions provide a general guide for estimating bond issue amounts; however, it must be recognized that the actual methods of obtaining investment income will vary in individual cases, thereby requiring different investment computations. The analysis should reflect the anticipated cash flows during

Table 5-9. Factors for Bond Issue Formula (Keyed to Assumptions in Table 5-8.)

Factor & Symbol		*Description*	
		1 year	*2 years*
Capitalized interest	x_1	interest rate i, (may or may not be same as interest for bond issue)	$(1 + i)^2 - 1 \cong 2i$
Debt service reserve	x_2	capital recovery factor, K	K
Bond issuance	x_3	0.03 (assumed)	0.03
Construction fund income	y_0	(applies to C)	
% Interest			
	7	0.03957	0.07976
	8	0.04550	0.09234
	9	0.05150	0.10516
	10	0.05759	0.11845
Capitalized interest income	y_1	(applies to C) investment income factor x interest rate (f. i)[a]	investment income factor x interest rate $\{f[(1 + i)^2 - 1]\} \cong 2fi$
% Interest	7	0.00317	0.01238
	8	0.00416	0.01644
	9	0.00529	0.02114
	10	0.00657	0.02654
Debt service income	y_2	K i	$(1 + Ki)^2 - 1 \cong 2Ki$

a. The investment income factor (f) represents the earnings per unit of investment resulting from quarterly payment of construction funds, and reinvestment of balance for quarterly periods based on annual interest rate. Thus, for a 1-year period, and 7% interest, it equals 0.0453. The product (fi) becomes 0.0453 x 0.07 = 0.00317.

both the construction and debt service retirement periods.

Table 5-9 gives specific values for factors in the bond issue formula.

• The construction fund investment incomes are shown for 7 to 10 percent interest rates assuming 1- and 2-year construction periods; they assume that the constructions funds are invested assuming a monthly drawdown during the construction period with interest paid at the specified annual rate for 30-day periods.

• The capitalized incomes further assume quarterly payment of capitalized interest with quarterly investment periods based on the annual interest rate.

(The accompanying box shows how the bond issue formula can be applied, using the factors given in Table 5-9.)

Illustrative Calculations. Table 5-10 contains bond issue formula calculations for a 600-car garage, assuming revenue bond financing. Because bonds are sold in $5,000 denominations, the computed bond issues have been increased upward to the nearest $5,000 amount.

Table 5-10. Estimated Bond Issues for Various Interest Rates and Debt Service Periods

Item	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*
Assumptions				
Number of Spaces	600	600	600	600
Interest rate & bond term	7%-25 years	7%-25 years	9%-25 years	9%-25 years
Constrution period	1 year	2 years	1 year	2 years
Revenue producing years	24 years	23 years	24 years	23 years
Capital recovery factor	0.08719	0.08871	0.10302	0.10438
Land cost/space	$1,500	$1,500	$1,500	$1,500
Construction cost/space	$7,500	$7,500	$7,500	$7,500
Project Development costs (capital required)				
1. Land	$ 900,000	$ 900,000	$ 900,000	$ 900,000
2. Construction "C"	$4,500,000	$4,500,000	$4,500,000	$4,500,000
3. Design & contingency (18% constuction)	$ 800,000	$ 800,000	$ 800,000	$ 800,000
4. Total project costs - P (capital required)	$6,200,000	$6,200,000	$6,200,000	$6,200,000
Finance Costs				
5a. Capitalized interest factor	.07	.014	.09	.018
5. Capitalized interest	$ 512,767	$1,667,435	$ 678,605	$1,420,743
6a. Debt service reserve factor	.08719	.08871	0.10302	0.10438
6. Debt service reserve	$ 638,688	$ 676,372	$ 776,776	$ 823,873
7a. Bond issue cost factor	.03	.03	.03	.03
7b. Bond issue costs	$ 219,757	$ 228,736	$ 226,201	$ 236,791
8. Subtotal: finance costs	$1,371,212	$1,972,543	$1,681,582	$2,481,407
Investment income				
9. Construction fund	$ 178,065	$ 358,920	$ 231,750	$ 473,220
10. Capitalized interest	$ 23,221	$ 94,392	$ 39,887	$ 166,858
11. Debt service reserve	$ 44,684	$ 94,696	$ 69,896	$ 148,310
12. Subtotal: investment income	$ 245,970	$ 548,004	$ 341,533	$ 788,388
13. Total bond issue	$7,325,242	$7,624,535	$7,540,049	$7,893,019
14. Bond issue rounded	$7,330,000	$7,625,000	$7,545,000	$7,895,000
15. Bond issue / project costs	1.18	1.23	1.22	1.27

Source: Adapted from materials furnished by Donald P. Ingold, Wilbur Smith Associates.

Illustrative Bond Issue Calculations

GIVEN: 600-Space Garage

Land Cost	$ 900,000	= L
Construction Cost	4,500,000	= C
Design/Contingency	800,000	
Project Cost	$6,200,000	= P

7% Interest (i)
25-Year Bonds
1-Year Construction Period, 24 Years Income

Based on Capital Recovery Factor of 24 Years at 7% = 0.087189 (K)

FACTORS: (see Table 5-9)

$x_1 = i = 0.07$
$x_2 = K = 0.087189$
$x_3 = .03$
$y_0 = 0.03957$
$y_1 = 0.00317$
$y_2 = Ki = (.087189)(.07) = 0.00610$

FORMULA:

$$B = \frac{P - y_0 C}{1 - (x_1+x_2+x_3) + (y_1+y_2)}$$

$$B = \frac{6{,}200{,}000 - .03957\,(4{,}500{,}000)}{1-(.07 + .087189 + .03) + (0.00317 + 0.00610)}$$

$$B = \frac{6{,}200{,}000 - 178{,}065}{1 - .18719 + .00927} = \frac{6{,}021{,}935}{0.82208} = \$7{,}325{,}242$$

Computations are given for both 7 and 9 percent interest rates for both the bond issue and the investment income; they assume 1- and 2-year construction periods. Thus, the computations illustrate how interest rates and construction periods affect the size of the bond issue. Lower interest rates and shorter construction periods substantially reduce the size of the bond issue.

Financial Feasibility Examples. The financial feasibility of a proposed parking facility is obtained by comparing its annual average net income with the annual average debt service. Table 5-11 gives a cost-income summary and feasibility calculations for a proposed publicly financed 600-space garage. Computations assume a 7 percent interest rate, 1-year construction period, and 24 years of debt service payment. In this example, the average annual net income of $720,000 compares with $639,000 in annual debt service. This results in a debt service coverage ratio of 1.13.

Table 5-11. Illustrative Financial Feasibility Analysis 600-Space Garage

Item	*Total*	*Per Space*
1. Capital funds required (project costs)	$6,200,000	$10,333
2. Bond issue amount 7% interest 1-year construction 24-year bond retirement	$7,330,000	$12,217
3. Average annual debt service	$ 639,000	$ 1,065
4. Average annual gross income	$1,080,000	$ 1,800
5. Average annual operating cost	$ 360,000	$ 600
6. Annual average net operating income	$ 720,000	$ 1,200
7. Annual average reserve (deficit)	$ 81,000	$ 135
8. Debt service coverage	1.13	1.13

Source: Computed

One means of improving financial feasibility is to include rental space in the garage to produce additional income that can be applied to the debt service. (Assuming the rental space is justifiable, given local market conditions.) The added cost of providing commercial rental space will increase the bond issue and annual debt service that must be offset with increased income.

Break-Even Revenues. Illustrative break-even revenues, assuming land costs of $10 per square foot, 25-year revenue bonds, and 24 years of garage operation are shown in Table 5-12. These calculations suggest that daily incomes of about $3.00 per parking space would be needed to cover costs for a lot, about $8.00 for a free-standing above-grade garage structure, and over $11.00 per space for an underground parking structure.

Table 5-12. Illustrative Parking Incomes Per Space to Break Even (1989)

	Suface Lot ($5/sq ft Construction Cost)	*Above-Ground 3+ Levels ($28/sq ft Construction Cost)*	*Below-Ground ($50/sq ft Construction Cost)*
Land cost (assumed at $10/sq ft)	$3,200	$ 457	----
Construction cost	1,600	8,900	16,000
Subtotal	4,800	9,417	16,000
Design & Contigency 15% (construction)	240	1,335	2,400
Project cost	5,040	10,752	18,400
Average annual debt service (9% interest)[a]	$ 648	1,385	2,370
Estimated annual operating costs	$ 150	600	600
Total annual cost/space	$ 798	1,985	$ 2,970
Required daily income (260 days/year)	$ 3.07	$ 7.64	$ 11.42

a. Assumes bond issue at 25% greater than project cost. Debt service factor of 0.10302 for 25 years (1 year for construction). Thus, average annual debt service equals 1.25 x 0.10302 x project cost.

CONCLUSIONS

Financing parking facilities calls for creative approaches by both the public and private sectors. It requires ways to bring costs and revenues into better balance. These range from care in siting and designing parking (to minimize development and operating costs) to ways of augmenting user revenues to assure financial feasibility.

CHAPTER 6

Parking Demands and Characteristics

Knowledge of parking demands and characteristics is essential in setting public, developing zoning requirements, and in planning, designing and operating parking facilities and programs. Information on where, why and how people park, how long they stay and how far they walk is needed for sizing parking facilities, estimating access requirements and applying parking management practices. Parking demand — the number of parkers attracted to a particular area or activity during specific times of day — when compared to available parking space within acceptable walking distance, provides a factual basis for determining parking needs.

This chapter outlines approaches for analyzing parking demands and needs. It describes parking characteristics and demands of various urban area activity centers, including central business districts (CBD), and it suggests appropriate planning and design values for these activities. It presents parking requirements for public transit and airport parking. It provides planning and design parameters for special event and institutional traffic (parking demand) generators, and discusses parking characteristics and demands associated with various land uses such as offices, retail stores, theaters and residential developments. Thus, the chapter addresses the fundamental question: How much parking is needed for specific kinds of development?

PARKING DEMAND AND NEED ANALYSIS

Understanding parking needs and developing appropriate responses calls for assembling and assessing facts within the context of each community's circumstances and resources. This can be done best by systematically studying parking conditions — whether as part of a downtown revitalization plan, a hospital expansion, or a new suburban shopping center. Studies of parking characteristics and analysis of parking demands and needs provide the basis for quantifying costs and impacts, and establishing plans and programs.

Parking Studies

Parking studies normally include information on (1) parker characteristics (when, where, why and how many people park), (2) parking supply characteristics (number, location and cost of spaces, who provides and how spaces are controlled and used), and (3) parking needs for new or existing developments. Information derived from these studies enables parking providers and public decisionmakers to anticipate and plan for parking needs. Parking studies provide the necessary information for comparing parking demands (present and projected) with the amount of available space to determine parking needs and responses.

Parking studies can be used to address different types of parking concerns and problems. Purposes can be as varied as the concerns, ranging from providing information to help decide public policy positions and parking regulations to determining parking needs of a specific traffic generator, multiple generators or an entire area. Studies may be conducted to answer a particular parking question such as the feasibility of removing or installing parking meters, or how to improve revenue control and accounting. Depending on purpose, a parking study may include information to compare possible actions and alternatives. Most parking studies, however, are primarily involved with determining (estimating) parking needs by comparing parking demands to parking space supply.

Parking demand and need analyses can be conducted on the basis of a limited or comprehensive study. The limited study relies primarily on data that is already available and easily assembled, requiring smaller efforts to collect new data and measure field conditions. It can be considerably less time consuming and expensive than a more comprehensive approach, but may not provide as accurate assessments.

Data required for estimating parking demands often are available from earlier forecasts and surveys. New field surveys may be required to supplement existing information. The degree of new field work required is the principal difference between limited and comprehensive parking studies. A comprehensive parking study reflects substantially more field work to collect data and measure conditions, and provides more documentation.

Limited Approach Parking Studies. The limited study derives parking demand by examining accumulated knowledge gained from experience with parking for similar land uses, and adjusted for apparent site-specific differences. Where possible, data is derived or substantiated on the basis of current activity records and limited field observations. The appropriateness of the limited study approach depends on (1) study purpose and use of findings, (2) quality of available data, and (3) available time and resources.

Comprehensive Parking Studies. Comprehensive parking studies may include parker interviews and a field inventory of the parking supply and usage characteristics. This type of study is generally used when a large amount of money hinges on the study's findings and recommendations, and sufficient current data is not otherwise available. Those supplying the financing for a parking improvement will require complete and reliable documentation of circumstances affecting the proposed project's projected financial performance. Often, this necessitates the detail provided only by a comprehensive study.

The comprehensive parking study can be used to appraise trends in parking space use, identify parking problems, and provide information needed to conduct feasibility and financial analyses. It can provide information on capacity and usage characteristics of existing parking facilities, characteristics of parkers, location and extent of parking demand, the influence of major traffic and parking generators, estimate present and future parking needs, examine adequacy of existing laws and ordinances, identify limitations of administrative arrangements and financial resources.

Parking study interviews are designed to obtain information on where people park, trip purpose and frequency, trip origin, primary destination, length of time parked, parking fee paid, and distance walked from parking space to primary destination. Determining where parkers desire to park normally is performed by interviewing people at parking spaces or at the pedestrian entrance of their destination. The location and extent of the sample interview is a prime factor in how comprehensive and expensive the study will be, as well as an indicator of the findings' usefulness. Questionnaires, trip origin-destination studies and license-plate surveys sometimes are used to collect information, although direct parker interviewing is the most reliable method.

Interviews of employees and visitors at major trip generators can provide ancillary information relative to household characteristics, trip origins, travel modes and attitudes, and pedestrian flows. Interviews also enable trip generation to be correlated with particular types of land uses.

The field inventory records facility type, capacity, restrictions and fee structures of existing public and private parking serving the designated study area. The comprehensive study also examines parking space occupancy and turnover characteristics. Occupancy can be recorded on an hourly or peak-period basis, depending on study purpose and resources. Aerial photography can be used to determine occupancy of surface lots and street spaces, but cannot detect utilization of covered parking. Parking turnover studies are used to determine length of stay and violation of posted time limits or other parking restrictions. They are normally associated with visitor, retail and other types of higher turnover parking, rather than employee or long-duration parking.

Demand Studies for Specific Activities

The general approach to estimating parking space demand for an activity is shown in Figure 6.1. The process begins by determining the population or person-accumulation for the given activity. This finding is converted into the accumulation of parked vehicles by considering mode split and vehicle occupancy for user groups having significantly different parking characteristics (employee, visitor, student, etc.). Specific steps are as follows.

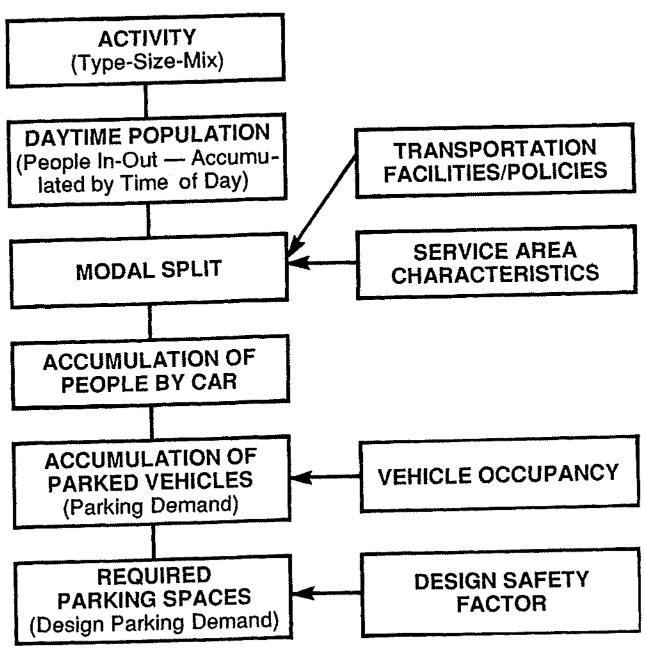


Figure 6.1. Estimating CBD parking demands.

1. Estimate person-destinations for the generator for critical time periods — usually when peak-parking accumulation normally occurs. This estimate should be related to the most appropriate unit (floor area, seating, beds, employee, etc.) for the particular activity, and should differentiate between population groups having dissimilar parking characteristics (based on trip purpose, length of stay or other parking characteristic).

2. Convert person-destinations into estimates of peak-person accumulation.

3. Estimate number of drivers for each population group that will require parking at the study activity. This calls for estimating the proportion of person-trips by car and the car occupancy. It represents the peak-parking demand for the given period.

4. Where different activities occur in the same study area or multiple-use development, estimate the peak-parking demands for each activity by adding the parking generated by different activities that occur during the same time.

In CBDs and in other multiple-use activity centers, parking provided for the primary trip destinations also serves smaller secondary attractions. Secondary attractions (newsstands, restaurants, business services, etc.) typically derive most of their business from people who have come to the activity center because it is their place of employment. Trips to secondary attractions in mixed-use centers involve far lower demand for parking space because of the high percentage of walk-in trade.

Parking Demand Overview. The parking generation or parking demand for any activity depends on the nature and size of the activity. It also depends on where the activity is located and what proportion of the daily population will drive and park or arrive by other means.

Parking demands are usually related to a unit of measure, representative of the parking generator. For example: per bed, employee, physician or floor area for medical treatment facilities; per faculty, staff member or student at a university; per square foot of floor area for retail, office and other kinds of land uses. Peak-demand indices for various activities show considerable variation from site to site and from study to study. Studies of 15 general hospitals, for example, found parking demand to range from 1.6 to 2.4 spaces per bed.[11]

Many factors influence variations in parking demand. They include when and how studies were made, the specific mix of activities within a study area, propensity for ride-sharing and public transit use, and parking availability and cost to use. Differences in parking demand also are influenced by location, market area characteristics, employee density and demographic factors.

Because of the many variables influencing parking demand, use of average parking rates from comparative studies of similar land uses may provide adequate parking only about half of the time. Accordingly, the concept of *design-level parking demand* is suggested for planning purposes when rates are based on experiences in other areas. This is the 85 percentile value, meaning that the suggested ratios would be exceeded by only about 15 percent of the observations.

It is not practical to provide parking on the assumption that every space will be fully utilized. Some reserve capacity is needed to allow for cruising vehicles in search of a space, vehicles unparking, and for peak surges. Thus, a design safety factor should be applied to account for these conditions. A design safety factor of 10 percent is suggested for most land uses. For example, if parking demand analysis shows a need for 500 spaces, the design should provide another 50 spaces.

In practice, the number of parking spaces that should be provided will depend on availability of parking space in the environs of a project. Sometimes, parking between various activities can be shared when their peak demands occur at different times.

CHARACTERISTICS OF CITY-CENTER PARKING

Downtown parking patterns, practices, and problems were the subject of many studies mainly conducted in the 1950s and 1960s. Data on parking characteristics and demands have been systematically summarized herein to provide a basis for estimating future space needs.

These surveys inventoried existing curb, lot, and garage spaces, and the hourly, daily, and monthly usage and parking fee rates associated with each. Parkers' interviews supplied information on length (duration) of stay, distances walked, trip purposes, average fee paid, trip origin, place of parking, and downtown destination. Existing parking space surpluses and deficiencies were estimated by comparing supply with estimated demand on a block-by-block basis. Future demands were based on anticipated activity changes in each block.

Parking patterns, practices, and problems in the city center reflect the types and intensity of downtown land use, amount of reliance on public transport, and each city's historic posture regarding downtown parking. Some of the salient parking characteristics based on parking studies conducted over the past two decades are shown in Table 6-1. Generally, walking distances become longer, parking durations increase, and work trips account for a greater proportion of all city-center trips as urban population rises. This is because downtown areas are predominantly places of work in larger cities.

The following sections discuss the results of recent parking surveys, and show how they compare with those from earlier studies.

Parking Supply

The downtown parking space supply increases as urbanized area population increases, but at a decreasing rate. The broad range in the number of CBD spaces provided at any population level reflects the differences in CBD structure, intensity, and reliance on public transport. Boston and Houston, for example, encompass approximately the same urbanized area population, but Houston has 50 percent more downtown parking space than Boston.

Over the past several decades, the number of CBD spaces in all population ranges has in-

[11] E.M. Whitlock, *Parking for Institutions and Special Events* (Westport, CT: Eno Foundation for Transportation, 1982).

Table 6-1. CBD Parking Characteristics for Selected Urban Areas

City	1980 Urbanized Area Population (000)	Study Year	Study Blocks	Total Space	Peak Accummulation		Average Walking Distance (ft)	Average Duration (hours, minutes)	Trip Purpose (Percent)		
					Parkers	% of Total Spaces			Work	Shop	Other
Atlanta, GA	1,613	1966	174	36,290	30,228	83.3	658	3h 9m	34	24	42
Baltimore, MD	1,755	1989	490	38,636	32,129	83.2	670	3h 37m	39	11	50
Boston, MA	2,679	1972	340	39,230	36,120	90.9	895	4h 40m	36	15	49
Buffalo, NY	1,002	1962	48	6,609	4,913	74.3	490	2h 6m	22	21	57
Charlotte, NC	351	1987	111	29,900	20,701	69.2	770	6h 41m	72	3	25
Cleveland, OH	1,752	1978	2 sq mi	53,912	39,700	73.6	671	4h 17m	40	10	40
Dallas, TX	2,451	1981	1.56 sq mi	59,610	49,600	83.1					
Honolulu, HI	582	1981	100	20,070			1.76 bks.				
Jacksonville, FL	598	1981	200	31,517	21,953	69.7	285	3h 37m	41	7	52[a]
Los Angeles, CA	9,479	1967	237	81,452	60,500	74.3	399	3h 10m	47	11	42
Memphis, TN	775	1981		16,986	12,253	72.1					
Milwaukee, WI	1,207	1972		30,707	28,142	91.6			59	5	36
Nashville, TN	518	1970		19,724	14,020	71.1					
New Orleans, LA	1,078	1960	113	13,624	12,167	89.2	478	2h 26m	32	11	57
Philadelphia, PA	4,113	1957 1977	352	39,024 41,682	22,640	58.0		3h 40m	30	12	48
Rochester, NY	606	1977	61	22,231	16,935	76.0					
San Francisco, CA	3,191	1966	200	61,000	52,000	84.2	478	2h 39m	35	9	56
Tampa, FL	521	1983	173	20,841	17,740	85.0	560				

a. 37.6 business, 1.3 sales, 12.9 other.

Source: Parking studies in each urban area.

creased significantly in city centers. In center city Philadelphia, for example, the number of parking spaces increased from 39,000 in 1951 to over 42,000 in the 1980s. The increased supply reflects the continued provision of parking to meet expanding use of automobiles.

As urbanized population increases, the proportion of total parking on downtown streets decreases. In communities of 100,000 or less, about a quarter to a third of all downtown parking is located along street curbs. But as urban population exceeds about 250,000, only about 10 percent of downtown parking is located on-street (Figure 6.2).

Generally, as urban area population gets larger, the proportion of off-street spaces in garage structures rises. This usually is because land values are higher, employment is more dense, and less space is available for surface parking. This pattern, however, exhibits wide variations. Older transit-oriented cities like Boston and Philadelphia have a higher proportion of off-street space in garages. In contrast, Dallas, Houston, Los Angeles, and other more auto-oriented cities have extensive surface parking lots.

Parking Fee Rates

Parking fees are influenced by land values and downtown parking policy. Fee rates reflect both

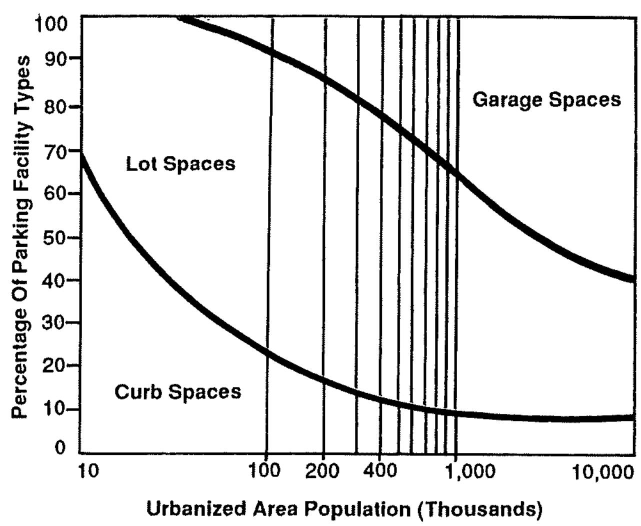


Figure 6.2. Type of CBD parking versus urban area population

parking demand and supply. They generally are greater in larger communities; however, wide variations in rates exist among communities in the same population group. These variations reflect differing economic and parking supply circumstances. Monthly parking fee rates in downtown New Haven and Bridgeport, Connecticut, for example, averaged less than $60 per month in 1988, while rates in downtown Hartford and Providence exceeded $100 per month.

The *patterns* of parking rates are consistent among city centers. Rates correlate with employment density, floor space and land values. They are highest in the downtown "core" (retail/financial center) and they decline as distance from the city center core increases and development intensity declines. (See Figure 6.3)

The pattern of existing parking fees can define acceptable rate schedules for a proposed parking

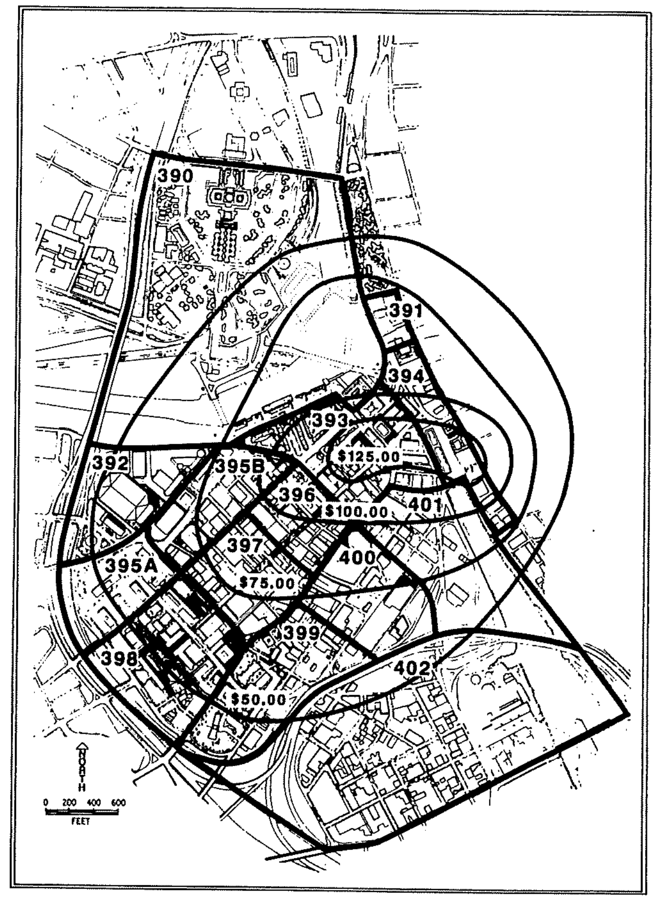


Figure 6.3. Monthly parking rate contours
Source: Wilbur Smith Associates, *Downtown Parking Garage Marketing Study* (Providence, RI: June 1987).

facility and also can serve as a simple gauge of parking demand. This is because the highest fees are usually obtainable where demands are greatest and land values are highest. Thus, a direct relationship exists between decreasing demands and lower parking fees away from the activity centers generating parking demand.

Plotted on a map of the city center, points of equal parking fees may be connected, as shown in Figure 6.3. Such parking fee contour maps show close agreement with more conventional indices of parking demand. Areas where high parking fees indicate the demand to be greatest are the most desirable locations to build new parking facilities, assuming that land is available. A close spacing of contours indicates a sharp decrease in parking demand, and the desirability of access to off-street parking on certain block faces is indicated by the shape and location of contours.

Responsibility for paying the parking fee is sometimes assumed by employers or merchants. In the Charlotte, North Carolina, business district, for example, 30 percent of the total parkers had their fee paid by employers; 9 percent by merchants or others; and 61 percent paid the fee themselves.

Trip Purpose

The proportion of motorists who park for work purposes tends to increase as urban population rises. This proportion averages less than 25 percent in urban areas of under 100,000, but exceeds 35 percent when urban population is over 1,000,000. It reflects the increased role of larger CBDs as centers of finance and commerce.

Parking Durations

Length of time parked reflects both city size and trip purpose. Parking durations for each trip purpose tend to increase as urban population increases (Figure 6.4). Work trips have parking durations of 6 to 8 hours in very large cities. Table 6-2 shows how parking durations vary by trip purpose in Boston and Charlotte. Work trips averaged 5.5 to 8 hours, as compared with about 2 hours for most other types of trips.

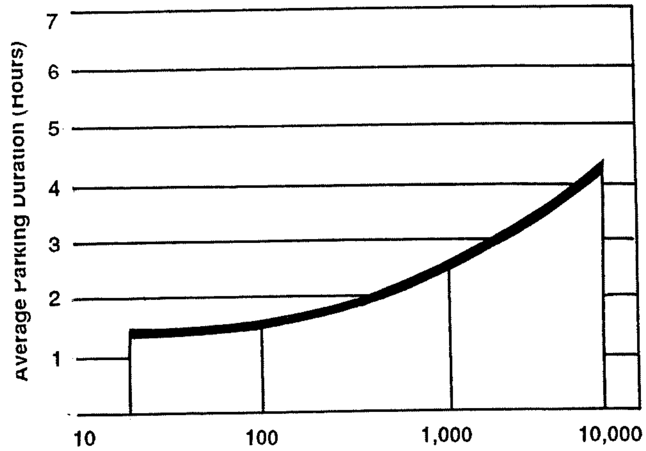


Figure 6.4. Parking duration by urbanized area population

Walking Distance

Walking distance (the distance measured along the shortest normal walking path between parking space and nearest pedestrian entrance at the parker's trip destination) varies by trip purpose and urban area population size. It reflects downtown street patterns and the proximity of parking space to parker's destinations.

Most parkers will walk further to a work destination than for any other CBD trip purpose except special events. They will walk further from

Table 6-2. CBD Parking Durations by Trip Purpose

Trip Purpose	*Average Duration (hours, minutes)*	
	Boston 1972	*Charlotte 1987*
Work		
Manager	5h 30m	
Employee	5h 59m	
All		8h 8m
Personal business	2h 6m	1h 5m
Sales/employment business	2h 14m	3h 32m
Service	2h 9m	
Recreational	2h 18m	
Shopping	1h 57m	1h 29m
Other	3h 12m	4h 17m
Average duration — all purposes	4h 40m	1h 41m

Source: *An Access Oriented Parking Strategy for the Boston Metropolitan Area*, Final Report (Wilbur Smith and Associates, 1972); and *Charlotte Options Parking Study* (Wilbur Smith Associates, 1987).

off-street space than they will from curb space. And, for all trip purposes, they tend to walk further as the size of the CBD increases (see Figure 6.5).

Even then, most drivers seek parking spaces that require the shortest perceived walking distance. For cities in the one to two million population range, more than 75 percent of all pedestrian trips are less than a quarter mile (see Table 6-3).

Parking Turnover

Parking turnover, is defined by the number of different vehicles that use a parking space during a given time period. Representative turnover rates in selected city centers are shown in Table 6-4. Turnovers of 1.25 to 1.50 vehicles per space per day are common; however, rates in a few cities approach or exceed 2.0 vehicles per space per day.

Turnover is greatest for on-street spaces where it is three to four times greater than for off-street parking. In downtown Boston, for example, each legal curb space turns over about 3.3 times a day as compared with 1.2 times for lot and garage spaces. Parking garages typically have lower turnover rates than parking lots because lots are perceived to be more convenient and less costly to use.

Turnover obviously is a function of trip purpose. Each space used by workers turns over once daily, while each space used by business or shopper parkers turns over several times each day.

Because larger city centers normally are more oriented to work-trip parkers, turnover is less. Parking space turnover is less than two times daily in urban areas of over 1,000,000 population, as compared with turnover of three to six times per space in areas of 100,000 people or less.

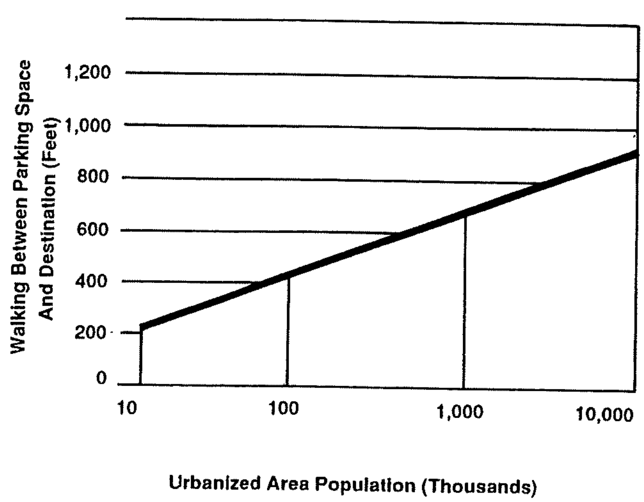


Figure 6.5. Average walking distance by urbanized area population

Table 6-3. CBD Walking Distances in City Center for Selected Group of Cities

Distance		Percent Walking This Distance or Further	
Feet	Miles	Mean	Range
0	0	100	
250	.05	70	60-80
500	.10	50	40-60
750	.14	35	25-45
1,000	.19	27	17-37
1,500	.28	16	8-24
2,000	.38	10	5-15
3,000	.57	4	0-8
4,000	.76	3	0-6
5,000+	.95+	1	0-2

Source: Available parking surveys in Atlanta, Pittsburgh. Special surveys in Dallas, Denver and Seattle as reported in *Urban Transportation Concepts* (Center City Transportation Project, Wilbur Smith and Associates, 1970).

Parking Accumulation

The accumulation of parked vehicles (the number of vehicles parked at any given time) reflects the daily ebb and flow of vehicles in the city center. Workers arrive first, and will use most of the nearest available space (unless these spaces are restricted to short-term parking). They are followed by shoppers and people on various business trips. The peak accumulation generally occurs between 11 AM and 2 PM with a small noon-time decline (see Figure 6.6). During the late afternoon, there is a gradual drop in the number of parkers followed by a sharp drop between 4 and 6 PM when workers go home.

All downtown spaces usually are never filled. This is because some spaces are too remote from where people want to go, or their availability is not apparent or obstructed by misparked vehicles. Peak variations in usage and delays inherent in entering or leaving facilities also reduce the efficiency of space usage. For these reasons, the maximum effective CBD parking supply is about 85 to 90 percent of the total. Similarly, the

Table 6-4. CBD Parking Space Turnover for Selected Urban Areas

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

a. Parkers per space per day.

Source: Institute of Transportation Engineers *Techincal Notes*, April, 1981.

peak CBD accumulation rarely exceeds this value.

The proportions of work-trip parkers in the peak accumulation varies among cities depending on the specific land-use mix. A range of 60 to 75 percent is typical. A 1965 study found that approximately 75 percent of all work-trip parkers, 25 percent of all shopping-trip parkers, and 20 percent of all business-trip parkers, are accumulated in the peak.[12] A study of downtown Boston found that workers accounted for about 62 percent of the peak-parking accumulation (Figure 6.7).

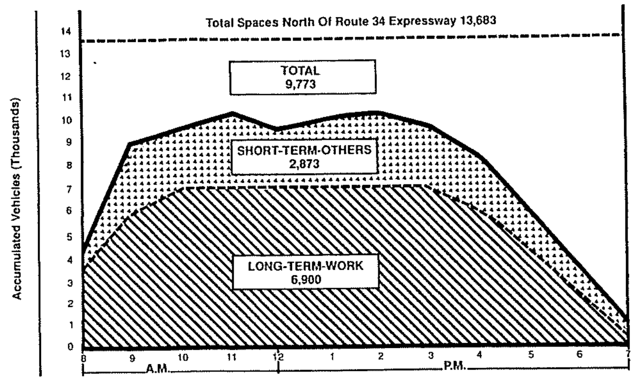


Figure 6.6 Parking accumulation north of Route 34 expressway by trip purpose typical weekday — 1982

Source: Wilbur Smith and Associates, *Downtown New Haven Traffic and Parking Study.*

Ratios of peak-parking accumulation to total daily parkers provide a basis for estimating peak-parking demands. These ratios are shown in Table 6-5. For each daily work destination, there are 0.75 parkers in the peak accumulation. For each daily non-work destination there are 0.22 parkers in the peak accumulation. Thus, if a particular study area had 1,000 daily parkers for work purposes, and 1,000 for non-work purposes, the respective demands would be 750 and 220 spaces respectively.

The peak-parking accumulation increases as urban population rises, but at a diminishing rate (Figure 6.8). Parking accumulation for any given size community, however, appears to increase over time, reflecting the progressive expansion of downtown activity and parking supply.

CITY-CENTER PARKING DEMAND

How much parking to provide depends on the demand for parking, availability of appropriate existing parking, transportation alternatives and costs, and community attitudes. It also depends on the ability of the public and private sectors to accommodate the demand. Parking demand largely means the same as parking generation. It represents the number of parkers who

[12] *Parking in the City Center*, prepared for Automobile Manufacturers Association by Wilbur Smith and Associates (New Haven, CT: 1965).

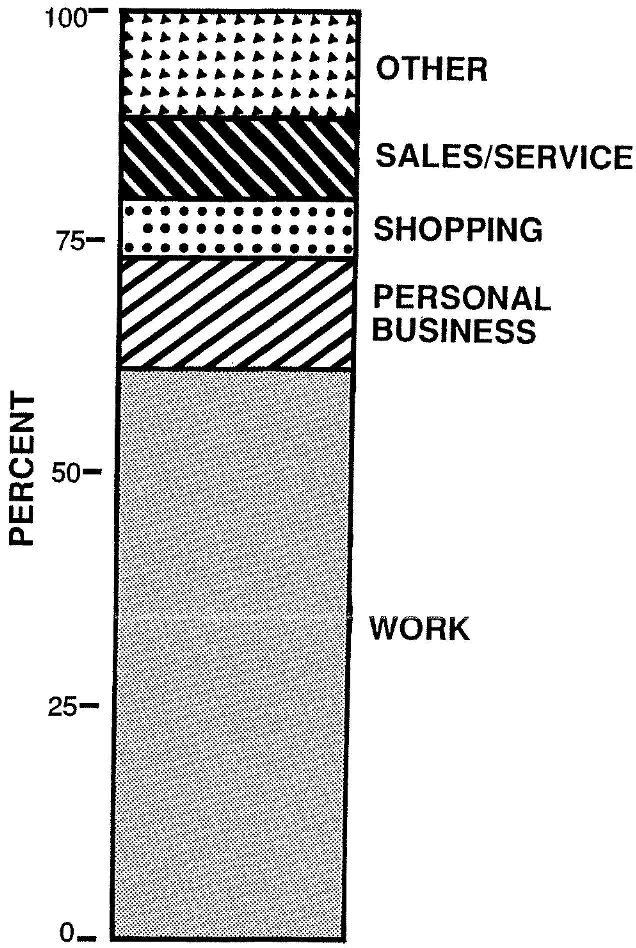


Figure 6.7. Peak parking accumulation by trip purpose (Boston Study Area, 1972).

Source: Wilbur Smith and Associates.

Table 6-5. Ratio of CBD Parkers in the Peak Accumulation to Total Daily Parkers

Trip Purpose	*Ratio*
Shopping	0.26
Business	0.18
Sales-service	0.16
Unload/unload	0.11
Other	0.22
All nonwork	0.22
All work	0.75

Source: Derived from Table 5, Parking in the City Center, prepared for Automobile Manufacturers Association by Wilbur Smith and Associates (New Haven, CT: 1965)

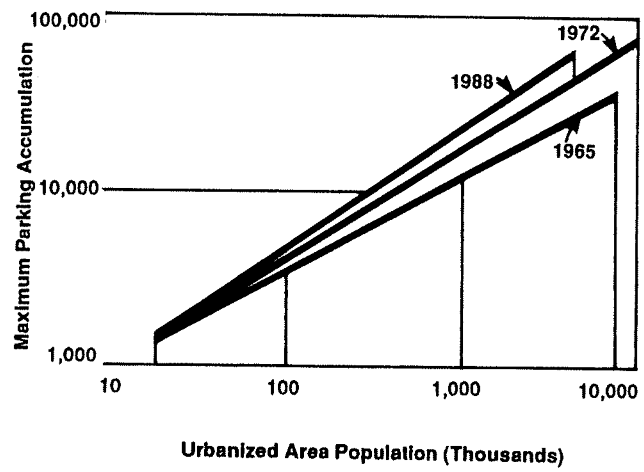


Figure 6.8. CBD parking accumulation by urbanized area population

would be attracted to a given facility or generator. Parking need, in contrast, represents the number of parkers who need to be accommodated, after considering availability and appropriateness of existing parking space.

Demand Factors

Existing parking demands correlate with the locations, types, and intensity of downtown activity, the user cost and availability of parking space, and the attractiveness and use of public transport and other ride-share options.

Future CBD parking demands depend on the economic growth of the community and its CBD. Factors influencing CBD parking demand growth include: (1) changes in population, motor vehicle registrations, and travel; (2) changes in CBD employment, floor space, economic activity new generators and loss of existing generators, competition from outlying areas; (3) economic factors relating to a specific parking project (competitive price changes and subsidies, and development of competitive parking facilities); (4) change in public transit availability, service and usage, or other changes in CBD accessibility; (5) public policies regarding parking and transit; and (6) general considerations, such as developments in technology or science affecting transportation, new laws and regulations affecting motor travel, energy or fuel shortages, and community and national economic health.

Existing parking demands in the city center can be estimated based on surveys of parkers' destinations, or on land-use type and intensity. Future parking demands generally are estimated based on anticipated changes in land use. Further descriptions of these methods follow.

Estimating Demands Based on Parking Surveys. The traditional approach to estimating existing CBD parking demands is based on surveys of parkers. Parkers along curb faces, in lots, and in garages are queried as to their times of entry and exit, trip purpose, and downtown destination. Demands then are aggregated for each block, zone, or district for each hour of the day. Peak demands then are compared with the effective supply area in each study area segment. Effective supply usually is considered to be 90 percent of the off-street spaces and 85 percent of the curb spaces.

Estimating Demands Using A Land-Use Approach. Several land-use based approaches have emerged in recent years that key demands to activity, and eliminate the need for detailed parker interviews. One such approach has been used in several communities, including Burlington, Vermont; Providence, Rhode Island; and New Haven, Connecticut. Peak accumulation of parkers, as obtained from parking studies, is assumed to approximate the aggregated hour-by-hour downtown parking demand. This demand is allocated to the various sub-areas based on each area's relative share of downtown activity.

Basic steps and data requirements include:

1. Inventory the location and number of existing parking spaces.

2. Observe the number of parked vehicles each hour from 6 AM through 5 PM on a typical weekday.

3. Obtain (or estimate) downtown employment and floor space for each analysis zone. Where there is a significant residential population in the downtown area, also estimate the number of dwelling units by analysis zone.

4. Estimate the approximate proportions of residential, long-term, and short-term parkers. The accumulated parked vehicles at 6 AM can be assumed to represent the residential parking demand. The accumulated vehicles at 10 AM, less one-half the amount present at 6 AM, can be assumed to represent the long-term parking demand. The accumulated vehicles during the hour of highest vehicle accumulation represents maximum parking demand in the study area. The accumulated vehicles at this time, less the accumulated vehicles present at 10 AM, represent the short-term parking demand.

5. Each component of the peak accumulation is allocated on a block or analysis zone basis in proportion to its relative share of parking demand generation as a function of the land-use intensity of each block.

6. The model may be defined as follows:

$$d_i = \frac{A_l e_i}{e} + \frac{A_s f_i}{f} + \frac{A_r r_i}{r}$$

where:

- d_i = design parking demand for zone i.
- A_l = long-term parking accumulation (10 AM accumulation minus one-half of 6 AM accumulation).
- e_i = employment in zone i.
- e = total employment in study area.
- A_s = short-term parking accumulation (maximum vehicle accumulation minus 10 AM accumulation).
- f_i = commercial, retail, service, institutional, restaurant square footage in zone i.
- f = commercial, retail, service, institutional, restaurant square footage in total study area.
- A_r = resident parking accumulation (6 AM observation).
- r_i = dwelling units in zone i.
- r = total dwelling units in study area.

The model allocates parking demand for three categories. The number of employees in a block (or zone) is used to define that block's portion of total long-term demand. Commercial, retail, service, institutional and restaurant square footage in each block (or zone) is used to define that zone's portion of total short-term demand. Likewise, the number of dwelling units in each block or zone is used to define that portion of total residential parking demand and represents the nighttime parking population.

Where detailed land-use information is not available, zonal parking demands can be based on allocations keyed to employment. While less accurate, this represents a reasonable approximation since workers typically constitute about two-thirds of the peak accumulation.

Table 6-6. Illustrative Example for Allocating Peak-Parking Accumulation by CBD Analysis Zone

	CBD Activity				*Parking Demand*				
	Employment		*Retail and Service Area*		*Long-term Parkers*		*Short-term Parkers*		
			Floor Space						
Zone	*No.*	*Percent*	*(sq ft)*	*Percent*	*Percent*	*No.*	*Percent*	*No.*	*Total*
1	3,000	60	200,000	33	60	1,800	33	330	2,130
2	1,000	20	300,000	50	20	600	50	500	1,100
3	1,000	20	100,000	17	20	600	17	170	770
Total	5,000		600,000			3,000		1,000	4,000

Note: Peak accumulation = 4,000; long-term accumulation = 75 percent (or 3,000); and short-term accumulation = 25 percent (or 1,000).

Source: H. S. Levinson and C.O. Pratt, "Estimating Downtown Parking Demands—A Land-Use Approach," *Transportation Research Record 957* (Washington D.C.: Transportation Research Board, 1987).

A simplified three-zone example (Table 6-6) illustrates the procedure. The peak accumulation of 4,000 parkers includes 3,000 long-term parkers and 1,000 short-term parkers. The 3,000 long-term parkers are allocated to each zone based on its share of the total employment — 60 percent in zone 1, 20 percent in zone 2, and 20 percent in zone 3. The 1,000 short-term parkers are allocated based on each zone's share of the retail and service floor space — 33 percent in zone 1, 50 percent in zone 2, and 17 percent in zone 3. Long- and short-term demands for each zone are then added to obtain each zone's total demand — 2,130 spaces in zone 1, 1,100 spaces in zone 2, and 770 spaces in zone 3.

An Iterative Land-Use Approach. This similar but somewhat more complex approach assumes parking generation rates for each land-use category, and applies these rates to the activities in each zone. Total demand is compared with the peak accumulation. The rates then are adjusted, and the process repeated iteratively until the total calculated demand equals the observed peak parking accumulation (see Table 6-7). Demands for special activities can be identified and excluded from the iteration process (in the example, this is done for the railroad station).

Parking Demands for New Activities. Parking demands for a new development (i.e., an office building or department store) depend on the activity type and size and the likely proportion of generated trips coming by car. Only those people coming to the generator as the *primary* destination of their trips should be considered; ancillary destinations should not be considered in estimating parking demand. The specific steps are:

1. Estimate primary person-destinations for the generator for critical time periods (i.e., weekday, evening, Saturday). This should be based on the nature of the activity (i.e., employees, floor space, etc.).

2. Based on the characteristics of the activity, translate person-destinations into estimates of the peak-person accumulation.

3. Estimate the *automobile drivers* in this accumulation considering transit use (mode split)

Table 6-7. Allocating Existing Parking Demands in Downtown Bridgeport, CT, 1987-88 (Based on Iterative Land-Use Parking Model)

Analysis Zone	*Based on Office, Retail, Residential, Other Uses*[a]	*Railroad*	*Total*
I	208	0	208
II	1,107	0	1,107
III	490	0	490
IV	863	0	863
V	1,396	350[b]	1,746
VI	1,411	0	1,411
VII	1,025	0	1,025
Total	6,500	350	6,850

a. Based on the following parking generation rates: office, 2.64 spaces per 1,000 sq ft; retail, 1.10 spaces per 1,000 sq ft; government, 1.44 spaces per 1,000 sq ft; residential, 0.48 spaces per 1,000 sq ft; other, 0.33 spaces per 1,000 sq ft.

b. Estimated railroad demand based on 1988 field observations.

Source: Wilbur Smith Associates, E. Carlton Heeseler, Shearson Lehman Hutton, Inc; and H. S. Levinson, *Downtown Parking Master Plan Study, Bridgeport, CT* (1988).

factors, and car occupancy. This represents the peak-parking demand for a given time period.

4. Where different activities in the same development peak during different times of the day, estimate the *peak-parking* demands for each time period by adding the parking generated by specific activities that occur at the same time.

The following examples illustrate how demands can be estimated for new developments.

1. *Example A.* This example estimates the parking spaces needed for an office building containing 400,000 square feet of gross floor area (GFA) and located in a central business area well served by public transport.

The solution process begins with determining a suitable ratio of employees per 1,000 square feet of GFA. The employee ratio is based typically on national averages, local studies of similar activities or a combination of these data. For purposes of this example, 3.5 employees per 1,000 square feet of GFA is assumed, resulting in 1,400 employees.

At this point, an estimate must be made as to how many employees will drive, participate in carpools, or use public transportation to arrive at the proposed building. Since the building is served by public transportation, fewer employees will drive than if the building were located in an area of lower population density (urban fringe or suburban area) and/or had a lower degree of public transportation availability. This example assumes that 60 percent of the employees will come by automobile, and an average employee car occupancy of 1.2 persons. It is further assumed that all employees would remain throughout the day.

These factors result in the following formula for estimating parking demand for any given time period:

$$D = \frac{N\ K\ R\ P \times pr}{O}$$

where:

N = size of activity measured by floor space, employment, hospital beds, dwelling units, or other appropriate land-use parameters.
R = person-destinations per day (or other time period) per unit of activity.
K = proportion of destinations that occur at any one time.
P = percent of people coming by car.
O = people per car.
pr = proportion of workers with primary destinations (for workers pr=1).
D = parking demand

Space demanded by employees is:

$$D = \frac{N\ K\ R\ P \times pr}{O}$$

$$= \frac{(1{,}400)(1)(1)(0.60)(1)}{1.2} = 700 \text{ spaces}$$

(R = 1 destination/employee/day)
(K = 1)
(pr= 1)

Reducing the spaces by 10 percent for absenteeism results in 630 spaces, or 1.6 spaces per 1,000 square feet.

To this must be added an estimate for visitors. Assuming one visitor per 2,000 square feet of GFA, or 0.50 spaces per 1,000 square feet of GFA, about 200 visitor spaces would be needed. This produces a total demand of 830 spaces.

2. *Example B.* This example illustrates how to estimate the parking needed for a 500,000 square foot retail complex in the heart of the CBD. The procedure is similar to Example A. However, allowance is made for CBD daytime workers who compose part of the shopping population. It is reasonable to assume that up to half of the shoppers will be downtown for some other reason. Assuming an 80 percent mode split (i.e., 80 percent coming by car), and a peak weekday parking accumulation of 5 people per 1,000 square feet of gross leasable area (GLA) and a car occupancy of 1.2, computations are as follows:

$$D = \frac{N\ K\ R\ P \times pr}{O}$$

where:

KR = 5.0
pr = proportion of shoppers with a primary destination in the retail complex. (pr is assumed to equal 0.50).

$$D = \frac{(500)\ (5)\ (0.80)\ (0.50)}{1.2} = 833 \text{ spaces}$$

This is equal to 2 spaces per 1,000 square feet (GLA).

Table 6-8. Representative Ranges in CBD Peak-Parking Requirements

		Parking Spaces per Indicated Unit		
		Transit Use		
Activity	*Unit*	*Light 20%*	*Moderate 40%*	*Heavy 60%*
Office	1,000 sq ft GLA	2.2-2.6	1.6-2.0	1.0-1.4
Retail	1,000 sq ft GLA	2.0-2.4	1.3-1.7	0.8-1.2
Residential (multi-family)	per unit	0.8-1.2	0.6-0.8	0.2-0.6

Source: Estimated

Representative CBD Parking Indices

Representative parking ratios for downtown establishments are summarized in Table 6-8. These ranges draw upon current experience in U.S. cities and take into account reductions for transit use and secondary trip destinations. Thus, they generally are lower than values for suburban developments.

PARKING OUTSIDE CITY CENTERS

Today's parking problems permeate the entire urban region. Wherever people congregate, and wherever new developments are placed, parking demands are generated, and ways to accommodate them are sought. As suburban developments proliferate, hospitals and airports expand, and as park and ride becomes an integral part of transit systems, there is a corresponding need for places to park. Parking space at airports, along transit lines, and at medical centers and suburban megacenters often exceeds that in the city center.

This section analyzes parking characteristics and demands for activity centers throughout the urban area.

The various parking demand indices mainly apply to developments *outside* the city center and the densely developed parts of the city. They assume that 90 percent or more of all visitors will come by automobile. Where more the 10 percent transit usage is anticipated, demands should be adjusted downward accordingly.

Change-of-Mode Parking

Change-of-mode parking occurs where people transfer from one transportation mode to another. These transfers normally take place at rapid transit and suburban rail stations, at bus stops and stations, and at airports. Parking for carpools may also be a consideration. Several states, notably California and Connecticut, have established extensive park-and-ride facilities for carpools.

Transit Park and Ride. Parking along commuter rail lines and rapid transit lines dates back to pre-World War II. This type of park and ride is necessary to attract riders from areas where densities are too low for walk-in and bus-rail trips. Today, all major rail systems provide park-and-ride facilities. These vary from small lots adjacent to express-bus terminals to multi-storied 2,000- to 3,000-space garages with direct freeway access such as found in the Boston area. Many transit agencies have become major parking providers and operators!

Studies of outlying park-and-ride facilities show an average daily turnover of about 1.1 cars per space and about 1.2 transit boardings per parked car. Kiss-and-ride (passenger pick-up and drop-off) may represent 20 to 40 percent of total peak-hour station arrivals; median driving distances of 3 to 4 miles for park-and-ride patrons and 1 to 2 miles for kiss and ride are common.

Table 6-9 summarizes some salient travel characteristics of park-and-ride lots within the United States. It indicates that nearly half of all patrons previously drove alone. More than three-fourths came as drivers, and 11 percent as passengers. Almost all patrons were traveling to (or from) work. Nearly half lived within 3 miles of the lot, and more than 90 percent traveled more than 10 miles from the lot to their destination. The occupancy of park-and-ride facilities varies widely. Many facilities along rail and bus lines are used to over 90 percent of their capacity, and some are always full. The quality of road access and transit service influences their use.

Parking provisions at selected transit stations are given in Table 6-10. This table shows how the number of boarding passengers per parking space varies for six major cities. The data show wide variations in the number of boarding passengers per space. These variations result from differing

Table 6-9. Overview of Travel Characteristics of Park-and-Ride Users (1985)

Characteristics	*Range*	*Number of Lots*[a]	*Average*[a]
Previous mode of travel			
Drove alone	11% to 65%	305	49.2%
Carpool/vanpool	5 to 28	303	23.2
Transit (bus or other)	5 to 49	304	10.4
Did not make trip	0 to 29	303	14.9
Arrival mode to facility			
Drove alone	38 to 91	146	72.6
Shared ride	3 to 36	146	11.0
Dropped off	0 to 31	117	11.1
Walked	0 to 21	132	4.4
Bus	0 to 10	132	1.3
Trip purpose			
Work or business	83 to 100	107	97.2
School	0 to 11	80	2.3
Other	0 to 17	80	0.5
Travel frequency (rd.-trips/wk.)			
Three or less	2 to 15	101	6.6
Four	3 to 16	86	7.6
Five or more	71 to 93	86	86.8
Home-to-lot distances (miles)			
Three or less	6 to 74	163	46.4
Four to six	18 to 42	162	22.8
Six or more	8 to 69	162	29.2
Lot-to-destination distance (miles)			
Less than 10	0 to 100	190	6.9
10 to 30	0 to 100	190	63.2
30 or more	0 to 51	177	30.4

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

Source: Charles E. Bowler, Errol C. Noel, Richard Peterson, Dennis Christiansen, *Park-and-Ride Facilities—Guidelines for Planning, Design and Operation* (Washington, D.C.: Federal Highway Administration, U.S. Department of Transportation, 1986).

development characteristics and densities, and the amounts of walking, bus, and kiss-and-ride trips to specific stations. At stations that rely mainly on auto access, there are about 2 to 3 boarding passengers per parking space — about 0.33 to 0.50 spaces per boarding passenger.

Railroad Stations. Selected data for commuter and AMTRAK stations (Tables 6-11 and 6-12) show similar patterns. The proportion of auto drivers varies from station to station depending on availability of public transport or walk-in traffic. Stations that are well-served by buses, or located near the city center appear to generate a lower proportion of auto driver trips (e.g., New Haven). Commuters are more likely to drive to stations than other types of travelers.

Parking spaces per boarding passenger average about 0.33 for AMTRAK and 0.36 for commuter rail lines. The 85 percentile design value approximates 0.45 spaces per boarding passenger in both cases.

Airports. Airports — together with the ancillary office and industrial areas — form the largest activity center outside the city center. In some cities they actually attract the most person-trips. Airports are served by rail transit in several large U.S. cities — Atlanta, Boston, Chicago, Cleveland, Philadelphia, and Washington. In a few cities — Atlanta, Los Angeles and New York — they are served by remote parking (ranging up to

Table 6-10. Parking Provisions at Selected Rail Transit Stations

Region	*Location*	*Boarding Passengers per Weekday*	*Off-street Parking Spaces*	*Boarding Passengers/ Parking Space*
Atlanta	Avondale	9,700	1,180	8.2
	Eastlake	2,800	610	4.6
	Hightower	10,300	1,400	7.4
	Chamblee	8,000	1,520	5.3
	Brookhaven	4,200	1,700	2.5
	Lenox	10,900	800	13.6
	Lindbergh	11,100	1,470	7.6
	Lakewood	4,300	1,900	2.3
	College Park	7,700	2,120	3.6
Boston	Wollaston	2,700	500	5.4
	North Quincy	2,400	800	3.0
	Quincy Center	7,500	930	8.1
	Commuter Rail - North[a]	11,000	3,360	3.3
	Commuter Rail - South[a]	3,800	2,640	1.4
Chicago	Ashland	4,750	264	18.0
	Cicero-Berwyn	2,700	360	7.5
	Cumberland	5,500	828	6.6
	Dempster	3,200	594	5.4
	Desplaines	4,750	596	8.0
	Howard	9,600	300	32.0
	Kimball	4,100	180	22.8
	Linden	3,500	456	5.5
	River Road	3,900	747	5.3
Cleveland	West Side (5 stations)	20,000	6,400	3.1
	East Side (3 stations)	10,000	900	11.1
Philadelphia	Bucks County[a]	4,000	1,800	2.2
	Chester County[a]	3,900	1,100	3.5
	Delaware County[a]	15,500	2,200	7.0
	Montgomery County[a]	19,500	4,300	4.5
	Lindenwold (New Jersey)	20,000	9,000	2.2
San Francisco	Concord line (6 stations)	20,360	6,555	3.1
	Richmond line (5 stations)	9,130	3,381	2.7
	Alameda line (8 stations)	27,100	7,562	3.6
	Oakland line (3 stations)	7,300	1,087	6.7
	Daly City	8,860	1,877	4.7
Toronto	Islington	23,500	1,300	18.0
	Warden	24,600	1,500	16.4

a. Commuter railroad stations.
Source: Herbert S. Levinson, "Planning Transit Facility Parking for the Boston Metropolitan Area," *Transportation Research Record 601* (Freeways, Automatic Vehicle Identification, and Effects of Geometrics), San Francisco data from BART, 1980. Transportation Research Board, 1976., Chicago data from Chicago Transit Authority (1985), and Atlanta data from Metropolitan Atlanta Rapid Transit Authority, June 1990.

70 miles away) with limousine service. Most U.S. airport workers, visitors, and travelers, however, arrive by car.

As air travel continues to grow, prompted in part by higher-valued travel time, there has been a corresponding growth in parking demands and parking facility development. Some of the largest free-standing garages in North America are found at airports: O'Hare's 9,000-space garage (Chicago); Logan's 5,000-space garage (Boston).

1. *Travel Modes.* Ground access to airports is provided mainly by automobile and taxi. As shown in Table 6-13, 25 to 56 percent of the originating passengers, 31 to 70 percent of terminating passengers, and over 80 percent of people accompanying air passengers arrive by automobile. These ranges in car use reflect the location and characteristics of specific airports.

2. *Car Occupancy.* Typical vehicle occupancy rates for airport ground access are shown in Table 6-14. Private automobiles average 1.9 persons per car as compared with 5.6 for limousines.

Table 6-11. Auto Drivers at Railroad Stations (Percent of Total Boarding Passengers)

Station	*Amtrak*	*Commuter*	*Combined Amtrak and Commuter*
Wilmington, DE	20	29	23
New Haven, CT	15	22	19
Providence, RI	18	42	22
Stamford, CT	—	—	50
New Carrollton, MD	44	—	44

Source: L. K. Carpenter, *Planning Rail Station Parking: Approach and Application*, (New Haven, CT); Wilbur Smith & Associates, James M. Hunnicutt & Associates, *Parking Feasibility Study—New Carrollton Station* (Washington, D.C., October 1978); Hunnicutt-Davis Associates, *Stamford Railroad Station Parking Feasibility Study* (Washington, D.C.: November 1978).

3. *Parking Durations.* Parking durations range from a few minutes to one week. A study of parking durations at the Seattle-Tacoma International Airport, for example, found that 68 percent of the total parkers stayed less than 4 hours, 13 percent remained for 4 to 24 hours, and 19 percent stayed more than one day. Durations averaged about 1 hour for all those who parked for less than one day.[13]

4. *Parking Demand.* Airport parking demand varies widely among airports. Key factors include number of annual enplanements, the mix between tourist and business travel, passenger trip purpose, proportions of originating and transfer passengers, and percentage of charter passengers. Parking demand for employees, rental cars, annual visitors, and others generally is proportional to the amount of air passenger traffic.

There are three general categories of parking demand: short-term, long-term, and remote.

• *Short-term parking* is usually located close to terminal buildings and serves motorists dropping off or picking up travelers. These motorists usually remain at the airport for less than 3 hours. The most expensive parking is found in the short-term parking facilities.

• *Long-term parking* serves passengers who leave their vehicles at the airport while they travel. With a low turnover rate and long duration of stay, long-term parking accounts for 70 to 80 percent of the occupied parking spaces at an airport, even though long-term parkers account for only 15 to 30 percent of all vehicles parked over the course of a year.[14]

• *Remote parking* consists of long-term parking lots located *away* from airport terminal buildings. Often, buses or vans may be available to

Table 6-12. Parking Demand at Railroad Stations

	Daily Parking Space Demand[a]			
Station	*Amtrak*	*Commuter*	*Combined Amtrak and Commuter*	*Boarding Passengers Per Space*
Wilmington, DE	0.33	0.31	0.32	3.1
New Haven, CT	0.27	0.32	0.30	3.3
Providence, RI	0.20	0.42	0.24	4.2
Stamford, CT	0.34	0.42	0.41	2.4
New Carollton, MD	0.52	—[b]	0.52	1.9

a. Number of daily parking spaces demanded per daily boarding passenger by type.
b. Amtrak station only.

Source: L. K. Carpenter, *Planning Rail Station Parking: Approach and Application* (New Haven, CT); Wilbur Smith & Associates, James Madison Hunnicutt & Associates, *Parking Feasibility Study—New Carrollton Station*, (Washington, D.C.: October 1978); Hunnicutt-Davis Associates, *Stamford Railroad Station Parking Feasiblity Study* (Washington, D.C.: Novemeber 1978).

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[13] James Madison Hunnicutt & Associates, *Future Traffic and Parking Requirements and Parking Financial Analysis*, Seattle-Tacoma International Airport (Washington, D.C., 1968), p. 12.

[14] "Measuring Airport Landside Capacity," *Special Report 215, Transportation Research Board* (Washington, D.C.: National Research Council, 1987).

Table 6-13. Ground Access Modes at Selected Airports

A. Passengers

	Percent Choosing Mode by Type of Passenger					
	Originating			*Terminating*		
Access Mode	*Miami*	*Denver*	*La Guardia*	*Miami*	*Denver*	*La Guardia*
Private automobile	42	56	25	47	70	31
Rental car (van)	11	14	9	20	8	4
Taxi	22	14	46	18	10	35
Limousine	10	5	13	10	5	20
Bus	15	3	5	5	5	5
Other	0	9	2	0	3	5

Note: Percentages may not add to 100 because of rounding.

B. Persons Accompanying Passengers

	Percent Choosing Mode by Type of Passenger					
	Originating			*Terminating*		
Access Mode	*Miami*	*Denver*	*La Guardia*	*Miami*	*Denver*	*La Guardia*
Private automobile	99	80	82	84	97	90
Rental car (van)	1	—	—	6	2	1
Taxi	—	7	9	5	1	5
Limousine	—	—	9	3	—	1
Bus	—	7	—	2	1	1
Other	—	7	—	—	—	3

Note: Percentages may not add to 100 because of rounding.

Source: P. Mandle, F. LaManga, and E. Whitlock, *Collection of Calibration and Validation Data for an Airport Landside Dynamic Simulation Model.* Report TSC-FAA-80-3. Federal Aviation Administration, U.S. Department of Transportation, April 1980.

transport passengers to the terminal. At some airports these parking facilities are called shuttle lots or, when used only during peak periods, holiday lots. Because parking rates at remote lots are less expensive than those for other airport parking facilities, these lots are often termed "reduced-rate" parking.

Table 6-14. Typical Average Vehicle Occupancy Rates for Airport Ground Access

Access Mode	*No. of Passengers per Vehicle*
Private automobile	1.9
Rental car	1.2
Taxi	2.5
Limousine	5.6
Other	4.2

Source: F. X. Kelvey, *Access to Commercial Service Airports: The Planning and Design of On-Airport Ground Access System Components.* Final Report. College of Engineering, Michigan State University, East Lansing, June 1984.

Since transfer passengers do not create parking demand, indices based on originating passengers only are likely to be most meaningful. Figure 6.9 gives public parking requirements for U.S. airports based on originating passengers. An airport with 3 million originating passengers would require about 3,500 to 4,000 parking spaces.

The actual number of spaces to be provided should be about 10 to 15 percent more, since it is more difficult to find the last empty space in a large facility.[15] (See Appendix I)

[15] *Guide for the Planning of Small Airports* (Ottawa, Ontario: Roads and Transport Association of Canada, 1980); *Planning and Design of Airport Terminal Facilities at Non-Hub Locations,* Advisory Circular 150/5390-9, U.S. Department of Transportation (Federal Aviation Administration, April 1980).

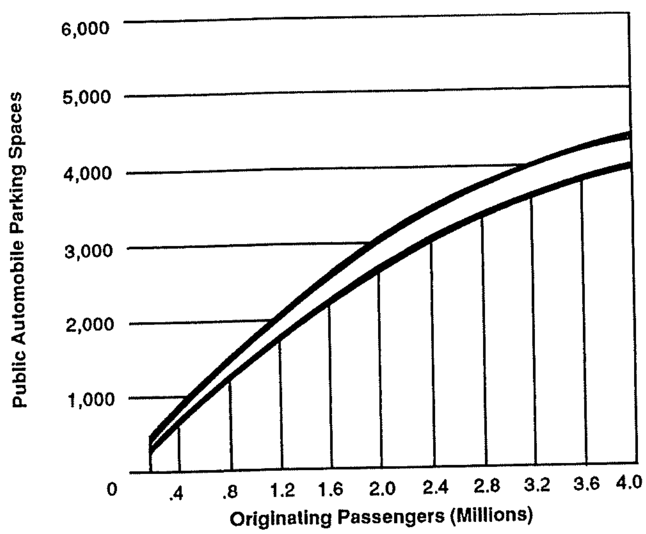


Figure 6.9. Estimated requirements for public parking at U.S. airports.

Source: Ralph M. Parsons Co., *The Apron and Terminal Building Planning Report*, Report FAA-RD-75-191, Federal Aviation Administration, U.S. Department of Transportation, July 1975.

Special Events

Parking for special events covers a wide range of circumstances that reflect the location and type of event. Parking needs at sport stadiums, convention centers, and exhibit halls are less in a CBD than for a suburban location because better public transport is available and a portion of the demand can be met by existing parking facilities.

Special events can occur anywhere. Large parking demands can be generated by football games, political conventions, PGA golf tournaments, air shows, or civic-sponsored festivals. Many events are held during evenings and on weekends to avoid conflicts with normal working hours. Even when convention/exhibition centers have daytime attractions, peak attendance frequently occurs during evenings and on weekends.

Travel Modes. Travel modes to special events are shown in Table 6-15. In most cases automobile travel dominates, accounting for most of the trips. Private vehicle usage is influenced by the event's location, parking cost and availability, and proximity to transit. Thus, private vehicle usage to professional baseball games at New York City's Yankee and Shea Stadiums represents 40 and 65 percent of the total trips respectively, as compared to an automobile usage approaching 100 percent for the same type of event held at Anaheim Stadium in California.

Transportation management programs can influence how people arrive at a stadium. Table 6-16 shows how the proportion of trips by car dropped from 76 to 66 percent at the University of Washington's stadium as a result of expanding park-and-ride bus service. The table also shows that about 45 percent of the vehicles were parked off campus.

Vehicle Occupancy. Vehicle occupancies vary by type of event. Occupancies of 3.5 persons per car are common for football games. Studies of special event parking found average occupancies of 3.0 persons per vehicle for professional football, college football, museums, concerts, and evening-weekend Jai Alai; 2.5 for horseracing and professional baseball; 2.3 for basketball, and 2.2 for daytime Jai Alai games.[16]

Parking Demands. The number of parking spaces provided for selected stadiums in the United States and Canada are summarized in Table 6-17. Because most special event parkers will accept walking distances up to 1,500 feet, a large amount of the total parking supply can be provided off-site. Stadiums within CBD or within close proximity to public transport service provide about one parking space for every 7 to 16 seats. Where good transit service or an existing parking supply is not available, one parking space may be needed for each 2 seats.

Cincinnati's Riverfront Stadium is somewhat typical of downtown sports stadiums. In conjunction with construction of the stadium, a three-level parking garage and adjacent surface lots were constructed totaling 4,800 spaces. However, because of its location adjacent to downtown Cincinnati, nearly 15,000 additional parking spaces are available within 2,000 feet of the stadium and 5,000 more beyond this distance. A 1976 study of travel modes to a professional football game at this stadium found that 85.3 percent of the spectators arrived by automobile, 12.3 percent by bus, and 2.4 percent by other means. Car occupancy averaged 3.25 persons per car.

[16] Whitlock, *Parking for Institutions and Special Events*

Table 6-15. Mode of Arrival to Various Special Events

Location	*Type of Event*	*Percent of Persons Arriving by Private Vehicle*
Oakland, CA[a]	Pro-footbal	88
	Pro-baseball	97
Shea Stadium, NY[a]	Pro-football	65
	Pro-baseball	65
San Diego, CA[a]	Pro-football	85
	Pro-baseball	97
Yankee Stadium, NY[a]	Pro-football	10
	Pro-baseball	40
Anaheim Stadium, CA[a]	Pro-baseball	100
	Football	100
Atlanta Stadium, GA[a]	Pro-football	66
	Pro-baseball	87
Dodger Stadium, CA[a]	Pro-baseball	85
Los Angeles Coliseum, CA[a]	College football	95
	Pro-football	90
Nets Stadium, NJ[a]	Pro-basketball	90
	Concert	70
Kansas City, MO[a]	Pro-football	60
Edmonton, Canada[a]	Pro-football	50
	Soccer	80
Mile High Stadium, CO[a]	Pro-football	82
	Baseball	100
Orange Bowl, FL[a]	Pro-football	73
	College football	78
	High school football	75
Cotton Bowl, TX[a]	Pro-football	82
	College football	87
Ohio State University, OH[a]	College football	84
Weber State, UT[a]	College football	75
Ware Memorial[a]	College football	73
Memorial Stadium, PA[a]	College football	68
Meadowlands, NJ[a]	Horse racing	80
American Museum of Natural History, NY[b]	Museum	73
Hagley Museum, DE[b]	Museum	49
Milford, CT[b]	Jai Alai	88
Husky Stadium, Seattle WA[c] (1984)	College football	76
(1987)	College football	65

a. *Traffic Engineering Magazine*, June, 1975. Technical Council Committee Report 6A5.
b. Wilbur Smith and Associates' Studies.
c. Michael E. Williams, *Husky Stadium Expansion Plan and Transportation Management Program* (Seattle, WA: University of Washington, Transportation Office, August 1988).

Major multi-purpose public auditoriums also are heavy generators. Many seat over 10,000 people, and require large numbers of parking spaces. Table 6-18 shows data for nine auditoriums. Spaces per seat ranged from 0.2 to 0.8, averaging 0.5. The 85 percentile value (exceeded by only 15 percent of the cases) was 0.7.

Hospitals and Medical Centers[17]

Hospitals, like airports, constitute a growth sector for the parking industry. They continue to expand and modernize — current trends point toward an increase in outpatient activity and services, and a decrease in average length of hospital bed stay. These factors have increased hospital parking demands.

Types and Characteristics. Hospitals function as general hospitals and medical centers. General hospitals provide acute care patient clinical and surgical services, as well as outpatient services. Medical centers generally provide those services, including a full range of outpatient services, while accommodating teaching and

[17] This section was drawn largely from Whitlock, *Parking for Institutions and Special Events.*

Table 6-16. Husky Football Game Mode Split, Seattle, WA
(Seating Capacity 58,500)

	1984				1987 Average Actual with Traffic Management Program			
Automobile Mode	*Persons*	*Vehicles/ Boats*	*ACO*[a]	*Percent of Persons*	*Persons*	*Vehicles/ Boats*	*ACO*[a]	*Percent of Persons*
On-campus parking								
Stadium area	3,510	975	3.6	5.8				
East campus	12,260	4,900	2.5	20.3				
Main campus	6,750	3,070	2.2	11.2				
South campus	2,420	1,010	2.4	4.0				
West campus	2,740	1,370	2.0	4.5				
Subtotal	27,680	11,325	2.4	45.9	26,269	10,284	2.6	36.8
Off campus parking								
U-district[b]	2,000	1,000	2.0	3.3	1,088	512	2.1	1.5
Neighborhoods[b]	16,340	8,170	2.0	27.1	2,300	1,150	2.0	3.2
					17,300	8,650	2.0	24.2
Subtotal	18,340	9,170	2.0	30.4	20,688	10,312	2.0	29.0
Total auto mode	46,020	20,495	2.2	76.3	46,957	20,596	2.3	65.8
Non-auto mode								
Transit								
Regular service	500			0.8	1,428			2.0
Husky special	2,050			3.4	1,818			2.5
Park-and-Ride					7,131			10.0
Charter bus	3,280			5.4	2,878			4.0
Charter boat	1,050			1.7	1,275			1.8
Private boat	1,440			2.4	1,811			2.5
Drop off/walk motorcycle/bike[b]	5,960			9.9	8,097			11.3
Total non-auto mode	14,280			23.7	24,438			34.2
Total	60,300[c]			100.0	71,395			100.0

a. ACO = average car occupancy.
b. Estimated number of persons and vehicles.
c. Includes 1,800 unseated attendees (press, game officals, vendors, etc.).
Source: Michael E. Willams, *Husky Stadium Expansion Parking Plan and Transportation Management Program* (University of Washington, Transportation Office, August 1988) and TRR No. 1232 (Washington, D.C.: Transportation Research Board, 1989) p. 49.

Table 6-17. Parking Provisions of Selected Stadiums

	Seating Capacity[a]	Parking Spaces		Total Spaces per Seat	Auto Occupancy		Distance from CBD	Served Rail Transit
		On Site	*Vicinity*		*Football*	*Baseball*		
Anaheim, CA	43,300	12,000	0	0.28		3.4		
Atlanta, GA	58,800	4,400	5,500	0.17	2.7	3.0	1 mile	
Cincinnati, OH	56,200	4,800	20,000	0.44	3.25		Adjacent	
Dallas, TX	72,000	4,000	10,600	0.20	3.6-3.8		2 miles	
Denver, CO	51,000	2,700	9,300	0.24	3.0	1.9	2 miles	
Edmonton, Alta	33,100	7,000	8,000	0.45			1.5 miles	LRT
Houston, TX	53,000	30,000	0	0.57			6 miles	
Kansas City, MO	78,200	16,000	0	0.20			10 miles	
Los Angeles, CA								
Coliseum	93,000	11,000	26,500	0.40	2.6		3.5 miles	
Dodger Stadium	56,000	16,000	0	0.29		2.6	1.5 miles	
Meadowlands, NJ	76,000	20,800		0.27				
Miami, FL	80,000	3,000	2,100	0.06	2.5	2.1	1.5 miles	
New Orleans, LA	78,000	5,000	0	0.06			Adjacent	
New York, NY								
Shea Stadium	60,000	7,400	1,000	0.14				NYCTA
Yankee Stadium	65,000	2,000	300	0.04				NYCTA
Oakland, CA	54,000	8,000	18,000	0.48	3.5	3.2		BART
Orchard Park, NY	80,000	15,000		0.19				
Philadelphia, PA	65,300	11,000	5,000	0.25	2.8	2.8	3 miles	SEPTA
Pittsburgh, PA	50,300	4,400	24,000	0.56		3.47	Adjacent	
St. Louis, MO	50,100	7,500	10,000	0.35			Adjacent	
San Diego, CA	54,000	14,700	500	0.28	2.5-3.1	2.8-3.0	6 miles	
Seattle, WA	65,000	2,300	5,500	0.12		2.8[b]	1 mile	
Washington, DC (R.F. Kennedy)	50,000	10,000		0.20				
Seattle-Husky Stadium	58,500	11,325	9,170	0.35				

Source: Adapted from *Traffic Considerations for Special Events*, Informational Report: Institute of Transportation Engineers, Washington, D.C., 1976, and from E.M. Whitlock, *Parking for Institutions and Special Events* (Eno Foundation for Transportation Inc. Westport, CT: 1982). Data for Seattle added, as obtained from source indicated in Table 6-16.

Table 6-18. Auditorium Parking (1976)

	Maximum Seating Capacity	Parking Spaces Adjacent	Auxiliary	On-street	Total	Transport Modes	Seats per Space	Spaces per Seat
Cleveland Arena	11,000	4,000	1,000	500	5,500	Auto, bus	2.0	0.5
Civic Auditorium, San Francisco	8,000	854	414	—	1,258	Auto	6.3	0.2
Coliseum - Richmond, KY	9,500	1,500	500	200	2,200	Auto	4.3	0.2
Cow Palace - San Francisco	15,000	7,000	150	850	8,000	Auto, bus	1.8	0.6
Maple Leaf Gardens - Toronto	19,500	350	3,500	—	4,000	Auto, bus, rail	5.1	0.2
Municipal Auditorium - Dallas	11,000	1,100	7,610	740	9,450	Auto, bus	1.2	0.8
O'Keefe Centre - Toronto	3,155	2,000	150	—	2,150	Auto, bus	1.5	0.7
Place des Arts - Montreal	3,000	389	725	250	1,364	Auto, bus	2.2	0.5
Veterans Memeorial - Columbus, OH	3,964	1,200	300	1,200	2,700	Auto, bus	1.5	0.7

Source: Adapted from *Traffic Considerations For Social Events*: An ITE Informational Report, 1976.

research activities. Both general hospitals and medical centers may contain significant floor area for medical offices and, frequently, free-standing doctors' office buildings. Medical centers generally have a greater population per bed than general hospitals.

Some facilities serve particular needs (i.e., children's hospitals, psychiatric and rehabilitation hospitals, free-standing dialysis centers, and extended daycare facilities). These facilities exhibit differing travel and parking characteristics. The daily population of hospitals and medical centers is categorized as staff and visitors, based on average duration and frequency of visit. Staff members, except for attending physicians, volunteers and clergy, remain through the day while working at the facility. Physicians have special parking requirements that are dictated by their need for mobility and daily schedules. Visitors generally have short-term stays of less than 3 hours.

Studies of about 30 hospitals and medical centers found that visitors comprise about 63 percent of a typical general hospital's daily population as compared with 59 percent at medical centers. This reflects the higher proportion of inpatient visitors at general hospitals, as well as the greater proportion of staff in a typical medical center's daily population.

Travel Modes. Hospital employees, visitors, and outpatients prefer to come by private automobile. Studies at selected general hospitals, medical centers, and specialized facilities are shown in Table 6-19. The percentage of employees/staff coming by car ranges from about 45 to 91 percent. The percentage of visitors coming by car ranges from 42 to 95 percent (excluding specialty hospitals).

The proportion that come by car reflects both the characteristics of individual hospitals, and their location. General hospitals in affluent suburban locations have a high percentage of arrivals by private automobile. Studies of four selected general hospitals in affluent suburbs found that automobiles were used by nearly 94 percent of everyone arriving on a typical weekday.

In contrast, visitors to "neighborhood hospitals," which serve a small densely-populated urban area, have a lower incidence of automobile usage. Two such hospitals within a major eastern city reported automobile usage of just over 50 percent. Employees and staff made up most of these motorists, since outpatients and visitors generally elected to walk the short distance to their neighborhood hospitals. Transit usage ac-

Table 6-19. Travel Modes of Hospital Visitors and Employees

	Employee Staff	Visitor
	Percent by Car	
14 General hospitals[a]	58-91	48-81
14 Medical centers[a]	45-91	42-83
3 Speciality hospitals[a]	49-75	25-52
3 Extended day care facilities[a]	65-81	50-67
	Percent Auto Drivers	
6 Hospitals[b]	78-84	87-95

a. E. Whitlock, *Parking for Institutions and Special Events* (Westport, CT: Eno Foundation, 1982); J. M. Hunnicut, "Parking, Loading and Terminal Facilities," *Transportation and Engineering Handbook* (Institute of Transportation Engineers, 1982).

counted for 10 to 15 percent of visitor and outpatient trips.

Analysis of data from three general hospitals (shown in Table 6-20) provides a generalized picture of how physicians, employees/staff, outpatients and visitors travel to hospitals.

- Virtually all physicians come as auto drivers because of their daily schedules and the need for flexibility in where they go and when they travel.
- Although most employees, outpatients and visitors come by car, there is a significant proportion of ridesharing. About 12 percent of employees and a third of the outpatients come as car passengers — but patients often depend on others for access to hospitals for treatment; visitors often come with friends to visit hospitalized patients.

Parking Durations. Duration of parking affects parking space turnover and, in turn, parking demands. Table 6-21 gives representative parking durations by type of parker. Parking durations average 7.8 hours for employees, 4.5 hours for staff, and approximately 2 hours for visitors and outpatients. Seventy-one percent of the employees parked for over 8 hours, as compared with 2 percent of the doctors and 3 to 4 percent of the visitors.

Parking Accumulation. Hospital parking systems must accommodate needs of a variety of parkers. Each type of parker has its individual perceived needs — needs related to such characteristics as arrival time, duration of visit, mode of travel, and amount the parker is prepared to pay for parking. The combined influence of these characteristics results in a particular pattern for the accumulation of parked vehicles.

These accumulation patterns reflect the daily activities at the hospital such as when shifts change, business offices open, and visiting hours begin. Table 6-22 shows when various activities begin. Table 6-23 shows the resulting hours of peak parking space accumulation and demand. Employees generally peak around 3 PM, outpatients around 10 AM, and visitors around 7 PM.

Table 6-20. Percent of People Arriving At Three General Hospitals by Automobile

	Percent of Total			
Category	*Auto Drivers*	*Auto Passengers*	*Other*	*Total*
Physicians	98	0	2	100
Employees/staff	78	12	10	100
Outpatients	62	33	5	100
Visitors	63	33	4	100

Source: Comparative Analysis of General Hospitals in Burlington, MA, Philadelphia, PA, and Norristown, PA. E. M. Whitlock, *Parking for Institutions and Special Events* (Westport, CT: Eno Foundation for Transportation, Inc., 1982).

Figure 6.10 gives a graphic portrayal of typical hourly parking accumulation by type of parker at medical centers. Before 9 AM most parkers are staff. During the peak period of accumulation, about 3-3:30 PM, about 65 percent of all parkers are staff, 10 percent are visitors, and 5 percent are outpatients. The remaining 20 percent comprise attending physicians (1 percent), students (3 percent), volunteers (2 percent), and all others (14 percent).

The 2-3:30 PM peak occurs during the day-evening shift change. At this time, evening shift personnel arrive at the hospital before most of the day shift departs. Thus, peak accumulation occurs at the time that departing day shift employees overlap with the arriving evening shift; there is also a peak-visitor accumulation at this time. This pattern is consistent from hospital to hospital. Some hospitals reschedule patient visiting hours around the peak and/or stagger employee arrival and departure times to help manage peak demands and traffic.

On a daily basis there may be more visitor parkers than employee parkers. However, because of their shorter durations, visitors' cars normally account for 15 to 25 percent of the peak accumulation. In contrast, full-time employees comprise less than 50 percent of total daily parkers but account for about two-thirds of peak-parking accumulation. Thus, parking problems at most hospitals are more employee than visitor related.

Peak-Parking Demands. Hospital parking demands (and hence requirements) are generally equivalent to average peak-parking accumulation. This demand varies directly with size of the medical institution's population; type of activity, and degree of automobile use. It is influenced by number of doctors and employees, number of beds, and outpatient load. Hospitals with heavy outpatient loads, specialized hospitals, and those with medical schools exhibit differing characteristics.

Parking facilities should be large enough to accommodate the afternoon shift change when the

Table 6-21. Frequency Distribution of Parking Durations at Hospitals and Medical Centers

Duration of Parking	Type of Parker (Percent)						
	Staff			Visitor			
	Employees	Attending Physicians	All[a]	Patient Visitors	Other Visitors	Outpatients	All
0-1 hour	Neg.	10	Neg.	34	30	25	31
1-2 hours	Neg.	14	1	38	44	33	41
2-3 hours	1	9	2	14	15	22	17
3-4 hours	2	17	2	4	2	12	3
4-8 hours	26	48	29	7	5	8	5
Over 8 hours	71	2	66	3	4	Neg.	3
Total	100	100	100	100	100	100	100
Average duration	7.8 hrs.	4.5 hrs.	7.5 hrs.	2.2 hrs.	1.9 hrs.	2.2 hrs.	1.9 hrs.

a Total staff includes employees, attending physicians, students, and volunteers.
Source: Based on analysis of data of selected hospitals and medical centers listed in Appendix Tables A-1 and A-2 of E. M. Whitlock, *Parking for Institutions and Special Events*, 1982.

peak accumulation occurs. Shift overlaps and visitors contribute to this parking accumulation pattern.

U.S. Department of Health, Education and Welfare (HEW) guidelines for short-term (acute area) hospitals require off-street parking be provided at a minimum ratio of 1.5 spaces for each licensed patient bed to satisfy the minimum needs of patients, employees, staff and visitors. In addition, HEW requirements suggest, in the absence of a formal parking study, a ratio of 1 space per day shift employee and staff member, plus 1 space per licensed bed. These regulatory requirements are generalized; therefore, they can only be used as a rough guide.

The number of parking spaces per hospital bed provides a general guideline for estimating parking space requirements. Space-per-bed ratios are shown in Table 6-24. General hospitals average 1.8 to 2.3 spaces per bed; however, the 85 percentile "design" value is remarkably consistent at 2.5 spaces per bed. Corresponding 85 percentile design values are for 2.6, 3.2 and 6.6 for extended daycare facilities, medical centers and specialty hospitals respectively. The higher unit demands at medical centers reflect increased outpatient activity and a broader spectrum of services.

Because outpatient services and visitors vary widely among hospitals, more refined estimates can be obtained by computing demands for each population component. For general hospitals, employees normally account for 65 to 75 percent of the peak demand, visitors 5 to 25 percent and doctors 2 to 10 percent. Representative design values by type of parker are: employees (staff), 1.6 to 1.9 spaces per bed; doctors, 0.1 to 0.2; visitors (excluding outpatients), 0.2 to 0.3; and outpatients, 0.2 to 0.4.

If parking spaces were reserved by population category for the entire day to serve peak-period

Table 6-22. Typical Daily Activities at Hospitals and Medical Centers

Daily Activity	Time of Day
Nursing service shift change	7:00 am
Business offices open	9:00 am
Clinics open	9:00 am
Afternoon visiting hour begin	1:00 pm
Nursing service shift change	3:00 pm
Afternoon visiting hour end	4:00 pm
Business offices and clinics close	5:00 pm
Evening visiting hours begin	6:00 pm
Evening visiting hours end	8:00 pm

Source: E. M. Whitlock, *Parking for Institutions and Special Events* (Westport, CT: Eno Foundation, 1982).

Table 6-23. Hour of Peak-Parking Space Demand for Hospital and Medical Center Demand Segments

Parking Space Demand Segments	Time of Peak Demand
Attending physicians	9:00 am
Outpatients	10:00 am
Students	10:00 am
Others	10:00 am
Other visitors	11:00 am
Patient visitors	7:00 pm
Employees	3:00 pm

Source: Based on analysis of accumulation data from 15 hospitals and medical centers, analyzed in Whitlock, *Parking for Institutions and Special Events* (Westport, CT: Eno Foundation, 1982).

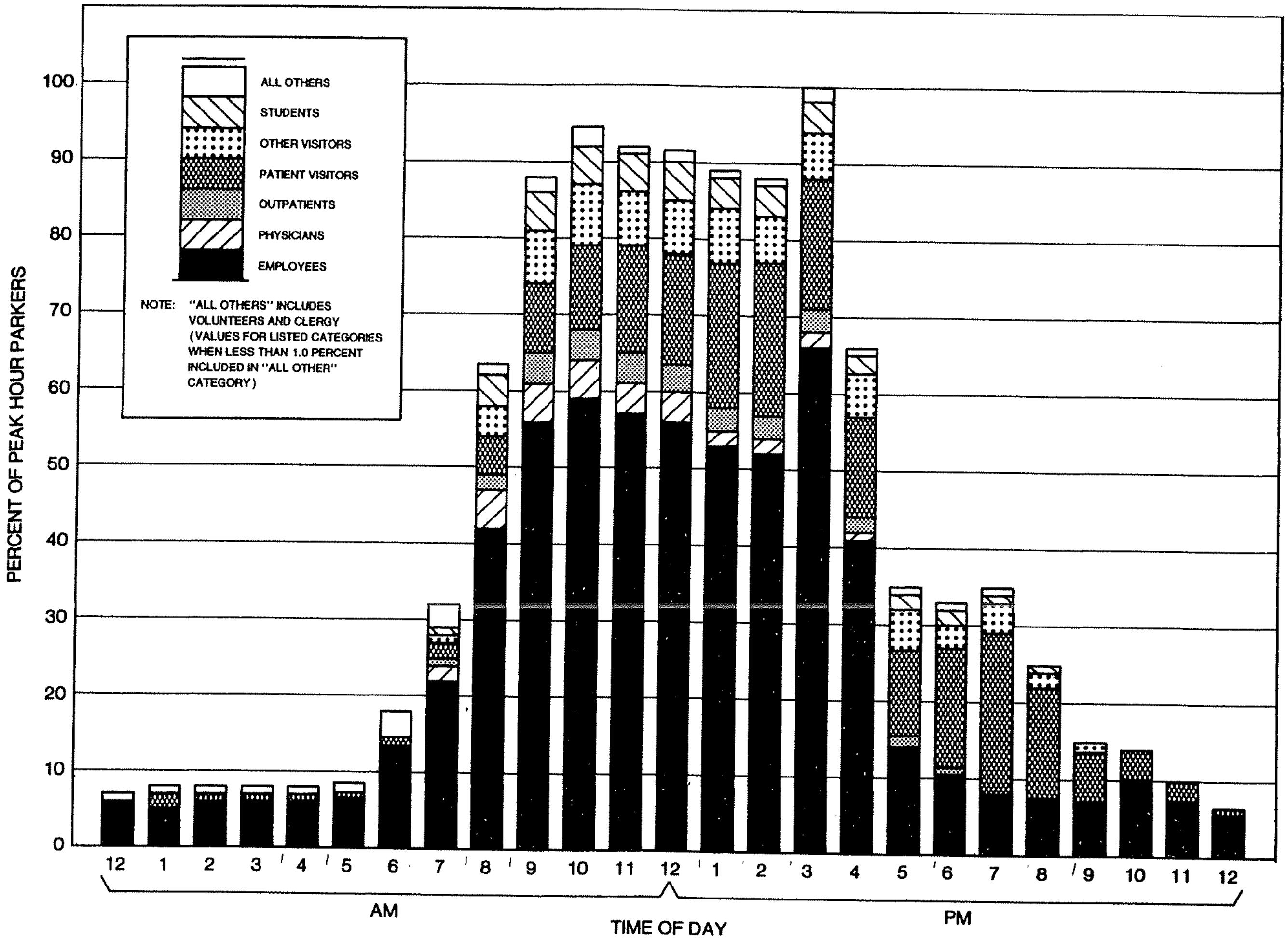


Figure 6.10. Hourly accumulation of parkers by type at medical centers

Source: Wilbur Smith and Associates.

Table 6-24. Hospital Parking Demands

	Spaces per Bed		
	Mean	STD Deviation	Approximate 85 percentile[a]
6 Hospitals[b]			
Employees (73%)	1.67	0.18	1.85
Doctors (8%)	0.18	0.05	.23
Visitors (19%)	0.43	0.10	.53
Total (100%)	2.28	0.25	2.53
14 General[c] hospitals	2.16	0.38	2.54
14 Medical centers centers	0.60	2.62	3.22
3 Specially[c] hospitals	4.36	2.30	6.56
3 Extended[c] day care facilities	1.68	0.88	2.56

a. Mean plus 1 standard deviation.
b. Hunnicut, "Parking Loading and Terminal Facilities."
c. Whitlock, *Parking for Institutions and Special Events*, 1982.

needs of each parking demand segment, the resulting number of required parking spaces would be 10 to 25 percent greater than actual daily peak-hour demand for spaces. This emphasizes the need for medical facility parking systems to be flexible in operations and location. For example, spaces used by employees and outpatients during the morning and afternoon can serve peak-period visitor parkers in the early evening. Similar dual-use operations may be combined to provide more efficient use of parking space.

Colleges and Universities

There are more than 3,000 institutions of higher education in the United States, with an aggregate enrollment of over 12 million students.

These institutions vary in size, location, and dependence on car travel. Overall, enrollment averages about 9,000 students, but there are wide variations, with enrollment as low as 135 students (Cathedral College, Douglastown, New York) to over 75,000 students (University of Massachusetts, Boston).

The size of university and college enrollment, faculties, and staff has increased substantially during the past 30 years. During this same period, automobile use — especially by students — has increased dramatically. The combination of rapid increases in enrollment and auto usage has produced major impacts on the physical plant at most universities and colleges.

Basic Variables. Planning for parking must recognize the unique character of each campus. In estimating parking space requirements, it is important to identify specific activities. A campus is a major gathering place for students and visitors; it is a place of employment, and a place of residence for both students and staff. Many universities have large residential populations. At 2-year institutions (community colleges), in contrast, the student is a daily commuter. Many universities also host cultural programs, sporting events and other types of activity that significantly affect campus parking needs.

University parking space needs are affected by (1) daytime and evening enrollment, (2) mix between commuter and residential population, (3) size of faculty and staff, (4) location and frequency of special events, (5) opportunities for ride-sharing and public transport (often keyed to campus design and location), (6) availability and cost of parking, and (7) university policies regarding automobile usage and parking.

Travel Modes. Travel modes at universities vary widely. Analyses of 16 case study universities show that 10 to 85 percent of the students drive. A sampling of these universities (Table 6-25) indicates that auto drivers account for 57 to 81 percent of staff and 16 to 78 percent of students.

Table 6-25. Utilization of Automobile as Mode of Arrival at Selected Universities

	Percent Auto Drivers	
Study University[a]	*Staff*[b]	*Students*[b]
Virginia	81	25
Texas	86	78
Massachusetts	67	38
Texas	69	47
California	95	79
Pennsylvania	57	16
California	70	52

a. See Appendix in source for individual universities.
b. Excludes residents, where applicable.

Source: Whitlock, *Parking for Institutions and Special Events*, 1982.

Parking Accumulation. Figure 6.11 gives parking accumulation patterns for students, faculty, staff, and visitors. Peak-parking accumulation generally occurs mid-morning from about 10 to 11 AM. Resident student parking needs are substantial at 5:30 PM when commuter and staff parking space needs are relatively low.

Parking Demands. Ranges in campus parking demands are shown in Table 6-26. Peak daytime demands for representative universities are as follows:

Faculty parking needs vary from 0.50 to 0.95 parking spaces per daytime staff member. The corresponding 85 percentile design value is 0.92.

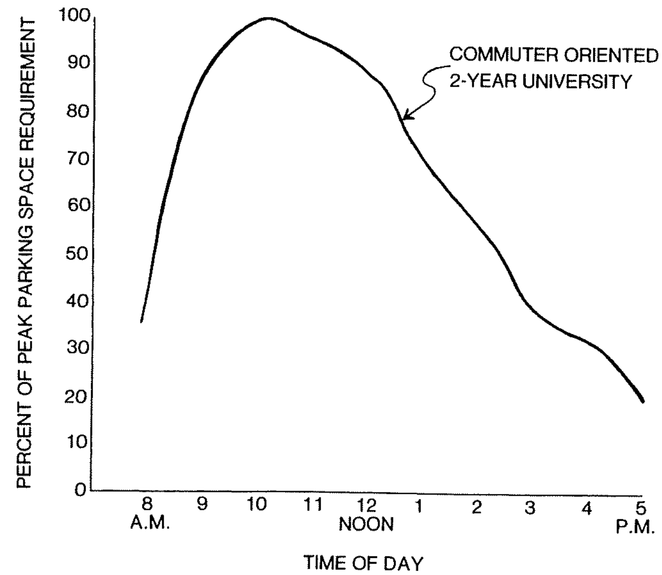
Daytime commuter parking needs range from 0.13 to 0.44 per daytime commuter student. The 85 percentile design value is about 0.37 spaces.

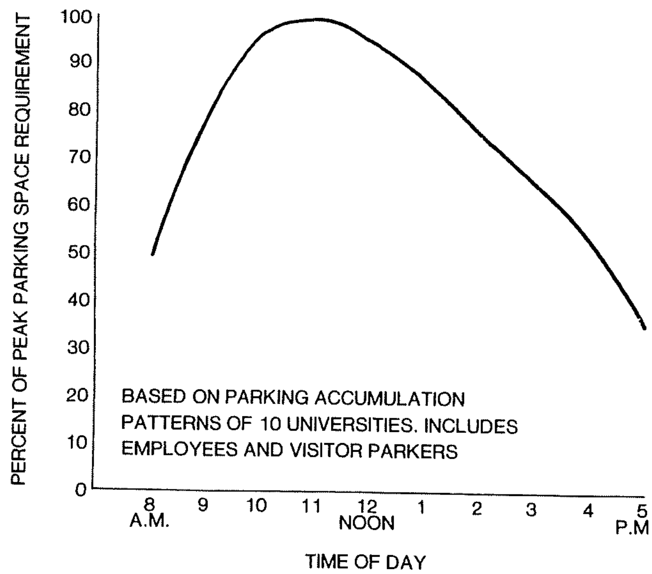
Resident commuter student demands are consistently less than 0.5 spaces per student (ranging from 0.15 to 0.40). The suggested 85 percen-

Table 6-26. Ranges in Peak-Parking Demand at Colleges and Universities

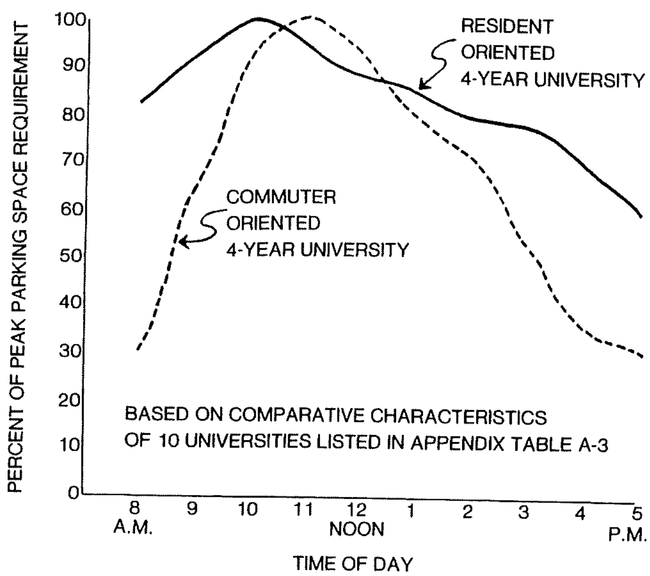
	Units	*Average (rounded)*	*Eno Range (rounded)*	*85% Design Values*	*Urban Land Institute*
Commuter students	per student	0.30	.15-.45	0.37	0.25-0.50
Resident students	per student	0.25	.15-.40	0.36	0.05-0.40
Faculty/staff	per faculty/staff }	0.70	.50-1.00	0.92	0.30-.90
Visitors	per faculty/staff }		N/A	N/A	.02-.05

Source: Adapted from Eno Foundation for Transportation, Inc. research and Urban Land Institute research.

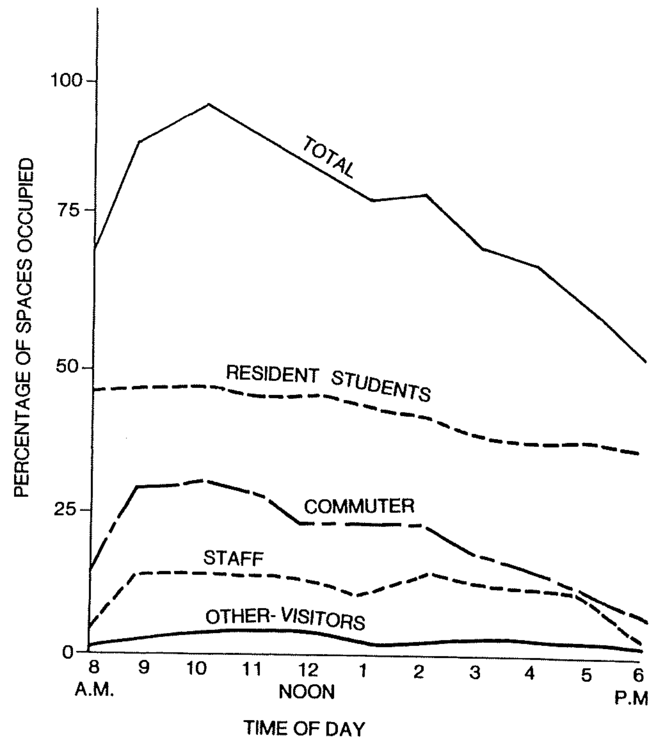




Accumulation patterns of daytime staff parkers.



Accumulation patterns of daytime student parkers.



Daily accumulation of all university parkers.

Figure 6.11. University parking accumulation patterns

Source: Edward M. Whitlock, *Parking for Institutions and Special Events* (Westport, CT: Eno Foundation for Transportation, 1982) p. 26.

tile design value approximates 0.36 spaces.

The amount of required on-campus parking space should be determined separately for each of the three categories. Ranges and design values shown in Table 6-26 provide initial guides. However, their application must be tempered by location and type of university. For financial feasibility analysis, in particular, site-specific parking studies will be required.

Industrial, Commercial, Recreational and Residential Developments

Most urban development takes the form of industrial, commercial, recreational or residential projects. Traffic, parking and planning agencies and community zoning boards are faced with the question: How much parking should specific new developments provide? In response to this question, the following sections describe demand characteristics for some common kinds of land use.

Industry. Parking characteristics of industrial developments depend on location, type and size of industry, employee density and amount of shift work. The following values are representative of industrial parking demands: industrial park, 1.0 space per employee or 2.4 spaces per 1,000 sq ft building area; light industry, 0.8 spaces per employee or 2.1 spaces per 1,000 sq ft; and heavy industry 0.6 spaces per employee or 2.3 1,000 sq ft.

Number of spaces should be based on employment where available. In other cases, demand should be based on building area. Peak demands occur during the daytime shift.

The 0.6 spaces per employee suggested for heavy industry reflects the 0.64 spaces per employee found in various surveys of industrial plants. About 0.79 spaces were actually provided by the facilities surveyed. Supply exceeded demand to reduce the need to search for a space or park illegally.[18]

Office. Office parking demand correlates closely with the number of employees and occupied floor space. Various studies have found an average parking ratio of 2.5 spaces per 1,000 sq ft of occupied floor space;[19] and an average ratio of 2.8 spaces per 1,000 sq ft of building area and 0.8 spaces for employees.[20]

The design (85 percentile) demands for a general office building approximates 0.9 spaces per employee; or 3.0 spaces per 1,000 sq ft of GLA. For office parks, a value of 3.3 spaces per 1,000 sq ft of GLA is suggested. These peaks occur during the normal working day.

Employment should be used as a basis for estimating demand wherever possible. However, where floor space must be used, periodic updates of the criteria are needed to account for changing employee densities. Over the past 40 years, employee density in general office buildings has dropped from about 6 to 3.5 employees per 1,000 sq ft. If such changes continue, appropriate adjustments will be needed to avoid excessive parking space requirements.

Hotels. Most major high-quality hotels are self-contained, multi-use developments. Major restaurants/lounges, banquet/meeting rooms and convention facilities are provided in addition to guest rooms. Various parking generation surveys suggest an average of about 1.2 parking spaces per room —with the peak normally occurring on a weekday evening usually in June, July or August.

More refined demand estimates can be obtained by disaggregating demands for each component of activity. Table 6-27 gives guidelines on an hourly basis for weekdays and Saturdays. These guidelines suggest: 1 space per guest room, 10 spaces per 1,000 sq ft of GLA for restaurants, 0.5 spaces per banquet room and up to 30 spaces per 1,000 sq ft of convention space.

Banks. Drive-in banks with more than 3,500 sq ft of floor space generate a design (85 percentile) parking demand of about 5.5 spaces per 1,000 sq ft. Studies suggest a higher rate of generation for banks with building areas of less than 3,000 sq ft (see Figure 6.12).

Shopping Centers. Shopping centers generate peak-parking demands during the 4-week period between Thanksgiving and Christmas. The Saturday before Christmas is generally the peak day. On this day peak accumulation occurs during mid-afternoon. The 20th highest hour, which is used for design purposes, usually occurs

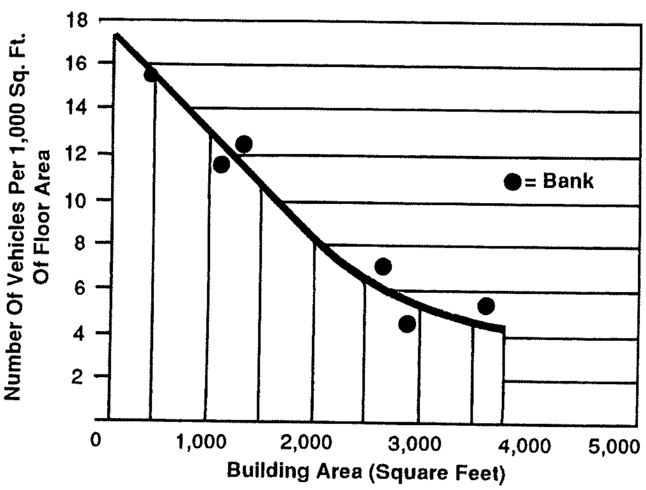
[18] *Parking Facilities for Industrial Plants* (Washington, D.C.: Institute of Traffic Engineers, 1969), p. 13.
[19] Barton Aschman Associates, *Shared Parking* (Urban Land Institute). The formula was $Y = 2.51x + 0.41$ ($r = 0.94$). Where: x = occupied floor area in thousands of sq ft and Y = demand (spaces).
[20] *Parking Generation* (Institute of Transportation Engineers). The formulas were $\text{LN } Y = 0.93 \text{ LN } X_1 + 1.253$ ($r = 0.93$) and $Y = 0.80 X_2$. Where: X_1 = 1000 sq ft of building area; X_2 = employment; Y = demand; LN = natural logarithm; and r = coefficient of correlation.

Table 6-27. Parking Demand Variations of Hotels by Component

	Guest Rooms		*Restaurant/Lounge Facilities*[a]		*Banquet/Meeting Rooms*[a]	*Convention Facilities*[a]
	Spaces per Room		*Spaces per 1,000 sq ft GLA*		*Spaces per Seat*	*Spaces per 1,000 sq ft*
Hour of Day	*Weekday*	*Saturday*	*Weekday*	*Saturday*	*Daily*	*Daily*
6:00 am	1.00	0.90	2.0	2.0	-	-
7:00 am	0.85	0.70	2.0	2.0	-	-
8:00 am	0.65	0.60	2.0	2.0	0.2	10
9:00 am	0.55	0.50	2.0	2.0	0.5	30
10:00 am	0.45	0.40	2.0	2.0	0.5	30
11:00 am	0.35	0.35	3.0	3.0	0.5	30
12:00 noon	0.30	0.30	5.0	3.0	0.5	30
1:00 pm	0.30	0.30	7.0	4.5	0.5	30
2:00 pm	0.35	0.35	6.0	4.5	0.5	30
3:00 pm	0.35	0.40	5.5	4.5	0.5	30
4:00 pm	0.45	0.50	5.0	4.5	0.5	30
5:00 pm	0.60	0.60	7.0	6.0	0.5	30
6:00 pm	0.70	0.70	9.0	9.0	0.5	30
7:00 pm	0.75	0.80	10.0	9.5	0.5	30
8:00 pm	0.90	0.90	10.0	10.0	0.5	30
9:00 pm	0.95	0.95	10.0	10.0	0.5	30
10:00 pm	1.00	1.00	9.0	9.5	0.2	10
11:00 pm	1.00	1.00	7.0	8.5	-	-
12:00 midnight	1.00	1.00	5.0	7.0	-	-
Peak-parking ratio	1.0		10.0	10.0	0.5	30
Percent auto use	80%		100%	100%	100%	100%
Average persons/auto	1.4		2.0	2.0	2.0	2.0

a. Represents nonguest parking demand, assuming 50 percent of restaurant patrons and 100 percent of conference and convention attendees are nongueats. Conference and convention demands indicated are upper bounds, which are very rarely achieved.

Source: *Shared Parking*, a study conducted under the direction of the Urban Land Institute by Barton-Aschman Associates, Inc. 1982. Data are based on surveys of 14 major suburban hotels, ranging in size from 265 to 1,020 rooms with restaurant/lounges of up to approximately 10,000 sq ft, banquet/meeting rooms of up to approximately 1,000 seats, and convention facilities of up to 40,000 sq ft,supplemented by comprehensive data on the use of facilities compiled at over 60 hotels by a major hotel chain.



Maximum Peak Accumulation Per Building Area (Sq. Ft.)

Figure 6.12. Maximum vehicle accumulations per 1,000 sq ft of floor area for drive-in banks

Source: Charles A. Vidich, *Regulating Off-street Parking Through Zoning* (Waterbury, CT: Council of Governments, Central Naugatuck Valley, 1985).

on a peak Saturday. Weekday peaks approximate 80 to 90 percent of Saturday peaks; they occur during the evening in centers over 400,000 sq ft, and mid-afternoon in smaller centers. Over the years, peaking has reduced as a result of extensive evening and Sunday openings.

The initial studies of parking demands at 270 centers conducted in 1965 suggested a design of 5.5 spaces per 1,000 sq ft of GLA as a design guideline, based on the 10th highest hour.[21] Surveys conducted in the 1970s at 32 major shopping centers larger than 800,000 sq ft GLA during the peak weekends before Christmas suggested a demand of 5.0 spaces per 1,000 GLA.[22]

Studies at 135 shopping centers from 1980-81 suggested average design demand ratios for the 20th highest day of 5.0 spaces per 1,000 sq ft of GLA for centers larger than 600,000 sq ft and 4.0 for centers between 250,000 and 400,000 sq ft and a linearly interpolated ratio of 4.5 for centers between 400,000 and 600,000 sq ft.[23] An actual

[21] Voorhees and Crow, "Shopping Center Parking Requirements," HRR No. 130 (Washington, D.C.: Highway Research Board, 1968).
[22] Barton-Aschman Associates, Inc., "Parking Demand at the Regionals," *Urban Land* (May 1977): 3-11.
[23] *Parking Requirements for Shopping Centers* (Urban Land Institute, Washington, D.C.: Wilbur Smith Associates, 1982).

Table 6-28. Peak Shopping Center Parking Demands

Source	No. Of Centers Surveyed	Size of Centers (GLA) Under 400,000 sq ft	400,000-600,000 sq ft	Over 600,000 sq ft	All
Wilbur Smith/Urban Land Institute, 1981 Average	135[a]	4.0	4.5	5.0	-
Wilbur Smith/Urban Land Institute, 1981 (85 percentile)	135[a]	5.0	6.0	6.3	-
Urban Land Institute *Shared Parking,* 1983 (90 percentile)	14	-	-	-	5.0
Institute of Transportation Engineers *Parking Generation* (85 percentile)	178	-	-	-	5.1
Suggested Value (85 percentile)		4.5	5.0	5.5	

a. Based on 149 data points. Table A in *Parking Requirements for Shopping Centers Summary Recommendations and Research Study Report.* A study conducted under the direction of the Urban Land Institute by Wilbur Smith and Associates Inc and sponsored by the International Council of Shopping Centers, 1982.

ranking of these centers, however, shows 85 percentile values of 5.0, 6.0 and 6.3 respectively.[24] Studies of 14 suburban shopping centers on December weekdays and Saturdays found demand rates between 3.5 and 6.0 for Saturday, and 2.9 and 3.9 for weekdays. Corresponding 90 percentile values were 5.0 and 3.8.[25] An analysis of parking generation rates for over 140 centers shows 85 percentile values of 5.1 for Saturdays and 4.4 for weekdays.[26]

Table 6-28 lists suggested design parking demand indices that reflect various studies. Values of 4.5, 5.0, and 5.5 spaces per 1,000 sq ft of GLA are suggested for shopping centers of under 400,000 square feet, 400,000 to 600,000 sq ft and over 600,000 sq ft, respectively. These values would only be exceeded on the 20th highest day about 15 percent of the time. Obviously judgement should be used in their application.

Recreational Activities. Suggested guidelines for recreational activities are shown in Table 6-29. These guidelines give order-of-magnitude space requirements for beaches, marinas, swimming pools, athletic fields, skating rinks and exhibition arenas.

Residential Parking. Residential parking demands normally approximate 1 space per car for each dwelling unit. Because it is hard to predict car ownership in advance, factors such as size, type and /or density of development are used as a proxy. Representative design values (i.e., 85 percentile) are 2.0 spaces/dwelling unit for single family housing. The breakdown for multi-family housing is as follows: efficiency, 1.0 spaces/dwelling unit; 1 to 2 bedrooms, 1.5 spaces/dwelling unit; and 3 or more bedrooms, 2.0 spaces/dwelling unit.

Residential parking normally peaks between 9 PM and 6 AM. Typical weekday peak daytime accumulation is about 60 percent of that for late night.

Table 6-29. Illustrative Parking Space Guidelines for Recreational Activities

Use	Ratio Parking Area to Area in Specific Use	Spaces/Unit (rounded)
Beach	3:1	10[a]
Marina slip		1
Swimming pool	10:1	30[a]
Athletic field	1:10	0.3[a]
Skating rink (ice area)	4:1	1.1[a]
Exhibition area	1:1	30[a]

a. Estimated at 350 sq ft/space; rounded.

Source: Vollmer Associates, *Parking for Recreation: A Primer on the Techniques of Parking Vehicles at Public Recreation Facilities* (Wheeling, WV: American Institute of Parking Executives, 1965).

[24] Ranking by Eno research team.
[25] Barton Aschman Associates, *Shared Parking.*
[26] *Parking Generation,* 2nd ed. (Washington, D.C.: Institute of Transportation Engineers, 1987).

SUMMARY OF PARKING DEMANDS

This section summarizes parking demands for various types of land use. (See Appendix J for additional details.)

Suburban Parking Demands

Suggested peak-parking demand factors for various land uses in suburban settings are summarized in Tables 6-30 through 6-33. These factors or indices can be used for typical suburban developments with minimum transit use. They provide a basis for determining parking requirements of both individual (stand-alone) and multiple or shared land-use developments.

- Table 6-30 gives parking demand indices for over 20 specific land uses. The cited values are the 85 percentile. The number of spaces that should be provided are 10 percent more than the cited demands to account for vehicles searching for space and peak surges.
- Table 6-31 gives suggested parking demand indices and their likely times of occurrence. These indices were derived from a variety of sources and can serve as a guide in preparing zoning guidelines.
- Table 6-32 gives short- and long-term demand indices for selected land uses.
- Table 6-33 gives peak weekday and Saturday parking demands by time of day for selected land uses. This table provides a practical guide for estimating shared-parking requirements.

Demand values shown in the preceding tables will prove adequate about 85 percent of the time. They provide a broad guide for planning purposes. Obviously, care should be used in their application since parking demands reflect the actual attractiveness of any given activity mix:

- A retail center may have a productivity of 20 to 30 percent more than the norm as a result of particular stores, promotions and the like.
- A lounge associated with a restaurant may attract a large singles group.
- Changing occupancy in an office building may result in a lower employee density and an excess of parking over time.

Factors such as these should be taken into account in developing demands based on the tables presented in this chapter and in assessing parking space requirements.

Shared-Parking Demands

Parking demands for each time period should be estimated for each use, and the composite demands should then be computed (see Appendix K). The largest combined parking demand should be used for estimating required spaces.

Where offices constitute most of the space in a mixed-use mega-development, retail shops and restaurants may draw on workers for their patrons. In such cases, appropriate deductions should be made in computing parking demands. One suggested approach is to consider the center as a CBD and to apply the methods outlined earlier in this chapter.

Computing Shared Parking Demands

GIVEN: 600,000 sq ft office
500,000 sq ft retail
(Gross leaseable area)

STEP 1: Identify factors by time period
(Spaces per thousand sq ft)

	Weekday Day	Weekday Night	Saturday Day	Saturday Night
Retail	4.0	4.4	5.0	3.4
Office	3.0	--	0.5	--

STEP 2: Apply factors to activity to obtain parking space demands

	Weekday Day	Weekday Night	Saturday Day	Saturday Night
Retail	2,000	2,200	2,500	2,700
Office	1,800	---	300	---

STEP 3: Compute total parking space demands

	Weekday Day	Weekday Night	Saturday Day	Saturday Night
Total:	3,800	2,200	2,800	2,700

THEREFORE: 3,800 spaces are needed.

Table 6-30. ITE Design Parking Demands

			Spaces per Unit	
Use	*Unit*	*Period*	*Demand*[a] *(85% tile)*	*Design Value*[b]
Commercial airport	Enplaning passengers	Weekday	0.64	0.70
	Enplaning passengers	Saturday	1.48	1.62
	Enplaning passengers	Sunday	2.05	2.26
Light industry	1,000 sq ft building area	Weekday	2.43	2.67
	Employee		1.00[c]	1.10
Industrial park	1,000 sq ft building area	Weekday	2.11	2.32
	Employee	Weekday	0.80	0.88
Manufacturing	1,000 sq ft building area	Weekday	2.28	2.51
	Employee	Weekday	1.00[c]	1.10
Low-rise apartment	Dwelling unit	Weekday	1.38	1.52
		Saturday	1.53	1.68
High-rise apartment (central area)	Dwelling unit	Weekday	0.59	0.65
Residential condominium	Dwelling unit	Weekday	1.41	1.55
		Saturday	1.23	1.35
Convention motel	Rooms	Weekday	1.10	1.21
Motel with restaurant/ lounge	Rooms	Weekday	1.49	1.64
Movie theater	Seats	Weekday	0.30	0.33
		Saturday	0.37	0.41
Sports club/ health spa	1,000 sq ft GLA	Weekday	6.37	7.01
Church/synagogue	Attendees	Sunday	0.62	0.68
Hospital	Beds	Weekday	2.48	2.73
Medical-dental clinic/office	1,000 sq ft building area	Weekday	5.50	6.05
General offices building	1,000 sq ft building area	Weekday	3.00[d]	3.30
	Employees	Weekday	0.93	1.02
Office park	1,000 sq ft building area	Weekday	3.28	3.61
Hardware/paint/ home improvement store	1,000 sq ft GLA	Weekday	3.23	3.55
		Saturday	4.19	4.61
Shopping center	1,000 sq ft GLA	Weekday	4.43	4.87
	1,000 sq ft GLA	Saturday	5.10	5.61
Quality restaurant	1,000 sq ft GLA	Weekday	17.40	19.14
	1,000 sq ft GLA	Saturday	20.11	22.12
	Seats	Weekday	0.54	0.59
	Seats	Saturday	0.61	0.67
Family restarant	1,000 sq ft GLA	Weekday	11.15	12.26
	Seats	Weekday	0.42	0.46
Fast food restaurant (without drive-in window)	1,000 sq ft GLA	Weekday	15.36	16.90
	Seats	Weekday	0.77	0.85
Bank-with drive-in and walk-in facilities	1,000 sq ft building area	Weekday	5.47	6.02
Fast food restaurant with drive-in window	1,000 sq ft building area	Weekday	13.36	14.70
	Seats	Weekday	0.70	0.77

a. Average rate plus 1 standard deviation.
b. 10 percent safety factor. May not be needed in all cases (i.e., residential).
c. Adjusted to 1.00 space/employee.
d. Adjusted to 3.00 spaces/1,000 sq ft of building area.

Source: Based on Institute of Transportation Engineers parking generation rates, *Parking Generation*, 2nd Edition.

Table 6-31. Suggested Peak-Parking Demand Indices

Use	*Unit*	*Peak-Parking Demand Index*[a] *Spaces per Unit*	*Peak-Parking Period*
Office			
Office building	Employee	0.9	Weekday-day
	1,000 sq ft GLA	3.0	Weekday-day
Office park	1,000 sq ft GLA	3.3	Weekday-day
Medical-dental clinic office	1,000 sq ft GLA	5.5	Weekday-day
Retail			
<400,000 sq ft	1,000 sq ft GLA	4.5	Saturday-day
400,000-600,000	1,000 sq ft GLA	5.0	Saturday-day
>600,000 sq ft	1,000 sq ft GLA	5.5	Saturday-day
Convenience Store	1,000 sq ft GLA	4.0	Saturday-day
Restaurant			
Quality	1,000 sq ft GLA	20.0	Weekday or Saturday Evening
Family	1,000 sq ft GLA	11.2	Weekday
Fast food (without drive-in window)	1,000 sq ft GLA	15.4	Weekday
Bank (with drive-in and walk-in facilities, over 10,000 sq ft)	1,000 sq ft GLA	5.5	Weekday-day
Cinema	Seat	0.35[c]	Saturday-evening
Hotel (convention)	Rooms	1.2	Weekday-evening
Light industry	Employee	1.0	Weekday-day
Industrial park	Employee	0.8	Weekday-day
Heavy industry	Employee	0.6[b]	Weekday-day
Light industry	1,000 sq ft building area	2.4[b]	Weekday-day
Industrial park		2.1[b]	Weekday-day
Heavy industry		2.3	Weekday-day
Medical			
Medical center	Beds	3.2	Weekday-day
General hospital	Beds	2.5	Weekday-day
Residential			
Single family	per dwelling unit	2.0	Evening
Multi-Family			
Condominium (all)	per dwelling unit	1.4	Evening
Efficiency	per dwelling unit	1.0	Evening
1-2 bedrooms	per dwelling unit	1.50	Evening
3 or more bedrooms		2.00	Evening
All	per car per dwelling unit	1.00	Evening

a. These indices represent 85 percentile values. Increase by 10% to determine *design values in most cases.*
b. Preferred values.
c. 0.33 is a commonly used value.

Handicapped Parking Demands

There is growing concern over providing parking for disabled persons. Suggested space-requirements are summarized in Table 6-34. The number of spaces that should be provided on-site will depend on actual or anticipated demand for handicap parking and local requirements.

Table 6-32. Representative Peak-Parking Demands by Type of Parker

		Peak-Parking Demand			
Activity	*Unit*	*Short-term*	*Long-term*	*Total*	*Peak-Parking Period*
Office	1,000 sq ft GLA	0.5	2.5	3.0	Weekday-day
Retail					
<400,000 sq ft	1,000 sq ft GLA	1.0	3.5	4.5	Saturday-day
400,000-600,000 sq ft	1,000 sq ft GLA	1.0	4.0	5.0	Saturday-day
>600,000 sq ft	1,000 sq ft GLA	1.0	4.5	5.5	Saturday-day
Light industry	1,000 sq ft GLA	0.1	2.3	2.4	Weekday-day
Industrial park	1,000 sq ft GLA	0.1	2.2	2.1	Weekday-day
Residential					
Single family	dwelling unit	0.2	1.8	2.0	Evening
Condominium	dwelling unit	0.2	1.2	1.0	Evening

Source: Adapted from J.M. Kenelpp, "Parking Demand" in *The Dimensions of Parking*, 2nd ed. (Urban Land Institute and National Parking Association, 1983).

Space Needs

Various tables in this section indicate the estimated parking demands that should be accommodated. The number of spaces to be provided should be somewhat greater than the demand since it is not practical to assume that every space can be filled. This is necessary to avoid waiting in aisles in search of a space, especially where parking turnover is high. As a general rule, about 10 percent more spaces should be provided. However, for regional shopping centers where peaks occur only a few times each year, and where some aisle space is available for waiting vehicles, a 5 percent factor is suggested. Similarly, for residential parking (which peaks at night with no turnover) the required spaces should equal demand.

Demands assume minimal public transport use. Where a substantial number of people come

Table 6-33. Peak-Parking Demands by Time of Day for Selected Activities

		Peak-Parking Demand			
		Weekday		*Saturday*	
Activity	*Unit*	*Day*[a]	*Evening*	*Day*[a]	*Evening*
Office	1,000 sq ft GLA	3.0	-	0.5	-
Retail					
<400,000 sq ft	1,000 sq ft GLA	3.8	3.4	4.5	2.9
400,000-600,000	1,000 sq ft GLA	4.0	4.4	5.0	3.2
>600,000 sq ft	1,000 sq ft GLA	4.0	4.6	5.5	3.6
Restaurant (quality)	1,000 sq ft GLA	14.0	20.0	9.0	20.0
Cinema	seats	0.15	0.25	0.20	0.35
Hotel	rooms	0.6	1.7	0.6	1.2
Residential					
Single family	dwelling unit	1.3	2.0	1.5	2.0
Condominium	dwelling unit	0.9	1.4	1.0	1.4

a. Day = before 5 pm.

Table 6-34. Space Needs for Handicapped Parkers
(98 percentile)

Use	*Unit*	*Spaces*	*Minimum Spaces*
Office	1,000 sq ft GFA	0.02	1
Bank		-	1
Industrial			*Designated for employees needing them*
Restaurants	GFA	0.30	1
Retail			
<500,000 sq ft	GFA	0.075	1
>500,000 sq ft	GFA	0.060	1
Hotel	rooms	0.02	1

Source: "Handicapped Parking Supply," Institute of Transportion Engineering Committee 5D-8 *ITE Journal*

by transit, appropriate reductions in demand, and space needs should be made as shown by the procedures outlined for CBD parking demand estimates.

The parking demands based on the "85 percentile" values of comparable activities provide a basis for sizing facilities. However, for revenue estimates and financial analysis, average demands should be used.

CHAPTER 7

Site Selection and Planning

Selecting a site for off-street parking development involves balancing economic, engineering, environmental and intended usage considerations. The principal concerns are accessibility, site availability and suitability for development, and costs. These concerns are influenced by the type of parker to be served. Whether parking is to be developed on-site to perform ancillary service for its primary traffic generator or as a standalone facility to serve one or more off-site generators, site selection and location are of critical importance.

This chapter addresses site selection and planning considerations. It presents guidelines for assessing alternative sites for parking development. It suggests evaluation and design criteria necessary to perform site selection and planning analyses for parking at major types of land uses.

GENERAL SITE SELECTION GUIDELINES

Site selection may involve consideration of alternative sites or alternative locations on a given site. The planning and analysis process for siting parking is similar in both cases. The analysis process must examine:

1. accessibility for vehicular and pedestrian traffic;
2. site suitability for intended type of development; and
3. site availability and cost implications.

The assessment process must begin with an approximate idea of how much parking is needed and an understanding of the parking characteristics/land use to be served. Knowledge of local policies, requirements, conditions and development review processes is prerequisite. The development timeframe may also be critical for assessing site alternatives for potential impacts and construction sequencing possibilities.

Site Accessibility

Accessibility is a necessary ingredient for nearly all developed land uses. For parking sites, accessibility is related to parking's proximity to its traffic generator and adequacy of the street or roadway system serving the site.

Proximity to Traffic Generator. Walking distance between parking space and nearest pedestrian entrance to the traffic generator is the principal criteria for assessing parking site proximity. Acceptable distance can vary by type of traffic generator, general location of the generator, and walking conditions perceived by those who would use the parking space.

Walking distance acceptability correlates with length of time parked (parking duration). Very high turnover parking (convenience stores, banks, fast-food establishments, etc.) should provide all patron parking within 100 feet of building entrances. Residential parking also normally requires parking very close to building entrances. Longer walking distances may be acceptable for some types of retail and service attractions where parking durations average nearly an hour or more. The longest acceptable walking distances are normally associated with commuter and employee parking, and many kinds of special events.

Acceptable walking distance for most city-center traffic generators is longer than for similar attractions situated in outlying or suburban areas. This is primarily because of the availability of well-defined and developed facilities to accommodate walking trips in city centers. In locations where climate poses extensive periods of extreme weather conditions (extremely hot, cold, windy and/or rainy), acceptable length of unsheltered walking distances may be substantially shortened for all types of trips, especially those of a shopping or discretionary nature.

Perceptions can affect the acceptability of parking proximity as much or more than the actual walking distance. Steep gradients, stairs, and street crossings are among conditions that are perceived to make walking distances longer and/or less attractive. Where hilly terrain leaves few alternatives, parking sites located uphill from the pedestrian entrances of the traffic generator are favored, since pedestrians are psychologically more influenced by the perceived walking trip to the generator rather than the return trip. The nature and character of existing and proposed development along the walking path also influences acceptability and perceived security of the walking trip. Parking sites that provide a view of the destination are preferred since this serves to orient the walker and shorten the perceived walking distance.

Other factors affecting walking distance include generator attraction and zoning requirements. Generator attraction reflects market-induced conditions, which may change over time. Proximity requirements in zoning ordinances should be considered early in parking site analyses.

Street and Roadway Access. Site selection analyses must consider adequacy of the street/roadway network serving the site. Ideally, parking should be situated to intercept most parking traffic as directly as possible from this network. The objective is to provide parking access that causes drivers the least amount of circuitous travel to reach the parking facility entrance point. Vehicular access is of major importance to driver, parking operator and the community. Most projects require some degree of traffic access assessment to satisfy development lenders, designers and community approval requirements.

To perform a traffic access assessment, the following information must be determined or estimated.

1. A land-use determination describing size and nature of the proposed traffic generator is needed to help establish traffic volume and characteristics.

2. An estimate of trip generation rates and directional distributions of site traffic, as well as a determination of existing traffic volumes and roadway conditions are needed for traffic capacity assessment, including a forecast factor for background traffic growth.

3. An identification of site entrance and exit point locations is needed to assess traffic turning movements and traffic distribution at the site.

Heightened public awareness and concern for traffic congestion and attainment of air quality objectives has given the traffic impact analysis major importance. Anticipated traffic impacts can affect size and costs of proposed development, as well as site selection. Traffic impact analyses provide design information needed to correctly size parking facilities and accommodate traffic movement. They also have become requirements for the public review/approval process for new development in most communities.

Traffic impact analysis is used to determine whether the roadway network in the area of a proposed development will be able to handle existing traffic plus additional traffic generated by a proposed development. If the roadway network cannot accommodate the additional traffic, the impact analysis should indicate the types and extent of improvements needed and/or how traffic will otherwise be facilitated (Figure 7.1).

Features that make a potential site desirable from a traffic viewpoint (especially for larger traffic generators) include: location on direct access routes; close proximity to freeways; oppor-

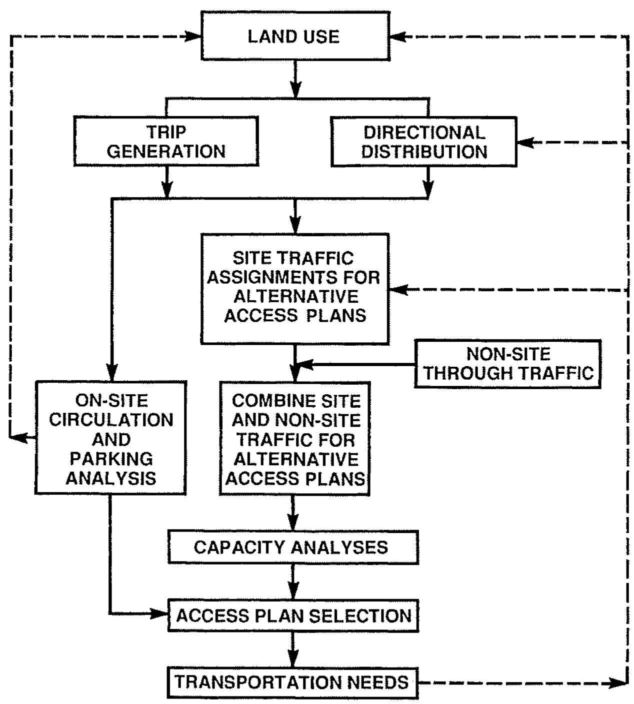


Figure 7.1. Site-traffic analysis

Source: Frank J. Koepke, Course Notes, The Traffic Institute, Northwestern University.

tunity for multiple access points; and excess capacity available on the street/roadway network serving the site.

Approach routes to the site should be capable of handling projected traffic loads at an acceptable level of service. Generally, this suggests that parking facilities exceeding about 1,200 spaces may require extensive traffic access provisions and/or nearby freeway access. A site requiring motorists to travel on side streets to enter a parking facility may be suitable for workers familiar with the location and routing, but would be less desirable for transient parkers. Side street access also may not be acceptable to residents and property owners affected by increased traffic.

Where parker origins are concentrated in one direction from the traffic generator or physical barriers force traffic to approach from only one direction, a parking site located between drivers' origin and generator destination is desirable. To locate parking on the far side of the generator from trip origins requires drivers to pass the generator on their way to park, increasing travel distance and traffic volume on local streets. In some instances this travel may not be avoidable, regardless of where the parking is located. For example, visitors to a tourist attraction often want to drive past the attraction to familiarize themselves with the location before parking. Under these circumstances a parking site on the far side of the generator may be more desirable.

Parking locations near freeways can minimize travel on local streets while providing easy access for motorists. Examples include Cobo Hall's parking in downtown Detroit, parking over Interstate 5 in Seattle, Copley Place over the Massachusetts Turnpike in Boston, and New Haven's Air Rights Garage (Figure 7.2). Albany's Empire Center has an Interstate highway spur servicing it directly, and the Roosevelt Field Shopping Center (New York) has direct access from the Meadowbrook Parkway. As shown in Figure 7.3, access may be provided via cross streets, or freeway ramp spurs may be used to provide direct ingress and egress to parking facilities.

A desirable parking site should enable access driveways to be located away from heavily traveled intersections. Figure 7.4 illustrates how access can be provided from city streets. The ideal traffic flow into a parking facility requires no turning traffic to cross through street traffic. Site access from high-volume two-way streets may require left-turn restrictions on entering and exiting the parking facility, special left-turn lanes at mid-block entrance locations, or access separated from adjacent street traffic.

Sites offering access from more than one street, such as corner locations, can be advantageous for parking if entrances and exits can be located without intersection interference. Corner sites, however, are desirable for retail development and often command a higher land cost. Figure 7.5 shows how a garage and commercial development can be arranged on a corner site to maximize commercial frontage and minimize traffic spillback across driveway access points.

Sidewalk pedestrian circulation should be recognized in site analyses. This consideration may limit the width (number of lanes) at driveway access points. Where vehicular entrances and exits are separated, entrances should be located in the upstream street traffic flow and exits located downstream. A detailed discussion of

Figure 7.2. New Haven, Connecticut's 2,800-space Air Rights Garage

Source: New Haven Parking Authority.

design criteria for driveway access is presented in Chapters 8 and 9.

Site Suitability for Development

Assessing site suitability for parking development involves site size, shape and topographical features. Environmental impact and aesthetic compatibility also have become major concerns in recent years. Other considerations include site development difficulties posed by subgrade conditions, existing improvements, easements and right-of-way dedications, and probable construction space needs and circumstances. Additionally, local zoning and other community-imposed requirements may severely limit development options.

Site Size, Shape and Topography. Parking design and layout efficiency are largely controlled by a site's size and shape. Rectangular sites generally are most desirable if they have sufficient width to develop multiple parking modules. Irregular-shaped sites may waste land or involve costlier construction. In some cases, however, odd-shaped sites may offer design opportunities that functionally benefit the overall project.

Steeply sloping sites may offer opportunities to access different parking structure levels from grade levels without the expense of interfloor ramps for vehicular travel. Surface parking lots

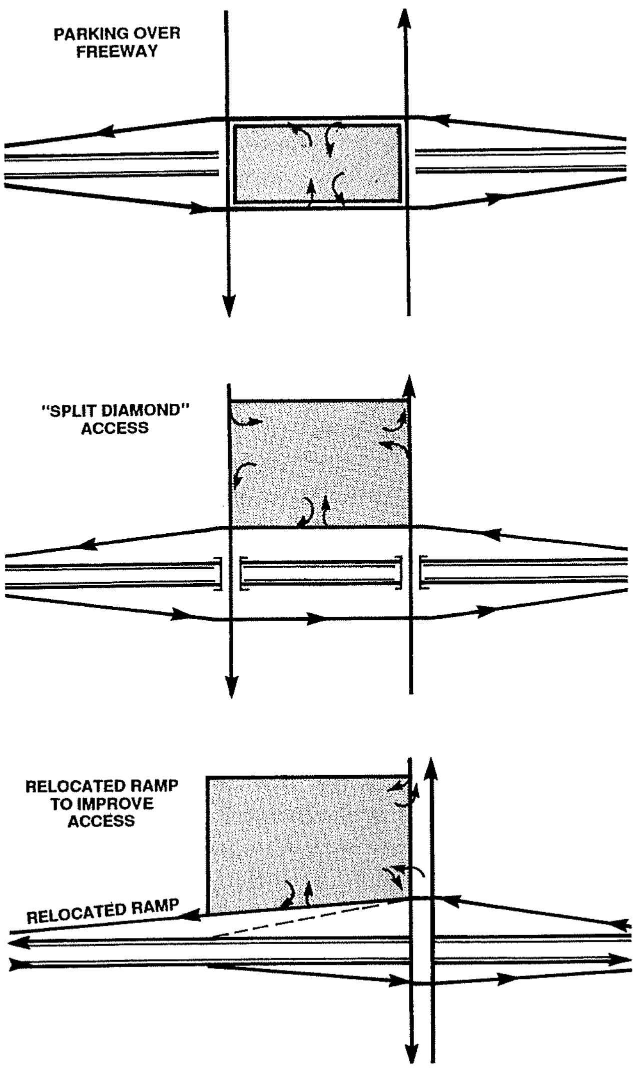


Figure 7.3. Illustrative freeway parking access concepts

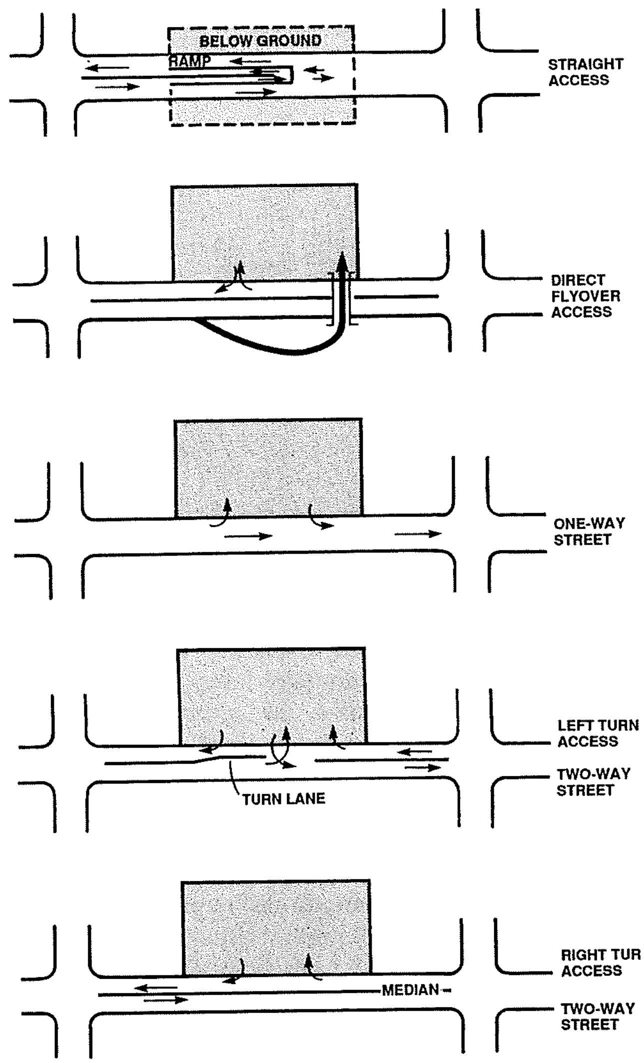


Figure 7.4. Illustrative street access parking concepts

can be developed on sloping sites if the gradient parallel and/or perpendicular to driving aisles is not excessive. The maximum slope depends on local regulation, type of parking to be served, climatic conditions, and lot surfacing material, among other factors. Parallel or cross-slope parking area gradients of up to 12 percent are commonly found. Sites requiring extensive retaining wall construction to facilitate development are generally avoided. Retaining walls are costly, and represent a potential liability and maintenance nuisance.

Site width is extremely important to parking layout efficiency. Maximum efficiency is afforded when site width (exclusive of required street and property line setbacks) can accommodate multiple parking modules of selected width. Double-loaded (parking on both sides of the driving aisle) parking module widths range from less than 50 feet to more than 60 feet, depending on parking angle, stall depth and driving aisle width used. The module width for 90-degree parking commonly ranges between 58 and 62 feet, for example.

Sites having effective minimum widths of 120 feet begin to provide the design flexibility needed to select cost-effective and efficient parking layouts. Effective widths of less than 120 feet limit design options and will generally increase con-

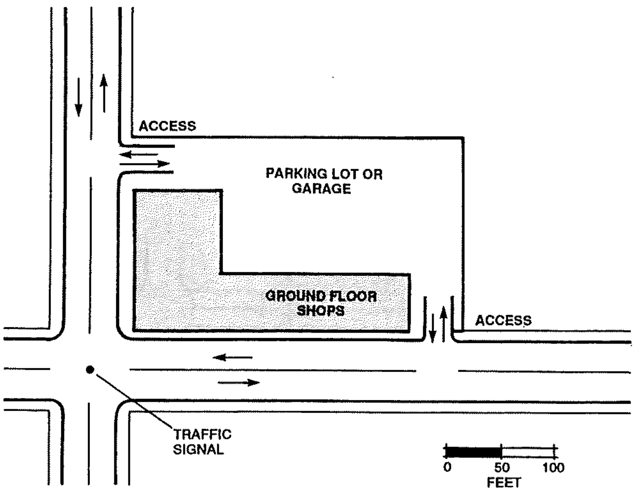


Figure 7.5. Illustrative treatment of a corner site where parking access points are located away from the street intersection and the ground-level is suitable for non-parking commercial floor area development.

struction and operating costs per parking space. Mechanical parking devices have been used on extremely narrow sites to provide necessary parking capacity; however, cost, serviceability and required on-site reservoir space for temporary storage of vehicles waiting to be parked should be considered in weighing the merits of mechanical devices and alternative sites.

Site length is relevant to both space and operational efficiencies. Longer sites permit more space-efficient parking development. As length increases, however, inefficiencies may result because of longer travel or increased traffic conflict when cross-over aisles are introduced to reduce travel length. Optimum site length is a factor of capacity analysis based on site-specific circumstances. Generally, about 300 feet of effective site length provides a good balance between area used per parking space and operational efficiencies.

Environmental and Aesthetic Considerations. Environmental concerns vary, depending on locale. Common to many are concerns for storm water runoff and snow removal dumping. In city centers of major metropolitan areas that are struggling to comply with clean air mandates, large parking developments and free-standing garages are increasingly discouraged. Many communities have strict requirements regarding maximum building heights and the percentage of a site that can be developed or covered by structure and surface parking.

Development compatibility, especially aesthetic appearance, has become a wider concern. Many communities have taken steps to augment and strengthen specific zoning requirements to help assure architecturally compatible and aesthetic parking development. A growing number of parking garages have facades that blend with their environs. In some city centers, stringent time limits (ranging from 1 to 5 years) have been placed on non-complying sites being "land-banked" as parking lots until conditions favor higher use development.

Assessments of environmental impact and compatibility are extremely site-specific. In cases where development may impact declared wetlands, the habitat of a rare or endangered life species, ancient burial grounds or ruins, historic structures, or the environmental quality of other properties, there is likely to be organized opposition supported by community groups if not specifically by the letter of the law. To the developer (public and/or private) this means delay and expense that alternative sites may avoid. Where market conditions are expected to be strong and alternative sites unavailable, developers have become extremely adept at developing environmentally-sensitive projects.

Architectural compatibility and aesthetics can increase development and maintenance costs. In a highly competitive market, however, these additional cost factors can be made insignificant by increased marketability and project acceptance (see Figure 7.6). While laws may require, and public pressures may demand new development to be environmentally sensitive and architecturally pleasing, the key to realizing these attributes rests primarily with market conditions, availability of alternatives and the artistry of the project design team.

Common Site Development Problems. Site assessment should consider the affect of obvious or potential problems that could hinder development or significantly increase development costs. Public records can reveal on-site existence of dedicated but undeveloped public right-of-way, and public or private easements or deed restrictions that might affect development. Public records also provide information on declared flood-

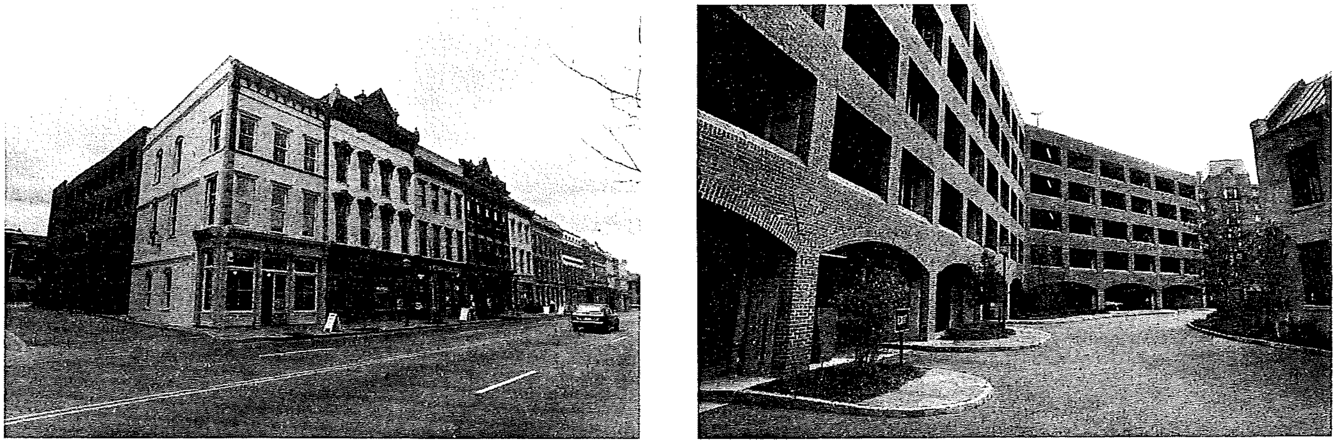


Figure 7.6. Charleston Place Garage was constructed behind older buildings that characterize the historical facades along Meeting Street in Charleston, South Carolina. Access to the garage is via an interior courtyard.

plain boundaries and restrictions applying to designated watershed areas. In some parts of the country, the control and disposal of storm water runoff is an issue that can affect development plans and costs.

Location and description of utility services at the site should be determined. Because of delays in developing sanitary sewage treatment facilities, some communities place temporary moratoriums or other restrictions on new connections. This could delay or affect development. The available capacity of water supply and storm sewers also should be checked to determine the extent of possible off-site service expansion work that may be necessary to accommodate new development. On-site relocation of existing utilities may also be a significant cost concern with some sites.

Existing developments or previously occupied sites may hide special problems. Soil contaminated by leaking petroleum or chemical storage tanks and/or waste dumping could mean significant clean-up costs to develop a site. Site assessment should consider the costs and consequences of clearing other existing improvements to ready the site for new development. Under some circumstances it might be necessary to provide relocation assistance to occupants of existing facilities.

Field inspections and site testing can reveal foundation soil conditions and presence of rock formations that might increase construction costs. Some development projects have been delayed because excavation uncovered archaeologically significant findings. While this type of situation is often difficult to foretell, it might be prudent to check with local authorities to see if there is reason to believe the site may be historically significant.

Site assessment should consider the availability of space needed for construction activities, as well as any other unusual requirements necessary to protect the environs and/or handle traffic during construction. Depending on proposed development plans, temporary off-site space may be necessary for construction staging. Temporary construction easements may be needed to facilitate site access or other construction activity. Handling traffic and parking, and maintaining access and activity (for possibly one or more affected properties) during the construction period may be an expensive proposition.

Site Availability and Land Cost Implications

Land availability and costs are major influences in determining what type of parking to provide. Where land is abundant and comparatively inexpensive, surface lot parking may be a better alternative than a parking garage. Under conditions of high land costs or limited land availability, structured parking may be financially justified. Where parking must be provided in environmentally or aestheticly sensitive places, underground parking may be necessary.

Limited availability of land in central business districts (CBDs) and major outlying centers results in relatively high land costs. This has increased pressure on public and private developers to make optimum use of land by building multiple-use parking structures to house the traffic generator as well as its parking.

Structured Versus Surface Parking. Land costs at which parking garages become economically warranted can be computed from the following formulas.

Parking garage versus lot:

$$L \geq \frac{N}{N-1} (C_2 - C_1)$$

Underground garage (no land cost) versus multi-story garage:

$$L \geq N (C_3 - C_2)$$

where:

N = Number of levels.
C_1 = Cost/sq ft, lot.
C_2 = Cost/sq ft, garage or deck.
C_3 = Cost/sq ft, underground garage.
L = Land cost/sq ft.

The effects of land and construction costs (exclusive of interest and finance costs) on the unit costs for surface parking lots and parking structures are further illustrated in Figure 7.7. This

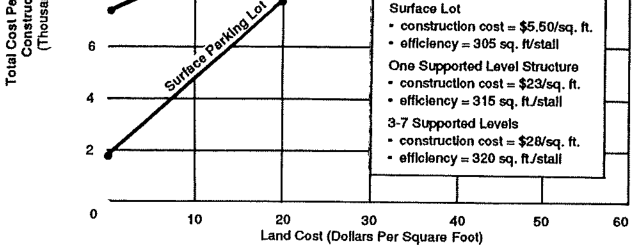


Figure 7.7. The effects of land value on parking space cost

figure denotes the economic range for each facility type in relation to land costs for 1989 conditions, and is based on the following assumptions:

- Depending on facility type, 300 to 320 square feet per parking space.
- Costs of $5.50 per square foot for lots, $23 per square foot for simple one-supported-level deck construction, $28 per square foot for multiple-level garage construction and approximately $50 per square foot for below-ground construction.
- 15 percent added to construction costs for engineering, architecture, and contingencies.

For land values below $25 to $30 per square foot, surface parking lots are more economical per space than structures. Where land costs exceed $110 per square foot, underground parking garages may be more economical.

The tradeoffs shown in Figure 7.7 reflect one point in time (1989), and will change depending on relative increases (or decreases) in unit construction costs. They also will vary when a portion of land costs can be assumed by non-parking developments on the same site as parking.

SITE PLANNING GUIDELINES FOR SPECIFIC ACTIVITIES

Location, type and arrangement of parking facilities must reflect the characteristics of the activities that the parking will serve. The following guidelines show how various locational, environmental and cost concepts can be applied to planning parking for activities commonly found in most urban areas.

Downtown Parking Facilities

The location of parking in the CBD depends on: (1) size, intensity, and character of the central area; (2) availability of public transport; (3) reliance on retail business, office employment and automobile travel; and (4) public policy decisions regarding development and roles of various transport modes.

In most city centers, conveniently located parking is still essential — especially for business and shopping trips. Parking is necessary to provide good access by car so that the central area can compete with suburban locations. Except for the large "transit-oriented" city centers, convenient parking is viewed as a key to continued economic vitality.

Location of parking within a city and its centers relates to the city's size.[27] In an idealized situation, parking facilities are provided in the CBD. As city size grows, parking is provided on the CBD fringe, adjacent to the core area. For large transit-oriented cities, additional parking is located along major radial and circumferential routes, and tied into express transit systems.

Downtown parking systems have evolved over time in response to changes in street patterns, development and access concepts. Initially, parking garages were most commonly located in or near the CBD core along major arterial streets. Parking lots were common throughout the city, with CBD lots usually representing a short-term interim land use. Madison, Wisconsin, is typical of the location strategy used to provide public parking. Parking garages were established just outside the core area, and keyed to major one-way street couplets (see Figure 7.8).

Current emphasis on downtown garage development focuses on providing parking as an integral part of multiple-use buildings. Parking may be contiguous to proposed shops and offices, like St. Louis Centre (Figure 7.9) and Charleston Town Center, Charleston, West Virginia (Figure 7.10). Or the parking may be placed at one of the stores (i.e., Broadway Plaza, Los Angeles, Figure 7.11), or located below the commercial development (i.e., Water Tower Place, Chicago, Figure 7.12), or "wrapped around" the shops as in Stamford, Connecticut's Town Center.

There appears to be a trend away from standalone, single-purpose parking structure development within urban centers. As land values increase, development economics encourage parking to be developed in mixed-use structures. This physical integration enables land costs to be shared, and assures greater "supportable values," higher tax rateables through higher development on limited site space.

Park-and-Ride (Transit Parking)

Park-and-ride facilities for transit riders and carpool passengers are a growing phenomenon in North America. They are provided at most suburban transit stations in areas where population densities are too low to generate walk-in patrons or frequent bus service. They vary in size, location and type, ranging from small bus and carpool lots of less than 100 spaces to 3,000-space parking garages.

Role and Rationale. The park-and-ride concept enables public transport and private automobiles to each operate in the environment that they are best suited. Commuters can drive to conveniently located park-and-ride lots, and then transfer to bus or rail transit, or carpool to complete their trips. Consequently, park-and-ride facilities are an essential part of regional transportation strategies that emphasize public transport and ridesharing to limit need for roadway infrastructure expansion and to address traffic congestion and attainment of air quality objectives.

Park-and-ride involves the *transfer* of parking space from the city center outward along express transit routes. It recognizes that the likelihood of driving increases as people move further from the city center. It allows the "line-haul" trip to be made by express transit or carpool, thereby reducing CBD commuter parking requirements and core-bound car travel with the attendant air quality and traffic implications. It saves passengers time, and expands the catchment areas of express transit service. The secondary distribution by automobile: (1) increases the public transport market; (2) reduces the extent of express and local transit routes; and (3) permits wider station spacings on express transit routes, thereby improving line-haul operating speeds and efficiency.

Types. There are three basic types of park-and-ride facilities from a planning and design perspective.

1. *Commuter rail station* lots date back to the early 1900s. Typically, lots were located near the town center and progressively expanded along rail right-of-way to meet growing demands. Parking facilities have been provided along most rail transit and light rail transit lines built since World War II. Lots up to 2,000 spaces are common. Large parking garages with capacities of

[27] Adapted from J.M. Hunnicut, "*Parking Loading and Terminal Facilities Transportation and Traffic Engineering Handbook*, 2nd ed. (1982).

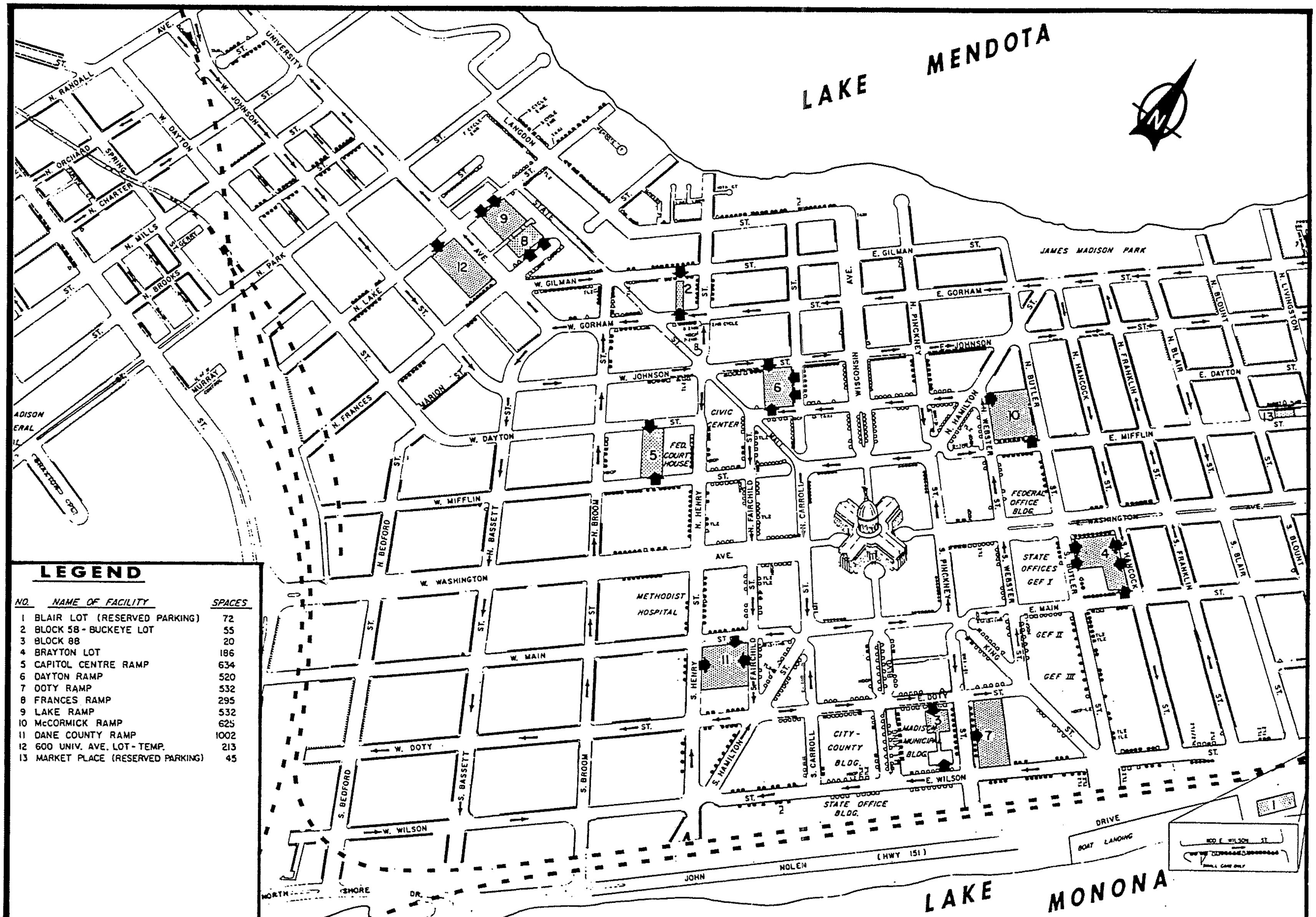


Figure 7.8. Madison, Wisconsin, is typical of strategies to locate public parking around the perimeter of the downtown core area.

Source: City of Madison, Department of Transportation, Parking Division.

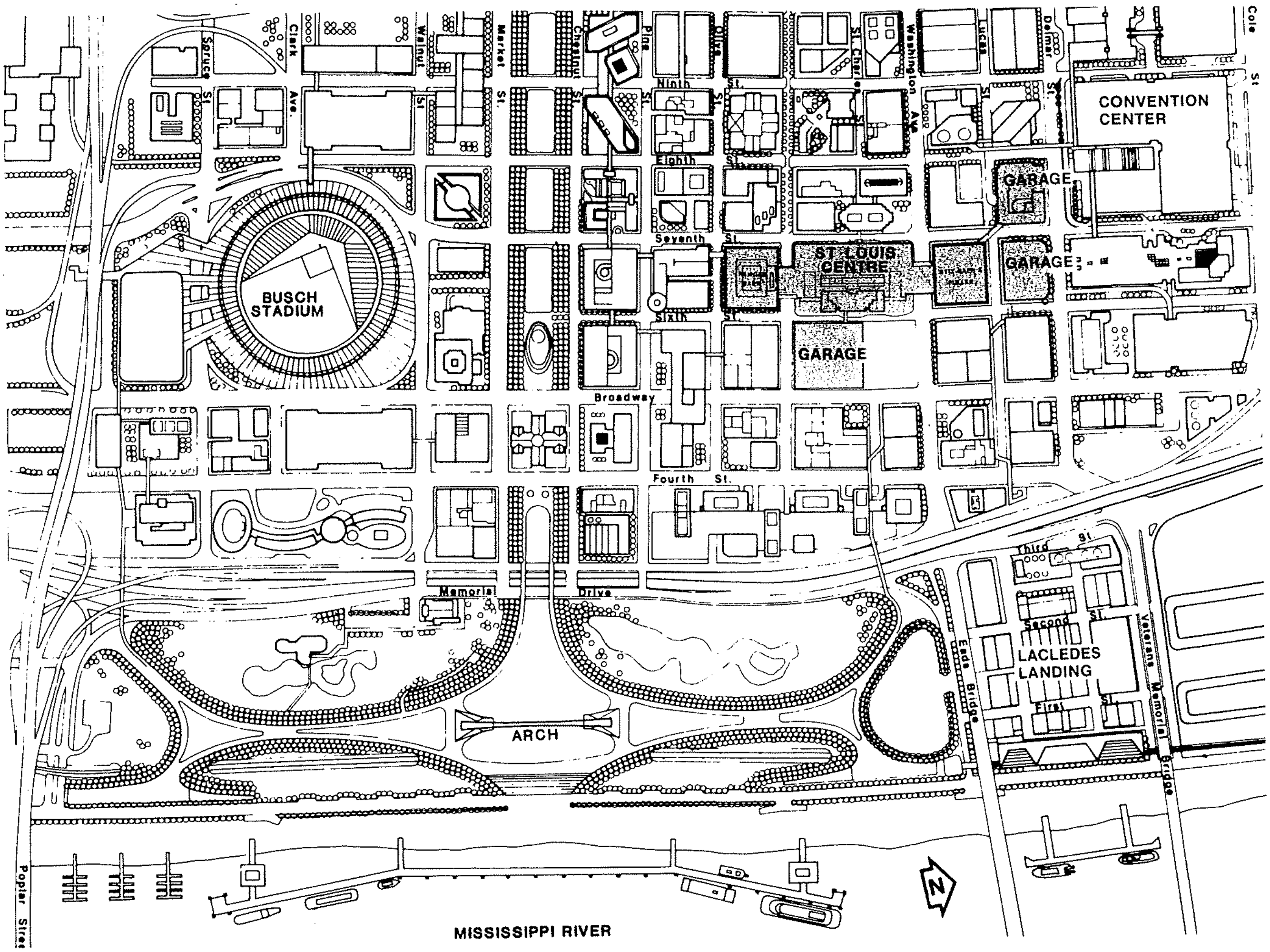


Figure 7.9. St. Louis Centre's strategic location within the central business district is designed to attract shoppers from the growing downtown workforce and tourist market. Skywalks link garages with major destinations.

Source: J. Thomas Black, Libby Howland and Stuart L. Rogel, *Downtown Retail Development: Conditions for Success and Project Profiles* (Washington, D.C.: Urban Land Institute, 1983) p. 46.

2,000 to 3,000 spaces are provided at key stations in Boston and Washington, D.C. (Figure 7.13).

2. *Bus transit* commuter parking lots serve express bus routes that often operate in non-stop service over priority high occupancy vehicle freeway lanes. Lots adjacent to freeways may range up to 2,000 spaces; most facilities, however, are smaller.

3. *Carpool* lots are provided at or near freeway interchanges (Figure 7.14). They may be provided by means of agreement with private property owners or on public property. The California Department of Transportation, for example, has 16,000 parking spaces in 283 facilities of which 148 are located on state owned property, 870 are on private property and 51 on local government property. Peak usage approximates 10,000 parkers daily. Most carpool lots contain less than 200 spaces.

Planning Criteria. Outlying change of mode parking facilities work best where car travel to the city center or other large employment center is inhibited by traffic congestion, tolls or costly parking — conditions that make transit and ridesharing more attractive. Carpool parking must be located for easy access to and from major

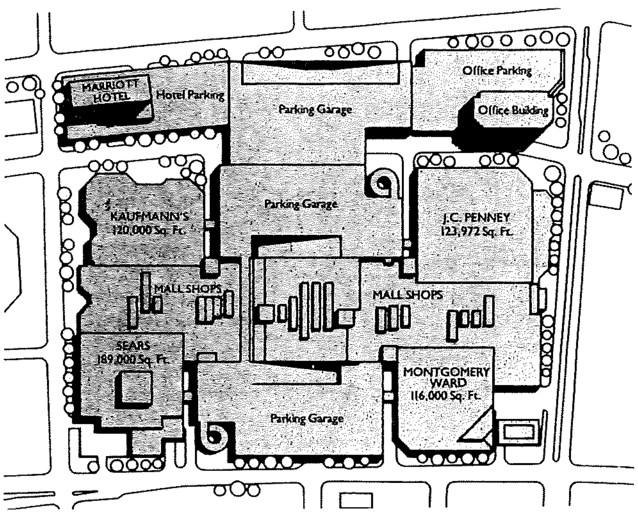


Figure 7.10 The Charleston Town Center is a critical component of the overall redevelopment plan for downtown Charleston. Parking garages are contlnguous to the multiple-use development.

Source: *Downtown Retail Development* (Washington, D.C.: Urban Land Institute).

roads, and free or at very low cost to parkers. The multimodal trip to the employment center should be cheaper and faster than the trip by car. Ideally, time savings should exceed 5 minutes during peak-travel periods.

Transit service should operate at frequencies of 10 to 12 minutes or less during peak periods. Service frequencies of 20 to 30 minutes are acceptable during midday hours. Headways of 20 to 30 minutes, however, may be provided where commuter rail service operates.

Site Selection and Location. Park-and-ride facilities should be placed where they can help promote the broader transportation objectives of (1) improving mobility and convenience for travelers; (2) encouraging desirable land-use development; (3) minimizing direct public expenditures for transportation; and (4) minimizing adverse impacts on local communities and neighborhoods.

Their location in relation to the city center (or

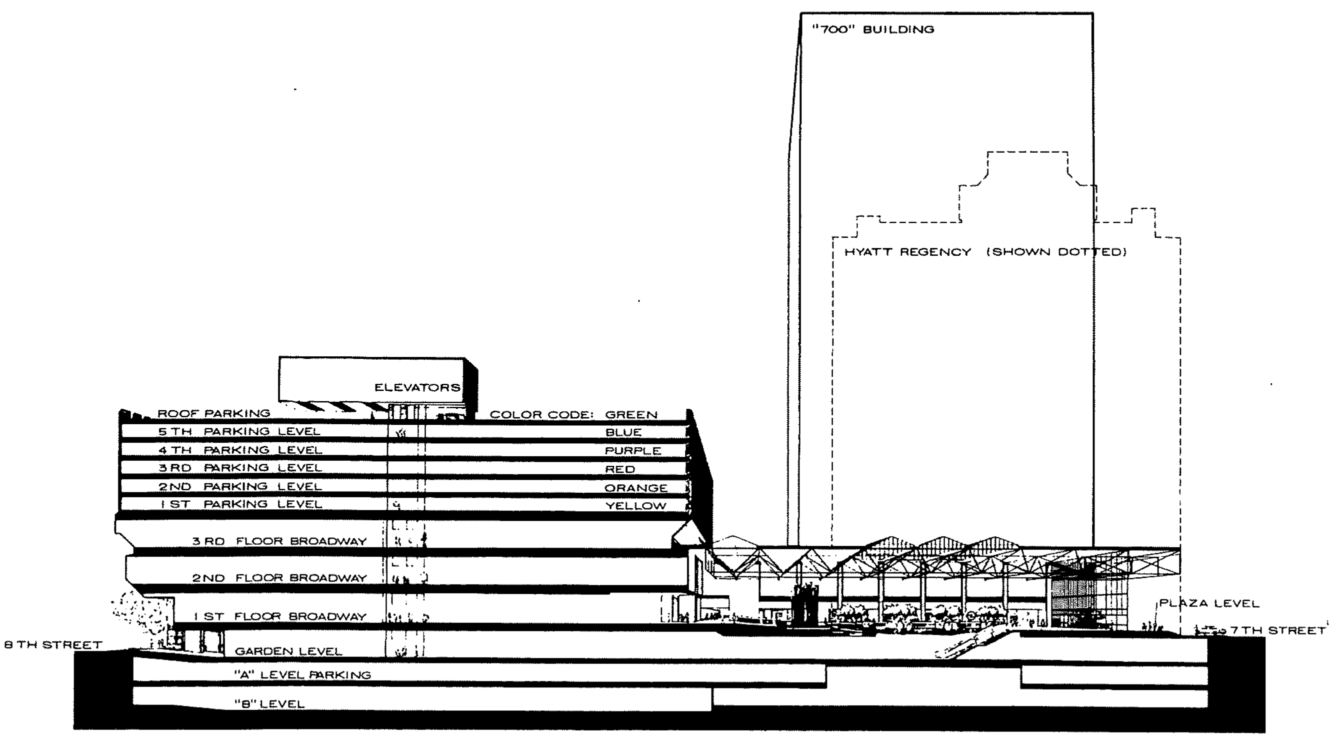


Figure 7.11. The Broadway Plaza retail mall occupies the first two levels of a 4.5-acre mixed-use development in downtown Los Angeles. Parking is provided both above and below retail levels.

Source: *Downtown Retail Development* (Washington, D.C.: Urban Land Institute, 1983).

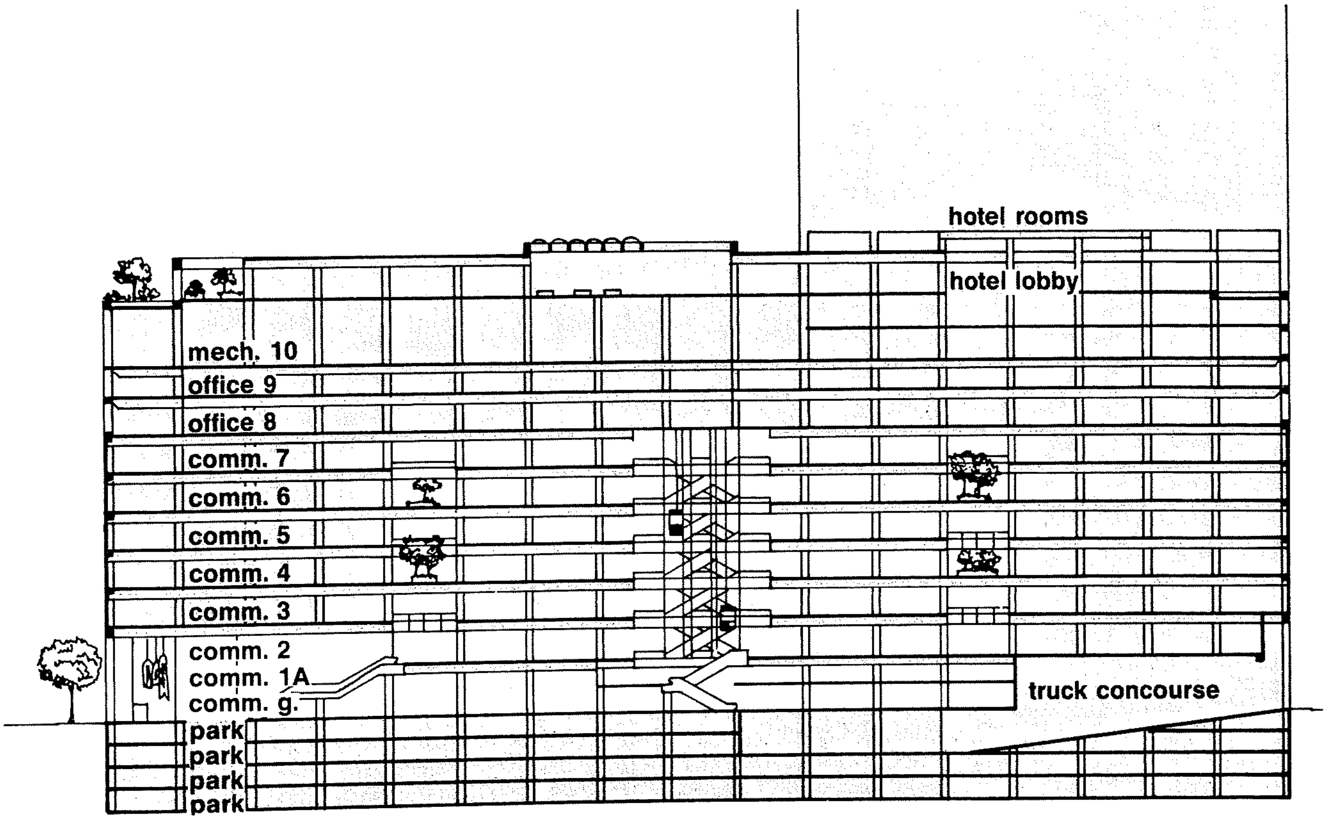


Figure 7.12. Water Tower Place offers specialty retail and fashion goods to the office workers, hotel guests, condominium residents, and theater-goers who visit the large mixed-use development.

Source: Courtesy of Loebl, Schlossman, Bennett & Dart, & C. F. Murphy Associates.

other major activity centers) depends on: (1) locations of topographic barriers, traffic congestion and travel constraints; (2) express transit routings; and (3) land availability and costs. These influences vary from city to city; however, in most communities, transit park-and-ride facilities should be located at least 5 to 8 miles from the center. Carpool lots work best where the journey to work exceeds 15 miles over congested highways.

The following guidelines influence *where* park-and-ride sites are located:

1. Park-and-ride transit services generate the greatest ridership in travel corridors that experience intense traffic congestion. Facilities should be located where they can intercept motorists in *advance* of *congestion* or *before* the point of major route convergence. Sites near junctions of radial transit lines and circumferential expressways provide ideal locations since they can tap a wide catchment area. Access should be upstream of major congestion points.

2. Sites should be located between their market area and major activity center. Motorists will use park-and-ride lots where they can be easily intercepted enroute. They are less likely to patronize park-and-ride where they must backtrack or leave the corridor of their primary route.

3. Transit park-and-ride sites should be located at least 5 miles from the city center, or other activity center served. (In most cities, they will serve CBD travelers; however, there is a growing tendency for some park-and-ride facilities to serve other major activity centers.)

4. Ideally, sites should be located as far from the downtown area as practical to remove the maximum number of vehicle-miles of travel during the peak-traffic period. Eliminating the last mile of a 6- to 8-mile auto trip to the center does not appreciably reduce radial highway conges-

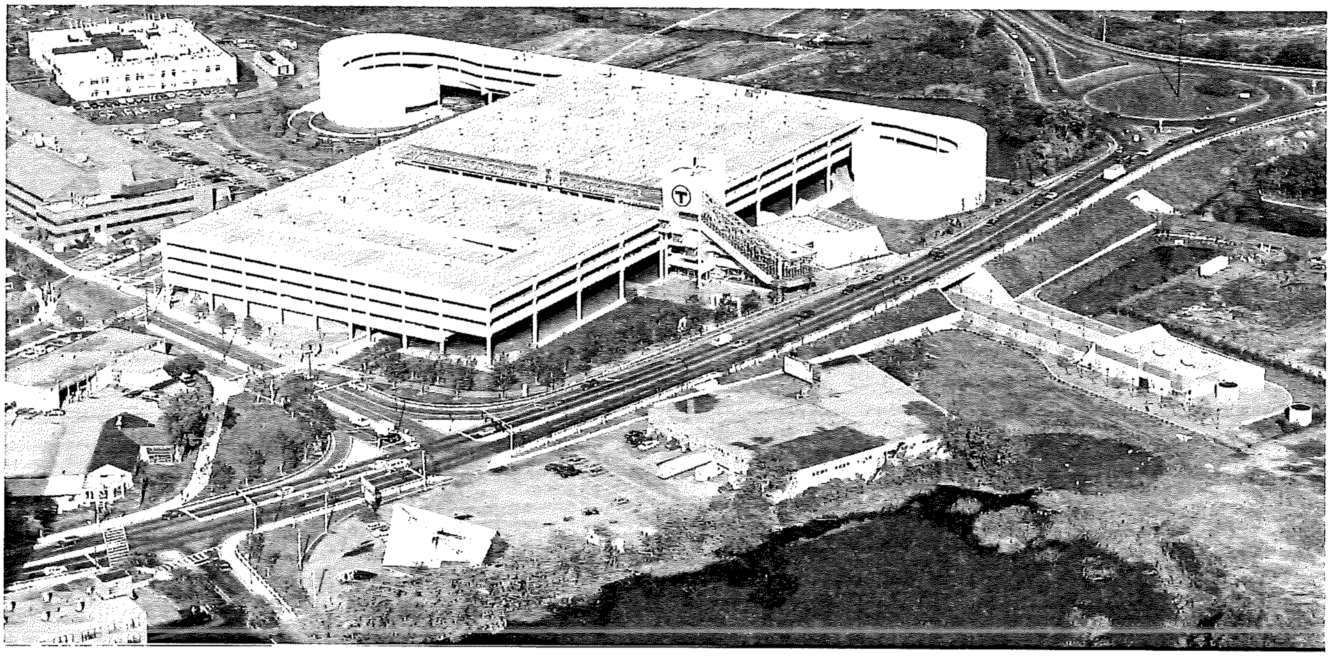


Figure 7.13. The Alewife transit station and parking garage in Cambridge, Massachusetts, contains 2,000 parking spaces, a car and taxi drop-off, a 12-berth bus platform, numerous bicycle racks, and a major subway stop.
Source: Photo by Alex S. MacLean/Landslides.

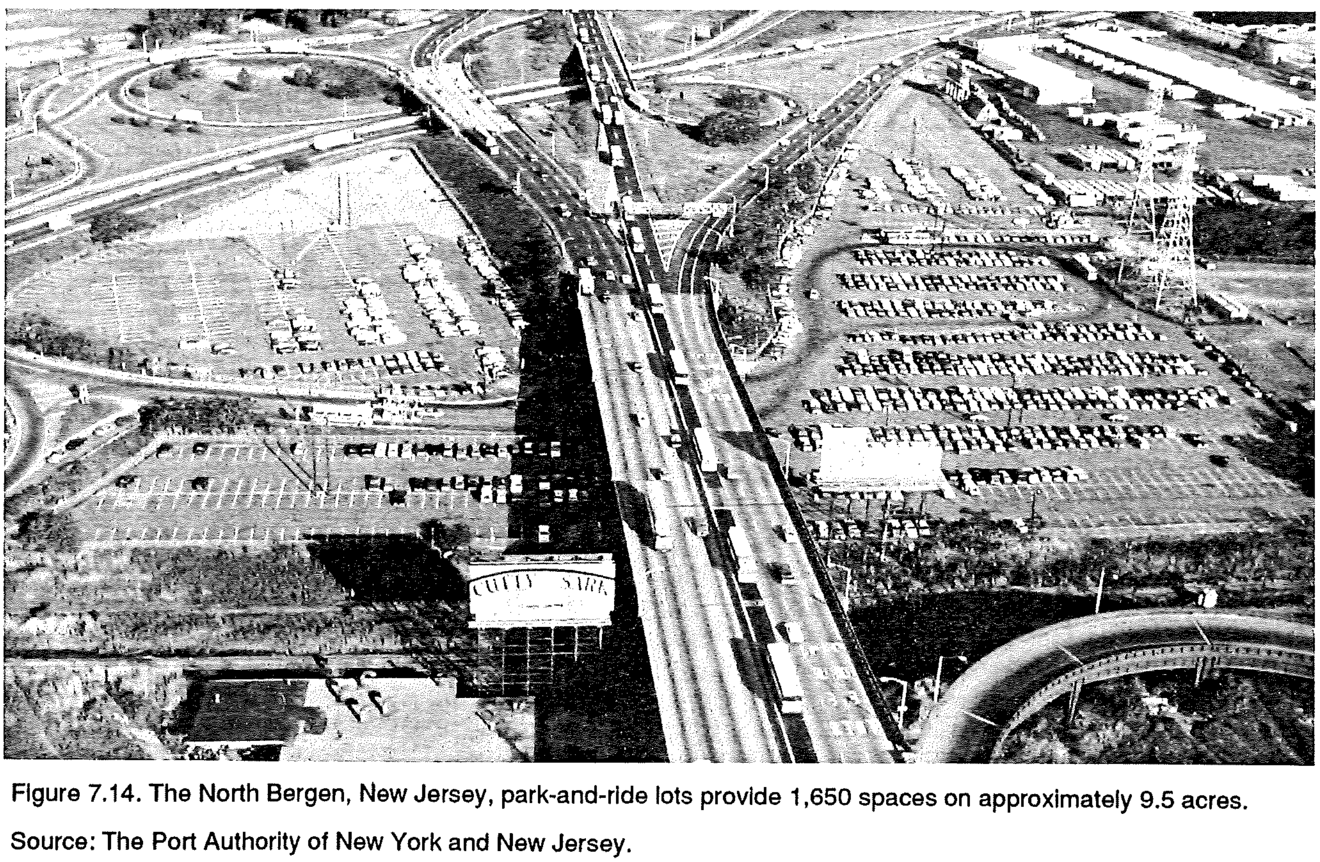


Figure 7.14. The North Bergen, New Jersey, park-and-ride lots provide 1,650 spaces on approximately 9.5 acres.

Source: The Port Authority of New York and New Jersey.

tion and capacity requirements. Moreover, increasing the parking supply on the downtown fringes might divert passengers from parallel line-haul transit routes.

5. Sites should be located where they will not draw patrons from parallel transit services. Park-and-ride transit service should not compete with local bus routes. If the current number of park-and-ride spaces available are sufficient to handle demand from a given area, other facilities in the same travel corridor should be located no closer than 2 to 3 miles.

6. Sites should be compatible with adjacent land uses, should not adversely impact nearby environments, and should achieve a reasonable level of usage relative to development costs. Site selection should give priority (in order of importance) to (1) land currently in parking use; (2) undeveloped or unused land now in public ownership; (3) undeveloped private land; and (4) developed private land. Every effort should be made to locate facilities where they will be acceptable to neighboring areas.

7. Park-and-ride facilities should be removed from town centers or other major activity nodes. This will allow high-density, transit-oriented development clusters at selected transit stops; it will separate commuter and local parking demands; and it will reduce development costs and impacts.

8. Parking development costs should be kept to a minimum consistent with needs. Consequently, parking lots are preferable where conditions permit. Parking garage construction, however, may be feasible where land supply is limited and demands are high.

9. Development costs and environmental impacts for bus and carpool parking sometimes can be minimized by jointly using existing parking facilities in shopping or recreation centers where peak usage does not coincide with commuter peaks.

10. Sites should be reasonably flat and well drained so that grading, paving, and drainage can be provided at minimum expense. For security purposes, sites should be selected and developed for convenient visual monitoring from adjacent roadways.

Site Size. Size of a park-and-ride facility depends on several factors: (1) estimated parking demands; (2) transit service frequency; (3) street system capacity; (4) availability of reasonably priced land; and (5) environmental constraints. More transit station parking space generally is needed in low-density suburban areas where there is very little feeder bus or walk-in traffic. Conversely, where space is limited, priority should be given to providing space for passenger drop off (kiss-and-ride) and short-term parking for drivers waiting to pick up passengers.

Unduly large or small facilities should be avoided. Small lots will not provide enough space to justify frequent transit service while very large facilities require long walking distances. Suggested size ranges are as follows:

- Carpool lots should range from 50 to 200 spaces depending on site conditions.
- Bus park-and-ride lots should contain at least 250 spaces. An optimum size range is 400 to 700 spaces, and 1,200 spaces represents a realistic maximum size.
- A lot should provide about 400 peak-hour riders to justify 10-minute bus service during the peak hour. This relationship assumes that (1) bus service is provided exclusively for the lot; (2) typical peak-period loadings of 45 persons per bus; and (3) 50 to 60 percent of the daily arrivals are in the peak hour.
- Rail transit facilities range from 500 to over 2,500 spaces. These facilities can support all-day transit service and draw patrons from a large catchment area. Larger garages usually create peak-hour street access problems and/or involve excessively long walking distances.
- The maximum accumulation of parkers should not exceed 90 percent of the total number of spaces provided. If there is no available back up space in adjacent areas, the design load factor should not exceed 80 percent.

Access Concepts. Park-and-ride facilities should be visible from major approach roads. Access and circulation patterns should be clear and simple, and they should enable patrons to arrive and depart via the same route.

About 40 percent of the daily traffic entering a transit park-and-ride site occurs in the morning rush hour and 30 percent of the peak-hour traffic enters in the peak 15 minutes to accommodate morning and evening surges. Careful location and sizing of entrances and exits is necessary. Traffic control devices (or signals) and directional and informational signs should be provided.

The following guidelines are suggested to assure convenient access and to minimize impacts of park-and-ride facilities on surrounding streets.

1. Access ramps and roadways connecting park-and-ride facilities to major commuter routes should avoid excessive interruptions from traffic signals, curb parking interferences or frequent commercial curb cuts. Parking site entrances and exits should be located to avoid spillback from nearby intersections or freeway interchanges. Park-and-ride traffic should not be made to filter through residential neighborhoods.

2. Access routes should be related to principal patron directions of approach. When practical, park-and-ride traffic should be equitably distributed over boundary routes and should not be unduly concentrated on a single approach route.

3. When a choice readily exists, it may be desirable for the park-and-ride lot to be located on the right side for inbound traffic to eliminate need for left-turn movements. When a park-and-ride facility is located on the left side of a two-way arterial for inbound traffic, left-turn storage lanes should be considered for inbound vehicles during the morning peak.

4. Directional and informational signs along major routes leading to the park-and-ride facility should be provided to introduce the service to commuters and make facilities easier to reach. Internal signing should delineate commuter parking areas, passenger drop off and short-term parking waiting areas, and bus passenger loading areas.

Site Orientation and Design. Layout of a transit park-and-ride facility is similar to that for other parking facilities in many respects. It is different, however, in that facilities (1) must accommodate transfers between automobiles and transit; (2) provide some short-term as well as long-term parking and passenger loading areas; and (3) handle most traffic in two short peak periods daily.

The transit passenger loading area represents the focal point of a park-and-ride facility. It should be located adjacent to, over or under the parking facility, rather than within the facility itself.

The internal site design should minimize pedestrian travel to reach passenger loading areas. The following location priorities are suggested in terms of proximity to the passenger loading area: (1) bus loading-unloading; (2) taxi loading-unloading (may mix with buses or cars); (3) handicapped, bicycle and motorcycle parking; (4) passenger drop off and pick up (kiss-and-ride); (5) short-term parking; and (6) long-term parking. Pedestrian-vehicle conflicts should be minimized.

Figures 7.15 and 7.16 show how park-and-ride lots can be arranged to give priority access to buses, taxis and kiss-and-ride patrons. Parking is oriented to enable parkers to use driving aisles as walkways to reach the transit terminal. Entrance and exit points are separated to simplify traffic control and vehicle routings.

Passenger loading and unloading areas should be physically separated from the parking area. Some transit agencies (i.e., Toronto Transit Commission and Washington Metropolitan Area Transit Authority) actually provide the bus interchange area, kiss-and-ride facilities and park-and-ride lots in separate locations that are clustered around the train station (Figure 7.17). A common practice is to provide physically separate access roads for buses within the parking area (Figure 7.18).

At low volume terminals (less than 12 to 15 ter-

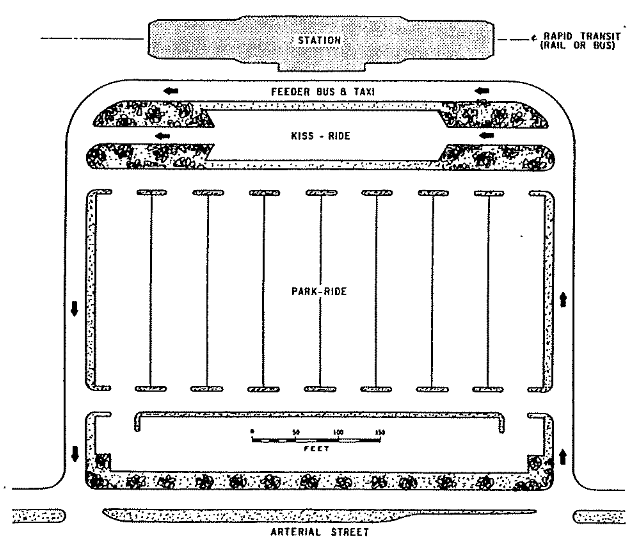


Figure 7.15. In this typical park-and-ride lot, the bus, kiss-and-ride dropoff, and parking areas are separate, but share common entrance and exit points.

Source: Herbert S. Levinson, NCHRP 155.

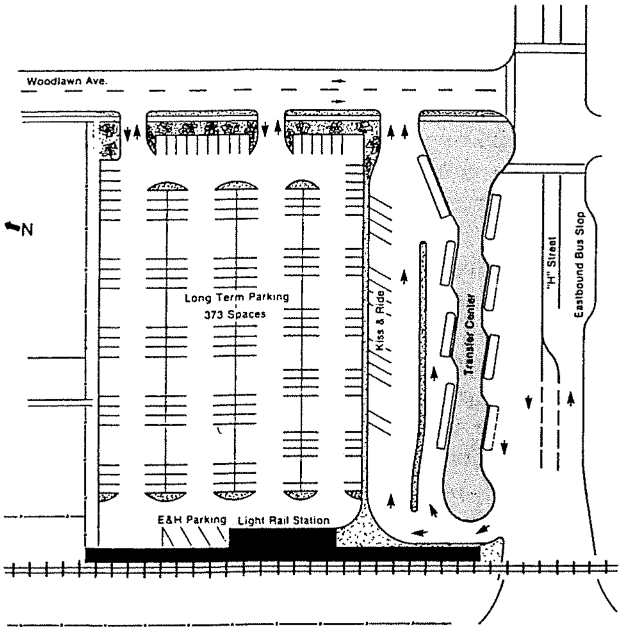


Figure 7.16. Plan view of Chula Vista LRT Transit Center, San Diego, California

Source: *Planning and Designing a Transit Center Based Transit System: Guidelines and Examples from Case Studies in Twenty-two Cities* (Seattle: Washington, September 1980).

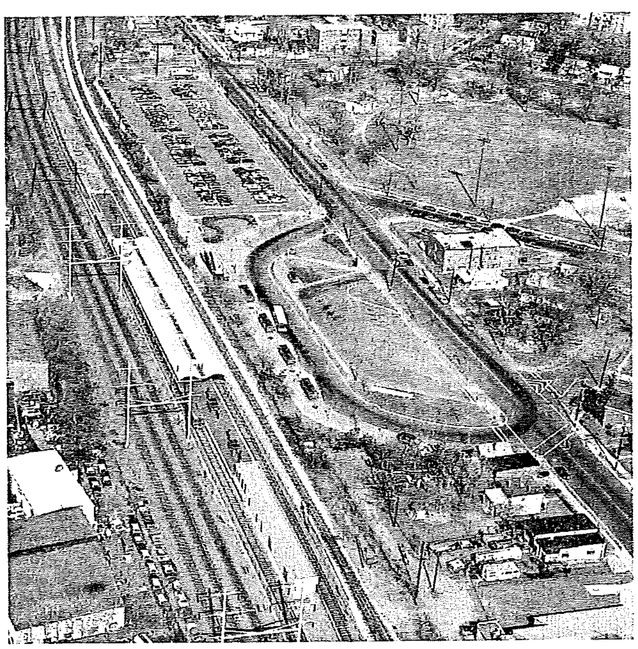


Figure 7.17. The parking area at this park-and-ride lot is completely separated from bus loading and transit platform areas.

Source: WMATA photo by Phil Portlock.

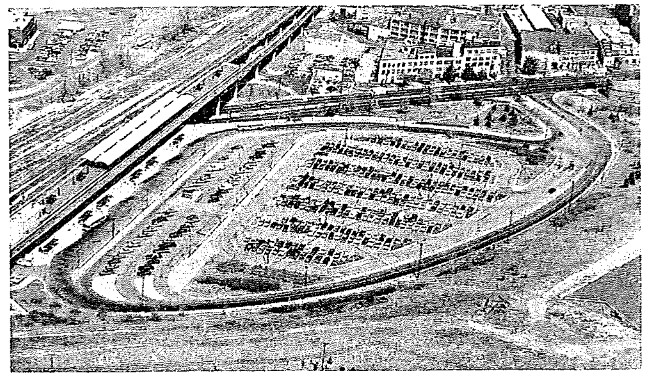


Figure 7.18. At this park-and-ride lot, bus access roads are physically separated from parking area access.

Source: WMATA photo by Larry Levine.

minating buses per peak hour) buses may share parking area roadways with passenger drop off and parking traffic. For greater volumes, buses should have special lanes or roadways to access passenger loading areas. All bus roads should be wide enough to permit passing of standing buses. Where facilities exceed 500 parking spaces, driving aisles serving parking should be clearly separated from bus and passenger drop off access lanes.

Accessible parking spaces for the physically handicapped should be provided in accordance with locally accepted standards. As a general guideline, approximately 0.5 to 1 percent of the total parking spaces should be provided for handicapped parking.

Bicycles generally play an insignificant role in access to U.S. public transportation. However, in recent years there has been notable growth in the number of transit agencies providing secure bicycle parking at rail and bus stops and at transit park-and-ride facilities. California, Connecticut and New Jersey are among the leaders in developing bicycle access to public transit. For bike-and-ride commuting to play a significant role, secure bike storage racks, lockers or supervised bicycle parking must be provided. While cyclists have demonstrated a willingness to pay modest fees for secure bicycle parking at transit stations (ranging between $20 and $60 a year), the more successful U.S. programs lease secured bicycle parking at no cost other than a key deposit.

Passenger drop-off areas should be provided close to the station entrance. Spaces for transient vehicles waiting for transit riders should be provided at each transit park-and-ride facility. About 1 to 3 percent of the total spaces should be designated for 20-minute parking. These spaces should be clearly separated from commuter parking areas, but they may be used for midday parking if properly controlled.

The parking area for commuters should be based on 400 to 500 square feet per parking space. These values account for parking stalls, pedestrian paths, access roads, and landscaping setbacks. They should be increased where irregularly shaped land parcels with unusual circulation patterns exist.

All-day parking generally is designed to be right-angle parking with the aisles aligned perpendicular to the bus loading area or transit passenger platform to facilitate pedestrian movement. Pedestrian walking distances should be less than 600 feet. They should never exceed 1,000 feet. These criteria limit maximum lot sizes to about 1,200 spaces.

Principal pedestrian waiting and loading areas should be sheltered, and a covered walkway should be provided for the remaining distance to bus (or train) boarding areas. Protection against rain, with a 14-ft clearance over the bus roadway, should be provided. In northern climates, transparent shelters, and in large facilities, heated waiting rooms, are desirable. Grade separated pedestrian crossings should be clearly marked.

Additional features may include lighting, perimeter fencing, security personnel, public telephones, landscaping, trash receptacles, newspaper stands, vending machines, informational displays, seating benches and public restrooms. Park-and-ride facilities might contain convenience stores, gas stations, dry cleaners, or even day-care centers to attract commuters.

Airports

Airport parking is an expanding market. This market has been triggered by air travel growth; dispersed origins of airport travelers; and the continued expansion of airport terminals. Airport parking is usually profitable, because its relative price is inelastic, and because the demand for parking space is around the clock each day of the year.

Siting of airport parking is influenced by the design philosophy for the landside terminal facilities. And, it is affected by the relation of the airport to the surrounding road system.

The parking system normally includes; (1) short-term parking for passenger drop off, pick up or waiting; (2) long-term parking for air travelers; and (3) remote parking off-site — either near the airport, or as part of a "park-and-fly" limousine/bus service. (Los Angeles' "Fly Away Program" and Connecticut Limousine's outlying parking terminals in major Connecticut cities apply the park-and-fly concept in the truest sense.) The appropriate mix of these types of parking depend on land availability, land costs, and policy decisions relative to managing the airport parking supply. Rates should encourage long-term parking at the outlying or remote facilities. Additional parking space should be provided for employees, buses, taxis, and car rentals.

Parking lots and garages within walking distance of the airport terminal should provide direct pedestrian connections to the airport terminals. Pedestrianways should be grade-separated from the access road system. Maximum walking distances should be kept generally within 600 to 1,000 feet of terminal curb front. Moving sidewalks and/or weather-protected walkways may be appropriate to aid pedestrian access.

Adequate staging areas should be provided for taxicabs, buses, limousines, and pre-arranged group transportation away from the terminal building. Ample terminal curb frontage should be provided for passenger pick up and discharge.

Ideally, the approach road system serving the airport should provide access from at least two directions of travel. Parking access roads should be separated from the road system serving buses, taxis, limousines, rental cars and passenger drop-off areas. Parking access roads should provide opportunities for traffic circulation past parking areas, connecting with terminal roads.

The capacity of entrance and exit points should be adequate to accommodate peak surges without excessive delays. Designs should accommodate Thursday, Friday and Sunday peaks that commonly occur, often equaling 25 percent of total parking space capacity. Up to two-thirds of this movement can sometimes occur in a 30-minute period.

The choice of building one large garage (i.e., O'Hare, Chicago, or several garages (i.e., Logan, Boston) depends on the terminal configuration. In all cases, it is essential that signing be clear, and that adequate security is provided.

Successful planning and siting of airport parking requires knowledge of the traffic desires. Typically, most arriving traffic is accumulated in the parking area. Some drivers will want to drop off passengers and luggage before moving into a parking area. Upon leaving airport parking, some drivers will want to go to the curb front to pick up passengers and luggage.

Planning and design of airport parking and vehicular access seeks to (1) separate commercial and public transportation from private vehicle traffic, (2) provide adequate advance notice of traffic routings and parking options, and (3) provide sufficient traffic lane weaving length to access traffic route and parking areas, and (4) provide opportunities for traffic to recirculate within the airport. Thus, vehicle traffic desires are especially critical to the location and planning of airport parking.

Auditoriums, Stadiums and Special Events

Most special event facilities host more than one attraction. When planning for these multiple uses, public transport, highway and parking provisions should be based on the largest crowds associated with regularly occurring events. Baseball, for example, usually does not attract as large a crowd per game as football. Thus, parking needs should be based on football spectators at a stadium that is regularly host to both sporting events.

Locational Factors. A location accessible by high volumes of vehicular traffic is essential. Facilities for events that attract large crowds require substantial road capacity to accommodate surges of vehicle arrivals and departures. Accordingly, stadiums commonly are located near or adjacent to freeways. These locations also enable a steady flow of vehicles in and out of the site to minimize traffic queuing.

Chicago's Soldiers' Field, San Francisco's Candlewood Park, New York's Shea Stadium, and Philadelphia's Veterans' Stadium are among the many facilities with adjacent or nearby freeway access. The New Jersey Meadowlands Sports Complex is located adjacent to the New Jersey Turnpike and N.J. Route 3; direct freeway access is provided to and from both roads to the parking areas surrounding the complex.

The exiting time required for traffic to leave parking facilities surrounding a stadium — "dump time" — is critical in planning parking access. Adequate external roadway and parking area exit capacity should be provided to enable all accumulated vehicles to disperse within 1 hour. About two-thirds of the crowd should be able to clear within 30 minutes.

The amount of parking depends on the likely proportion of visitors arriving by car. Because car travel is the primary means used to reach sporting and most other types of special events, large parking areas must be provided.

Parking areas are normally located on all sides surrounding a large stadium. Different parking areas may be connected with a perimeter road. This arrangement reduces walking distance and helps to distribute traffic between parking areas and the approach road system.

Remote parking with shuttle bus operation may help alleviate parking and traffic problems. It is essential where on-site parking space is not adequate. Arrangements for use of available and strategically located parking/bus pick-up areas should be formalized between the special event facility operator, bus operator, and parking space supplier.

Functional Design Considerations. Special event parking facilities should be designed to minimize dump time. Given an external roadway system with adequate capacity, dump time will depend on the internal design of the parking complex.

Since most types of special event crowds leave simultaneously, and there is little or no demand for traffic movement in an opposing direction, reversible driving aisles and access points can be considered. Reversible direction driving aisles allow space-efficient 90-degree parking layouts, with the simplicity and safety advantages of one-way traffic that are normally associated with angle parking. When reversible traffic operation is contemplated, consideration should be given to access for emergency vehicles.

Directional signing should be provided as necessary within parking areas, and along connecting access routes. The magnitude and concentrated nature of special event traffic, however, typically requires greater reliance on traffic-directing personnel than other types of parking generators. Entrance cashiering, whereby fixed parking fees are collected as parkers arrive, is a popular means of collecting parking fees at special events.

Loading and parking areas should be provided for charter buses. Bus use by out-of-town groups and remote parkers may generate several hundred buses at some events. Larger recreational vehicles, such as motor homes, are popularly used as a means of travel to some events. A segregated parking area should be designed and reserved for oversize vehicles.

Separation of pedestrian and vehicular movements should be achieved whenever possible because of the large volumes of pedestrian traffic generated by special events. Pedestrian-vehicular separation measures such as walkways, bridges, and tunnels increase costs and require more space; however, specially constructed pedestrian ways may reduce walking distances, as well as increase safety. Directional signing for pedestrians should enable parkers to easily identify the area in which they have parked.

Temporary Parking Provisions. Special events that occur on a one-time or occasional basis, where regular parking is grossly inadequate or not available, require temporary arrangements to handle parking and traffic demands. It is essential to plan for such events far enough in advance to allow traffic and parking arrangements to be made.

Special arrangements should be based on anticipated parking and traffic characteristics likely to result for the type of event, expected crowd, and location or area that will host the event. A community festival, for instance, may be characterized by vehicles arriving and departing throughout the event's duration. In contrast, an air show may have far different parking and traffic characteristics.

Estimated parking needs can be satisfied by using a combination of (1) existing parking having non-concurrent parking demands; (2) remote parking with shuttle bus operation; and (3) use of unimproved areas suitable for temporary parking.

Potential parking areas should be selected in regard to their accessibility. A special event may require temporary vehicular traffic detours, on-street parking prohibitions, or other restrictions affecting potential parking sites. Parking on roadway shoulders or streets with insufficient width or without walkways should be prohibited and enforced. If pedestrians are encouraged or forced to walk in roadways, they are endangering themselves and impeding vehicular traffic flow.

Where special event parking is inadequate and/or inconvenient, nearby property owners may decide to become one-day parking entrepreneurs, offering their yards and driveways for parking at a price. This practice is prohibited in most communities, and it should not be encouraged or counted on in establishing an adequate parking supply.

Planning should encompass details for advance public notice and making and erecting appropriate standard signs to advise motorists where and where not to park. Contractual agreements for privately owned parking must be made far in advance of the actual event. Sometimes it may be desirable to contract with a professional parking company to handle parking and parking fee collections at specific parking sites. Civic groups and other organizations can often provide a manpower source for directing parking operations and picking up trash in the parking areas after the event concludes.

Hospitals and Medical Centers

Parking should be keyed to the peak demands of employees, outpatients and visitors. Parking space should be sufficient to minimize spillover into surrounding neighborhoods. Because people are willing to pay to park at hospitals, user charges can be set to cover costs.

Location Factors. Patient and visitor parking should be located close to the hospital. Barrier-free and convenient pedestrian access should be provided to the main emergency and hospital entrances. Parking areas should be located and designed to channelize pedestrians to their proper destinations and to minimize walking distances. It is essential to accommodate the physically handicapped and incapacitated.

Most daytime staff parking need not be as conveniently located as spaces provided for patients and visitors. Evening and night-shift employees are often allowed to use parking areas nearest building entrances.

Some medical facilities, as a matter of policy, reserve a given number of conveniently located parking spaces for physicians. However, the practice of reserving parking for the exclusive use of employees is not generally recommended; this is, because vacations, sick days and work-shift variations make it difficult to maintain optimum use of the spaces.

Functional Design Considerations. The arrangement of roads and parking areas must allow convenient and direct access for emergency room admissions. This access may be incorporated into the overall parking plan or it may be provided in a separate area. It must be conspicuously marked, and it should have sufficient driveway width and building overhang vertical clearance, etc. to allow passage of oversize vehicles (recreational vehicles and fire trucks, for instance, as well as larger ambulances). Ample parking should be provided as near as possible to the emergency room entrance. Special design arrangements should be made to allow one or more ambulances (depending on anticipated activity) to unload directly to the emergency room entrance, without interfering with other vehicular and pedestrian traffic (see Figure 7.19).

Adequately-sized passenger loading zones should be provided at building entrances. Suitable access and loading areas also should be provided for service vehicles and delivery trucks. Access and parking for delivery and service vehicles should be separated from employee-patient-visitor parking.

Security is a major concern for medical facility parking because activity occurs around the clock. Location and previous experience provide indications of the security precautions and measures needed.

Colleges and Universities

Colleges and universities are major traffic and parking generators that can significantly impact surrounding areas. Some generate as many vehicle trips each day as CBDs of comparable population. Consequently, each institution should coordinate its traffic and parking plans with traffic plans for surrounding off-campus areas. The campus should not be treated in isolation from its neighbors.

Location Factors. Differing university settings result in a wide range of parking plans and policies. It is necessary to determine who should park, where, and at what cost. Parking permit systems that designate spaces for faculty, staff and students are common.

Campus parking should be placed as near as possible to major buildings and activity centers. Walking is the major form of campus travel, and special attention should be given to pedestrian connections between parking areas and campus attractions. These locations, however, may conflict with the desire to control vehicular traffic movement on the campus. To minimize vehicular traffic penetration of the campus, parking areas can be sited to intercept traffic at points where traffic enters the campus, reducing unnecessary circulation on campus streets.

Parking for resident dormitory students historically has been provided on the campus periphery. Today, many university administrators recognize the increasing student demand for parking near their place of campus residence. More students now desire their cars on a routine basis.

Peripheral parking areas (long-term storage lots) should still be considered for resident students who do not need their car on a routine basis or have restricted use of a vehicle because of administrative policy. Some universities provide remote parking areas with shuttle bus service for students (i.e., a mini park-and-ride service).

Functional Design Consideration. Campus parking demands frequently exceed the parking supply. Since parking is typically subsidized, the institution should provide the most economical parking feasible. This often means less generous parking dimensions and fewer amenities — made possible by the familiarity of campus parkers with the available facilities, and the fact that campus parkers are a captive audience. It also means that special attention must be given to parking regulation enforcement practices and parking facility design features that complement rather than complicate enforcement.

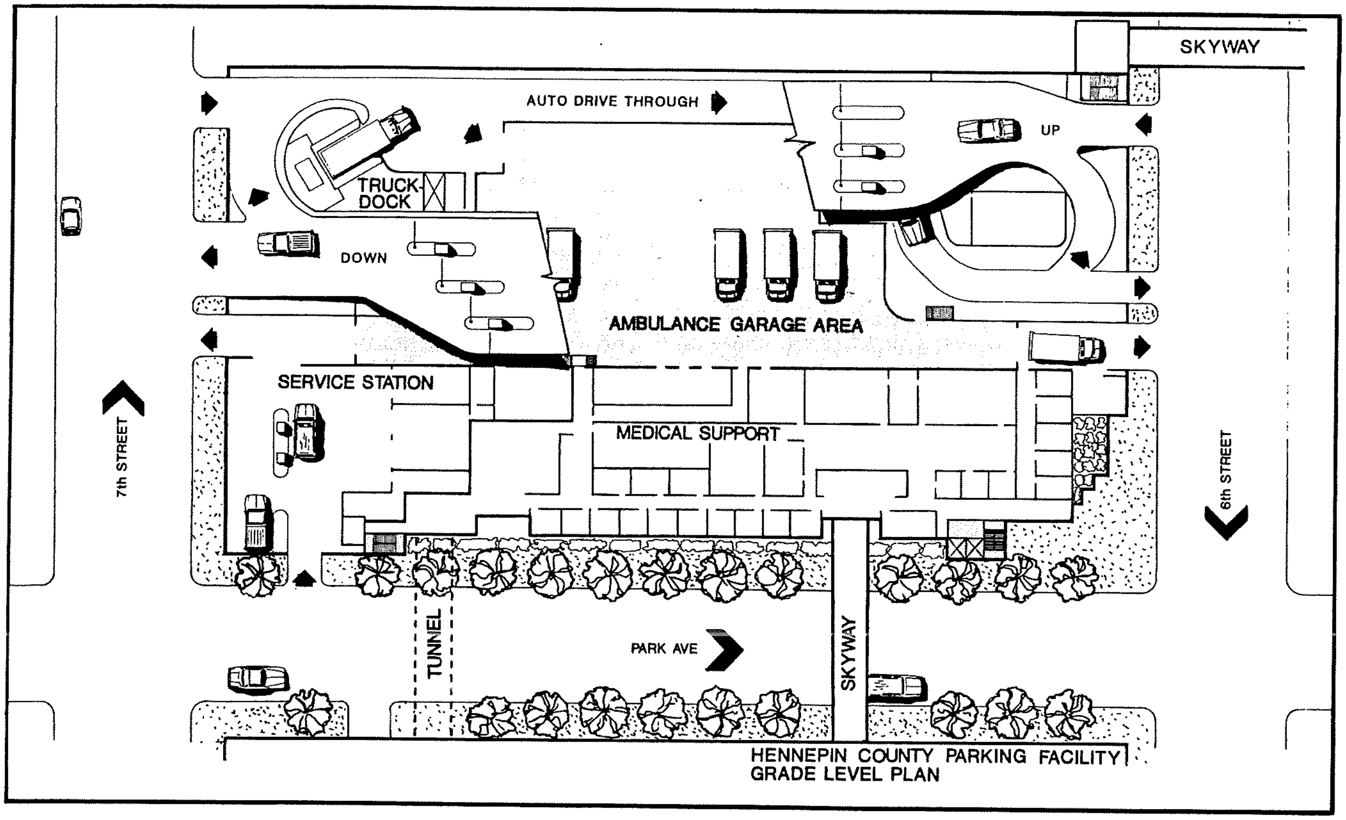


Figure 7.19. The Hennepin County Medical Center parking provides for the separation of vehicles and pedestrians, as well as separating ambulance access from other types of traffic.

Source: William Arons, "Hospital Garage Has It All," *The Parking Professional*, February 1987.

Shopping Centers

Substantial numbers of suburban shopping centers were first built in the mid- and late-1950s. This evolving development experience produced successful practices and innovations that led to tested procedures for shopping center planning. As a result, the shopping center became recognized as a distinct building and land-use type. Shopping center development accelerated during the 1960s, but new center starts since 1970 have slowed. Most attention is now focused on modernizing and expanding older existing centers. This has created opportunities for updating parking and traffic circulation systems at these centers to reflect current practices.

Shopping center attraction has relied heavily on being visible and highly accessible to automobile traffic. Expanses of surface parking fronting and surrounding shopping centers have long been recognized as a primary element of shopping center visibility, suggesting easy access and convenience. As a broad gauge for visualizing the relative scale of site coverage, centers generally exhibit roughly 10,000 square feet of building area and 30,000 square feet of parking for each 40,000 square feet (about 1 acre) of site area.

Center types range from relatively small neighborhood and community centers to large regional centers. Neighborhood and community shopping centers are typically situated with access from major collector and arterial streets. Because most stores in these types of centers usually represent convenience goods and services with limited lines of shopping goods, accessibility from an extended trade area via high-speed freeways is unnecessary. In contrast, regional centers, dependent on a much larger trade area, are customarily located where the site is easy accessible from freeway/ expressway interchanges.

Access, parking and traffic circulation arrangements are influenced by size and shape of the site, building orientation and the surrounding road system. Site depths of 400 feet or more generally distinguish shopping centers from the old standard strip commercial areas, which were usually placed on narrower sites. Requirements for parking access and circulation in shopping centers dictate much greater depth than was required by the old patterns.

The long axis of shopping center buildings are normally arranged parallel with the longest site dimensions; and it is usually preferable that the long axis of both building and site parallel the major roadway used to access the site. In most neighborhood centers and smaller community centers, the building is typically located to the rear of the site, with parking placed between building and roadway frontage. For larger community centers and regional centers, the building is centered on the site and surrounded on three or four sides by parking. This arrangement is appropriate to service higher traffic volumes and to provide greater amounts of parking. It facilitates vehicular and pedestrian traffic circulation and distribution, and allows more parking spaces to be located within short walking distances of building entrances.

Vehicular Access. Shopping center entrance driveways should present a defined and regulated traffic pattern that encourages a logical flow of vehicles. This begins with proper location and design of street access points. Access points may be designed for one-way or two-way traffic operation. They will range from simple two-lane driveways to multiple-lane access points. Major access points should have two lanes inbound and two lanes outbound, separated by a raised median divider. Where traffic volumes are large, three (or even four) lanes are sometimes provided in each direction. Design depends on site specific traffic volumes and turning movements.

Major factors influencing the number and location of shopping center access points include these considerations.

1. *The amount of site frontage available for access facilities.* Access from more than one major street is desirable to help distribute traffic. Generally, non-signalized access point spacing ranges between 400 and 800 feet. Signalized access spacing is predicated on achieving an optimum balance of speed, signal phasing and cycle length, green time requirements and roadway geometrics.

2. *Traffic volume generated by the center, as well as background traffic volumes on adjacent streets.* Design of access points is based on estimated traffic volumes. If driveways are designed to provide higher capacity, larger volumes of traffic can be accommodated at fewer entrances.

3. *The directional distribution of traffic approaching and departing the shopping center.* An unbalanced approach pattern to a site is often the case, requiring careful traffic engineering analysis and design of access points to avoid spillback on to surrounding highways. It is usually desirable to provide at least two opportunities to enter the center from each major direction of approach.

4. *Types of traffic movement to be served at the access points.* It may be necessary or desirable to prohibit left turns into or out of the center to simplify signal phasing and to increase capacity, or provide special provisions for left-turning traffic at access points. Truck and transit bus traffic may require special access considerations. Driveway provisions for pedestrians also may be needed.

5. *Location and geometrics of existing and future cross streets.* The relationships of access points to existing and future intersections may indictate their location. Generally it is desirable to align opposing driveways or driveway and opposing street to handle traffic more effectively. When opposing driveways must be offset, it is desirable for the offset to be at least 200 to 300 feet.

Sufficient driveway lane length must be provided to establish a reservoir to store vehicles waiting to enter or exit the center. Reservoir length depends on traffic volumes and intersection performance and may easily exceed 150 feet. Design of shopping center entrance/exit driveways depends on site-specific traffic volumes and turning movements that must be served. Figure 7.20 illustrates a typical shopping center access treatment.

Parking Arrangements and Traffic Circulation. Ease of parking is the guiding criterion for shopping center parking arrangements. The layout must be simple and consistent with parking dimensions generous enough to avoid frequent

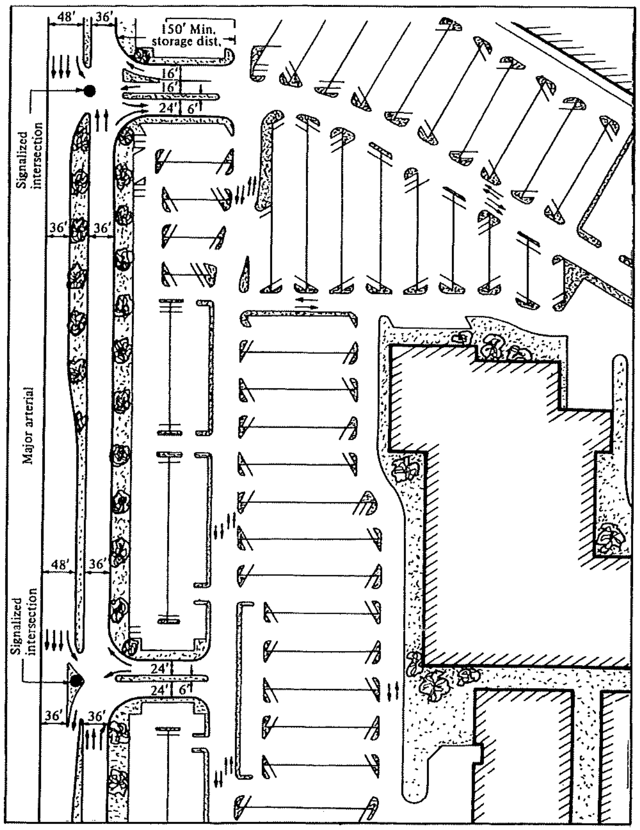


Figure 7.20. Sketch of site plan with desirable access and parking-aisle arrangement. Note that building setback must be at least 400 feet in order to provide adequate throat length and parking aisles of reasonable length.

Source: Vergil G. Stover and Frank J. Koepke, *Transportation and Land Development*, Institute of Transportation Engineers. (Englewood Cliffs, NJ: Prentice Hall, 1988) p. 189.

complaints. All parking spaces (except employee parking and spaces provided for overflow seasonal parking) should be within 400 feet of building entrances.

The angle of parking to use for shopping center layouts is primarily a function of available site dimensions. When sufficient space exists to enable a choice between 90-degree perpendicular parking and angle parking, the choice should be influenced by the pattern generally used in the community and what will be most convenient and space efficient. (See Chapter 8 for parking lot design details.) Small-car-only spaces are not well suited for shoppers because of control problems. However, they have been used successfully in some centers where an adequate number of spaces could not otherwise have been provided.

Shopping center parking is arranged with driving aisles perpendicular to the building. This enables pedestrians to approach the building directly, walking along the driving aisles. Raised sidewalks are normally not necessary or desirable. Large parking areas should be compartmentalized into areas of 500 spaces or less. This is achieved with landscaped islands, which also serve to channelize traffic and control speeds.

Regional centers and many larger community centers use a ring or perimeter roadway to encircle prime parking areas within 400 feet of the building. This ring road is necessary to disperse traffic to various center destinations and to collect exiting traffic. It is the primary access to driving aisles serving parking rows. Employee or peak-season overflow spaces can be located outside the ring road. The road should have a relatively smooth alignment without abrupt turns or changes of direction.

Depending on traffic requirements, the ring road can provide two or more traffic lanes and range from 30 to 48 feet in width. At driveway access points with surrounding streets, the ring road should be set into the site far enough at access points to allow adequate reservoir lane length to be developed between it and the public roadway for exiting vehicles. It should be channelized at major access drives to provide lanes for right and left turns.

Many centers have an inner roadway paralleling the curb line around or in front of the shopping center buildings. This roadway allows for fire and emergency access, as well as delivery and customer drop off and pick up. At neighborhood centers and smaller community centers this inner roadway may be used as the primary access to parking. However, higher pedestrian and vehicular volumes generated by larger centers require layouts that discourage vehicular traffic from using this road to reduce conflicts with pedestrian crossings.

Inner roadway widths are typically 28 or 30 feet; some segments may be wider to accommodate bus loading areas or other special needs. Except for small neighborhood convenience centers parking spaces between building and inner road are discouraged because parking manuevers can interfere with traffic and pedestrian movements and may pose unnecessary safety risks.

Truck delivery and freight platforms should be strategically located in screened areas. These areas should be accessible without requiring trucks to pass through customer parking areas. The truck delivery route and dock area should provide adequate geometrics to easily accommodate truck movements.

Parking Garages. Larger community centers and regional shopping centers are beginning to use parking garages far more than in the past. In many cases land for expansion is not available or is so costly that a parking structure becomes feasible.

Garage spaces offer a number of advantages. They can avoid excessive walking distances between parked car and destination, and depreciation can be taken on a parking structure, while it cannot on land. Parking garages may be more space efficient than lots. Garages also can eliminate many objections over parking lot aesthetics and environmental degradation, the latter stemming mainly from storm water drainage runoff, snow removal and dumping, and spillover lighting.

Disadvantages mostly relate to higher development and operating costs for garage spaces as compared to a surface lot. While these higher costs can be offset by land savings and increased revenues, a future market is never absolutely certain. And, for an attraction that originally based much of its success on high visibility of available and convenient-to-use surface parking spaces, customer acceptance of parking inside a garage is a concern for many shopping centers contemplating parking garage development.

Potential problems of inadequate geometry or perceived security sometimes associated with parking garages can be avoided with proper planning, design and operation. Many patrons actually prefer garages because of closer proximity to destination and shelter from the elements.

Office and Employment Centers

Office centers, mixed-use developments, business parks, and industrial plants each have unique requirements for parking. Surface parking is common, but a growing number of office centers and mixed-use developments provide garages. In all areas, it is important to fit parking functionally and visually into the overall site plan.

Most employment centers are characterized by a high percentage of long-term parkers who are familiar with the facilities. There may be an overlap of peak-parking requirements when the employment center operates on a multiple work-shift basis. However, this is more likely with industrial plants than with office facilities.

Location Guidelines. Many of the parking principles for shopping centers also apply to mixed-use developments, office complexes, business parks, and industrial developments. Parking location depends on how and where the buildings are placed; roadway and parking facility design depends on type of employment center and its parking characteristics.

Office and corporate parks may be combined with recreational, hotel and retail facilities. Separate parking areas, lots or garages, can be provided for various users, each with its own pricing and access requirements (Figures 7.21 and 7.22). Site and development amenity is increasingly important.

Parking for an industrial plant, in contrast, may favor security over amenity. As in other employment centers, ingress and egress capacity should be adequate to accommodate peak-traffic demands. Parking facilities should be located where they are convenient to building and plant entrances and where they can be easily reached from the approach road system.

Special facilities are usually provided for visitors and should be located as close as possible to visitor entrances.

Where the employment center operates a vanpool or high-occupancy vehicle program, preferred parking in terms of walking convenience should be provided for these vehicles' occupants. Transit stations or terminals, including shelters and other passenger amenities may be desirable at large employment centers. Trucks and other delivery vehicles should not be required to travel through parking areas.

At large complexes, parking areas should be compartmentalized in 300 to 500 car units to fa-

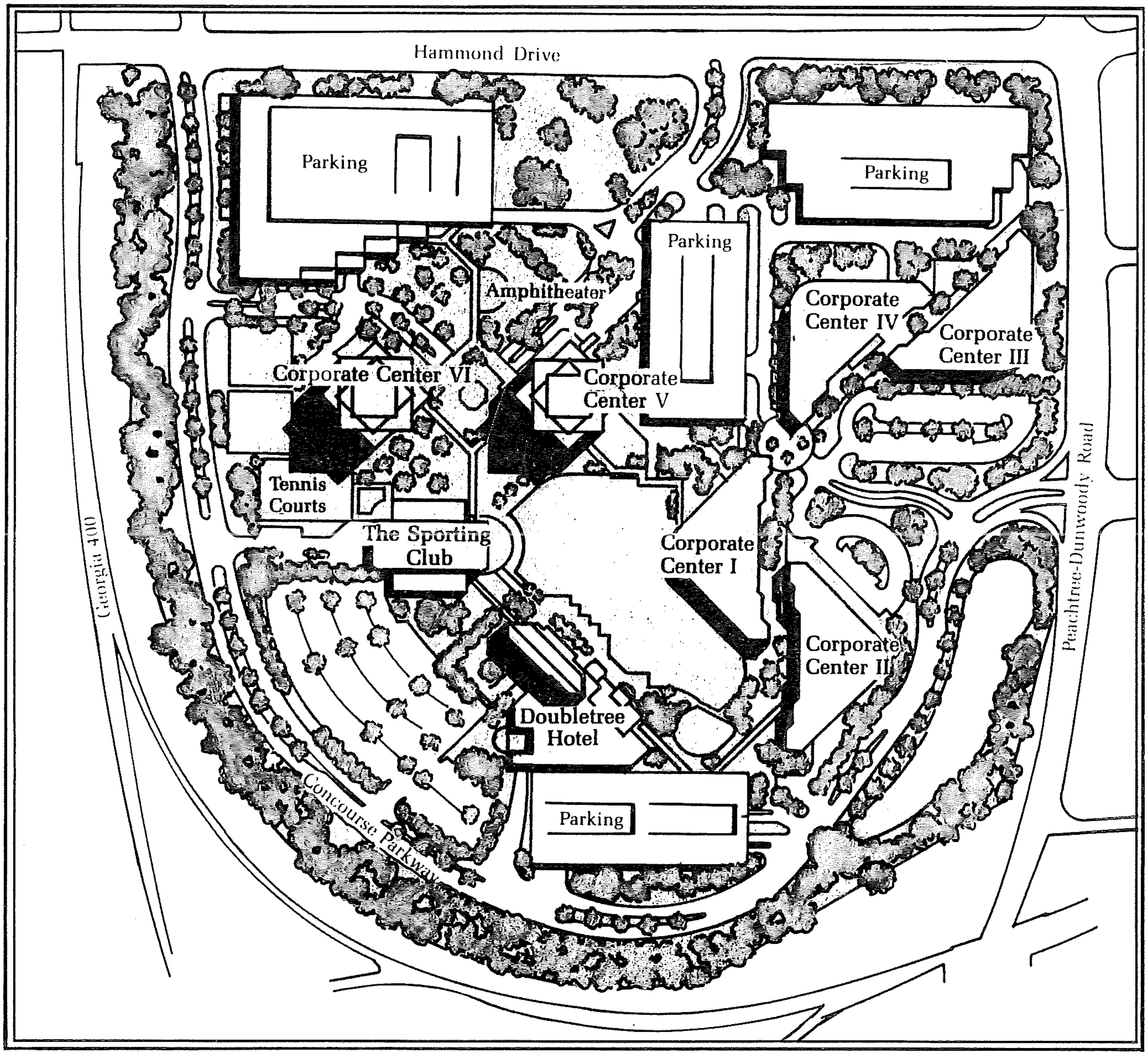


Figure 7.21. In mixed-use developments with substantial acreage, numerous options for parking depend on the needs of surrounding land uses. Concourse at Landmark Center in Atlanta has several parking structures as well as a surface lot near the hotel and sporting club.

Source: Urban Development/Mixed-Use Council, *Mixed-Use Development Handbook* (Washington, D.C.: Urban Land Institute, 1987) p. 187.

cilitate parking space, assignment, aesthetics, and traffic flow.

Functional Design Considerations. The choice of parking angle depends on site-specific conditions. Because the parking mainly services employees, parking dimensions can be less generous than for customer parking. An 8 to 8 1/2 foot stall width is adequate.

Where there is evening or night employment, adequate illumination is essential. Additional

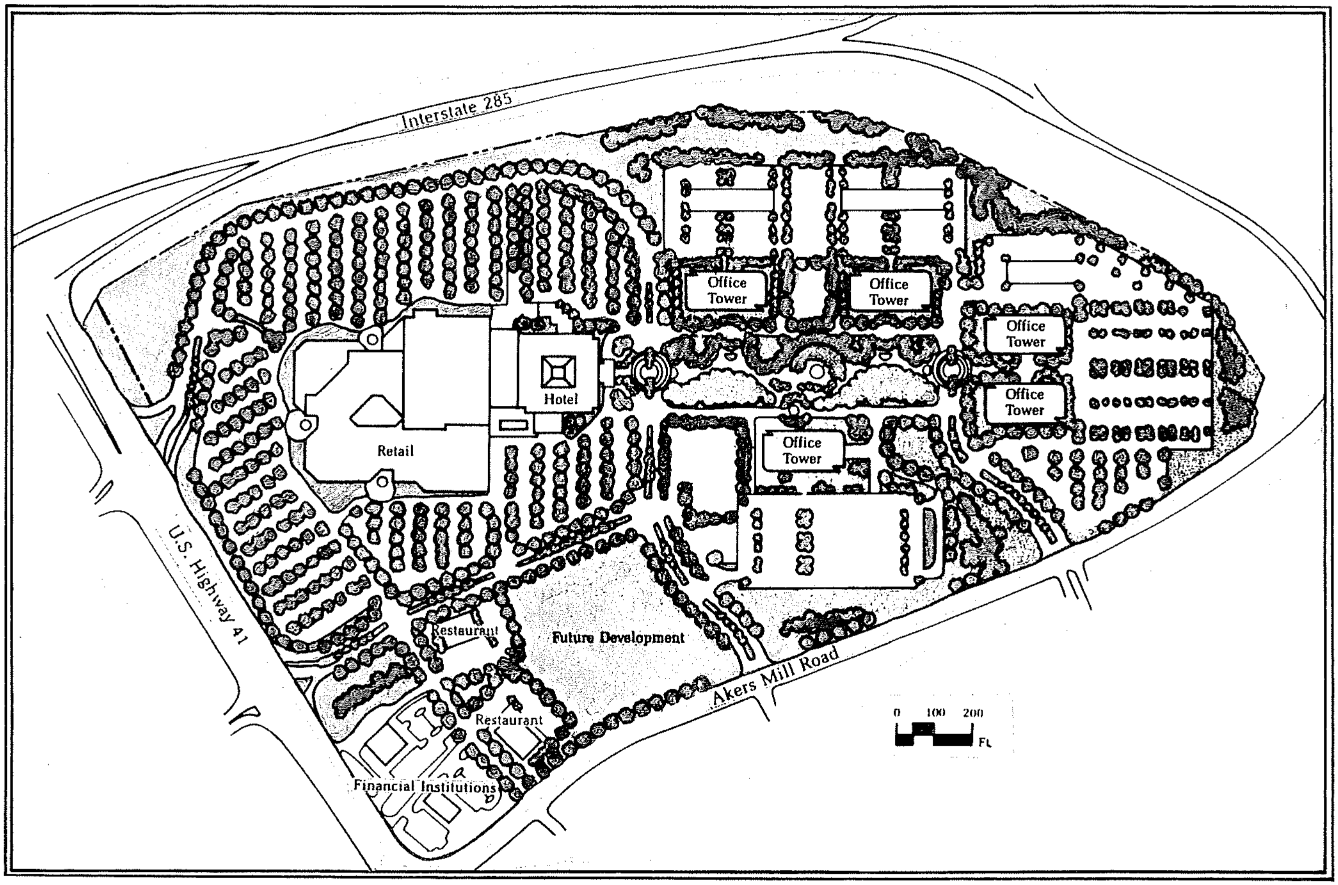


Figure 7.22. Mixed-use developments should consider shared parking. Despite an overall parking ratio of 4.4 spaces per thousand square feet, the retail and hotel uses in this development often experience a shortage of parking in the evenings. Office parking, located behind the office buildings, is too far away for convenient use by retail and hotel users. Thus, the concept of shared parking does not work as well as it could have.

Source: Urban Development/Mixed-Use Council, *Mixed-Use Development Handbook.* (Washington, D.C.: Urban Land Institute, 1987) p. 309.

lighting should be provided along pedestrian routes, at entrances to buildings, and at major access routes.

Fences may be necessary where security is essential. They can be keyed to gates that are mechanically or manually controlled, or are within effective visual range of security personnel.

Residential Parking

The location and arrangement of parking facilities for residential units reflects a wide range of types and sizes. Parking for single-family homes is normally provided in a garage next to or contiguous with the residence. Parking for group housing may be provided adjacent to the units or more commonly in a parking lot or garage near the condominium or apartment cluster. Lots are common; however, garages may be provided for high-rise buildings, especially in high-density environments.

The arrangement of parking lots and garages is straightforward. They should be located adjacent to the building or buildings that they serve. Lighting must be adequate for night-time use. It is essential to maximize the number of spaces that are provided within the site; therefore, 90-

degree parking predominates. Entrances and exits from adjacent streets should be removed from street intersections. Provisions should be made within the lots for passenger drop off and pick up, and trash collection. Often, spaces are designated for visitors.

Parking garages for apartments may involve fee collection. Entrances and exits may be controlled by attendants, or by means of parking passes.

SUMMARY

This chapter has set forth the principles and guidelines that underlie the location, layout and siting of parking space. It has shown how parking should be related to adjacent streets and activities, and how it can be integrated into the surrounding environment. Clarity, proximity and land-use compatibility emerge as the major themes.

CHAPTER **8**

Parking Lot Design

Parking lots dominate off-street parking. They provide more than three-quarters of all off-street parking space and accommodate nearly 90 percent of the parking demand not satisfied with street spaces. They vary in size from a few spaces to acres of parking spaces. Lots serve as an auxiliary to nearly every type of land use, and are commonly operated as commercial parking ventures in downtown areas.

Relatively low development and operating costs account for the widespread use of lots. Construction costs of $3 to $7 per square foot (typically less than $2,000 per space for a fully improved lot) are far less than the cost of a simple parking structure. Even though the choice between lot or garage is driven largely by economic considerations, several other factors also have encouraged use of surface parking lots. Open parking lots are highly visible to approaching motorists. They are generally perceived to be easier and safer to use than a parking structure. They can serve as a short-term interim use of land until circumstances call for a higher use; during this interim period, they provide parking and may produce revenues.

There are three primary objectives of parking lot design.

1. *A parking lot must be convenient and safe for the intended users.* It should provide adequate access that avoids or minimizes conflict with street traffic. Adequate sight distance should be provided at access points, and sufficient reservoir space should be provided for vehicles waiting to enter the parking lot. Internal circulation and search patterns should be as direct and obvious as possible to drivers and pedestrians who may not be familiar with the facility. Parking dimensions should be generous enough to enable average drivers to maneuver into and out of parking spaces without difficulty. Walking distance between any parking space in the lot and nearest building entrance should be within acceptable limits for the type of user. There should be provisions for handicapped access and parking and, if warranted, for oversize vehicles, bicycles and motorcycles. Passenger and service vehicle loading areas should be provided when warranted. Lot surfaces should be paved and parking stalls clearly delineated; the surface should be sloped to drain storm water. Lighting and other security measures should be provided as circumstances warrant.

2. *A parking lot should be space efficient and economical to operate.* Ideally, parking dimensions should be selected based on the anticipated type of user and the size and maneuvering characteristics of the vehicles to be parked. In reality, parking dimensions are often dictated by local zoning regulations, which may or may not be optimum for site-specific circumstances. The parking layout should take best advantage of the site to maximize the number of parking spaces in the least amount of paved space. If warranted, the layout should provide service vehicle access and maneuvering that avoids unacceptable conflict with access to parking space for patrons. The lot design and layout should minimize maintenance needs and operating labor requirements.

It should avoid or minimize potential liability problems stemming from the existence, operation and use of the parking lot. Depending on type of operation and expectations, it may be appropriate for the design to consider parking attendant facilities, access or revenue control equipment, on-site storage for maintenance equipment/supplies, or future change in parking space needs or operating conditions.

3. *A parking lot should be compatible with its environs.* The design should meet or exceed local design requirements for development setbacks, boundary barriers, visual screening, landscaping, and general aesthetic treatment. In the absence of local requirements, the owner/developer should incorporate visual amenities to enhance the lot's appearance and complement surrounding development. The design should help to assure proper handling of storm water runoff. It should discourage unacceptable points of vehicular and pedestrian access and encroachment on to adjacent properties. Depending on the nature of surrounding development, it may be advisable (if not required by ordinance) to prevent lot lighting from spilling over onto other properties. Lot design should provide suitable provisions for protecting and maintaining landscaping.

Balancing convenience, efficiency and economy — concerns of the first two design objectives — have been traditional challenges of parking lot design. More recently, concern for appearance has elevated the third objective to a status equal to the first two objectives. Sensitive design of parking lots, from both functional and aesthetic perspectives is essential.

This chapter describes parking lot design elements. It provides criteria and dimensions for arranging the various design elements into a well-designed parking lot.

PARKING DIMENSIONS

Vehicle characteristics, notably their size and turning performance, influence parking dimensions. Optimum parking stall, driving aisle and other parking dimensions are a function of the design vehicle, average driver ability, and the type of parking.

Design Vehicle

A parking stall must be wide enough to store vehicles and to allow vehicle doors to be opened far enough for passenger access, even though vehicles may be parked adjacent to a wall or other vehicles. Driving aisles that provide access to parking stalls must be of adequate width to enable average drivers to maneuver their vehicles into parking spaces in one continuous movement. And the parking stall must be long enough to store the vehicle plus a little additional length to compensate for times when the vehicle may not be pulled all the way into the stall. The vehicle having the dimensions on which the parking stall and aisle dimensions are based is called the design vehicle.

The parking design vehicle is a hypothetical car that has dimensions and a turning capability equalling or exceeding those of most cars expected to frequent the parking facility. Design vehicles are used to judge the adequacy of proposed stall and aisle dimensions. Overall vehicle width and length and minimum turning path dimensions are the primary vehicle characteristics that apply to the design of parking stall and driving aisles. The design vehicle must represent these characteristics for new vehicles, as well as for older vehicles that may be in use. The design vehicle also must attempt to represent future vehicles that will gradually add to and replace earlier models.

A parking design vehicle should be no larger than an 85 percentile vehicle. This means that it will be as large or larger than 85 percent of the vehicles expected to use the parking facility.

Smaller automobiles have come into widespread use in North America since the 1970s. Energy constraints and mandated miles-per-gallon requirements have contributed to this trend. Energy costs and availability in future years will probably influence the fleet size mix. The significance for parking facility design has been the downsizing of most large cars.

Cars currently in use in North America range in size from under 64 inches in width and 169 inches in length to over 77 inches in width and 215 inches in length. There are many combinations of car widths and lengths. For practical planning and design purposes, cars are generally classified into two groups — the "large car" and the "small car." The size definition of large and small cars varies depending on source; generally, a small car is a vehicle whose width is 69 inches or less and whose length is no more than 187 inches. A large car is all larger car sizes.

Table 8-1 lists a range of possible parking design vehicles for both large and small cars. To demonstrate the relationships between vehicle size and parking dimensions, and to evaluate the adequacy of parking dimensions now in common use, two design vehicles are delineated in the table to represent the large and small car categories. The 77" x 215" large-car design vehicle is large enough to provide assurance that it is at least an 85 percentile vehicle for most North American communities.

The 66" x 175" small car design vehicle is smaller than the 69" x 187" small car definition presented earlier, which represented a 100 percentile vehicle. The 66-inch small car design vehicle is used here to represent an 85 percentile vehicle, but the actual small car design vehicle could be different for specific circumstances.

Parking Stall Width

Minimum stall width, based on any given design vehicle, can be determined by adding 22 inches to the width of the design vehicle. The 22 inches is a design door opening clearance, but different values may be used, depending on anticipated parking activity. For circumstance of very high parking turnover, a 26-inch or wider door opening clearance may be more appropriate. Wider clearances also may be appropriate for special event parking, designed to accept parkers

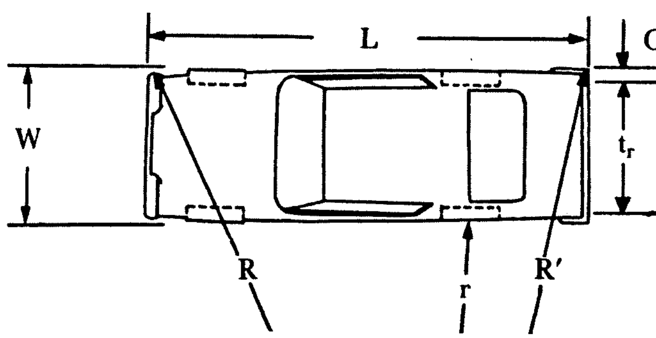
Table 8-1. Dimensions of Typical Parking Design Vehicles

W = Overall width
L = Overall length
O_r = Rear overhang

O_s = Body side overhang from center of rear tire

t_r = Width from center of rear tires

Minimum Turning Radius:
r = Inside rear wheel
R = Outside point, front bumper
R' = Outside point, rear bumper



	Width (W)	Length (L)	Wall-Wall Front Radius (R)	Curb-Curb Rear Radius (r)	Rear Width (t_r)	Body Overhang from L rear tire (O_s)	Wall-Wall Rear Radius (R')
Large Cars							
	80"	218"	20.75'	12.25'	5.08'	0.75'	17.5'
DESIGN VEHICLE	77"	215"	20.50'	12.0'	5.10'	0.63'	17.4'
	74"	208"	20.40'	11.9'	5.00'	0.67'	17.3'
	72"	202"	20.30'	11.85'	4.90'	0.65'	17.1'
	71"	196"	20.00'	11.60'	4.80'	0.60'	17.0'
Small Cars							
	69"	187"	19.37'	10.7'	4.71'	0.50'	16.2'
	68"	182"	18.7'	10.5'	4.75'	0.54'	15.8'
DESIGN VEHICLE	66"	175"	18.0'	9.6'	4.60'	0.46'	15.0'
	64"	169"	17.4'	8.2'	4.67'	0.44'	13.6'
	63"	164"	17.0'	8.0'	4.46'	0.44'	13.3'

Source: Robert A. Weant, "The Influence of Smaller Car Sizes," *Transportation Quarterly* (Westport, CT: Eno Foundation for Transportation, July, 1985).

as rapidly as possible. When parking turnover is expected to be very low, such as might be experienced for employee parking, a design door opening clearance of less than 22 inches, possibly as small as 20 inches, may be acceptable.

Regardless of clearance selected, those vehicles smaller than the design vehicle will have an effective door opening clearance greater than that provided by the design. A large proportion of smaller-than-design vehicle size cars reduces the possibility of design vehicle size cars parking side by side. The larger cars typically will be separated by smaller cars, meaning that larger than designed clearances will usually be afforded all car sizes.

Figure 8.1 illustrates how stall width is determined from the width of vehicle and selected door opening clearance. Note that door opening clearance between adjacent parked cars is shared by both vehicles.

Based on a 77-inch wide large-car design vehicle, the required stall width could range between 8 and 9 feet, depending on how much door opening clearance is allowed in anticipation of parking characteristics. For the 66-inch wide small car design vehicle, the required stall width could range from 7'2" to 7'8". This suggests that a stall width of less than 9 feet can very easily maintain an acceptable level of convenience for most users. The acceptability of the popular 7'6" wide small car space is also confirmed. And, the nearly as popular 8-foot wide small-car-only space appears to be overly generous, even for a 69-inch wide small car design vehicle.

S_w = Stall width
W = Design vehicle width
i = Door opening clearance
S_w = W + i

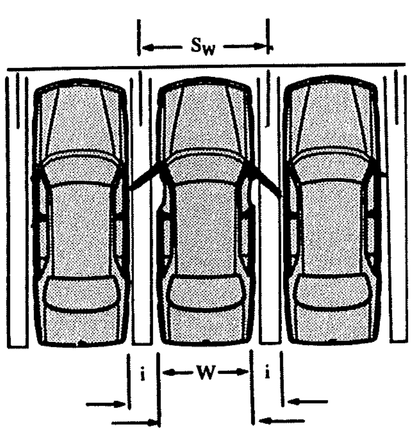


Figure 8.1. Measurement of door opening clearance as a variable in calculating stall width

Table 8-2 shows stall width ranges related to general characteristics of parking turnover. Practical stall widths that will accommodate most cars and light trucks range between 8'0" and 9'6". Selection of the optimum width within this range depends primarily on who is to use the parking, and anticipated parking turnover. High turnover parking, such as for convenience stores, fast-food restaurants and banks, suggests stall widths of 8'6" or wider. Lower turnover employee and commuter parking suggests stall widths of 8'6" or less. For site-specific applications, the most appropriate stall width also is influenced by the anticipated vehicle size mix over the life of the parking facility.

Optimum stall width also can be influenced by other factors. Where site width is minimal, stall widths may be increased to help assure that an acceptable level of maneuvering convenience is provided. For supermarket parking, 9-foot or wider stalls may be appropriate to enable shopping cart movement and convenient loading through vehicle side doors. Where experienced parking attendants or valets will perform parking manuevers, stall widths of 8 feet or less may be appropriate.

Parking Stall Length

The length of a parking stall, measured parallel to the angle of parking, is the sum of the design vehicle's length plus a minimum of 6 inches for bumper clearance. Bumper clearance is the amount of spacing provided in the design to compensate for vehicles parked short of the end-of-stall marking or a vertical obstruction such as a wall or another vehicle's bumper. The actual clearance is a function of driver performance and, therefore, assumed values are arbitrary. To encourage drivers to pull as far into a stall as possible, stall striping on the pavement is cut short of the actual design length of the parking stall.

Another aspect of stall length is stall depth. Stall depth is defined as the sum of projected design vehicle length and bumper clearance. At a parking angle of 90 degrees, stall length and stall depth are equal. As the angle of parking is reduced, the stall depth (measured perpendicular to the driving aisle) becomes longer than the

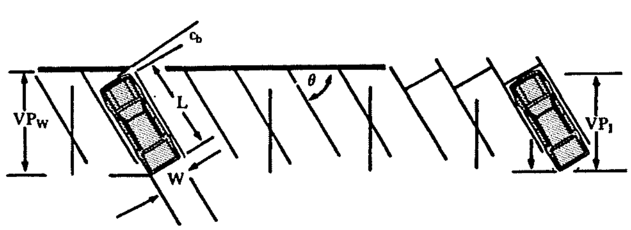
Table 8-2. Stall Width Ranges by Turnover Usage

	Parking Turnover			*Stall Width (feet)*	
Application	*High*	*Medium*	*Low*	*Large Car*	*Small Car*
Convenience store, fast-food restaurant, bank or other very high turnover attraction	X			9.00-9.50	NR
Retail customer or visitor such as at a shopping center, church, stadium, medical building or theater	X	X		8.50-9.00	NR
Employee, student or other lower turnover attraction		X	X	8.00-8.50	7.50
Valet/attendant parking	X	X	X	7.50-8.00	NR

NR=Generally not recommended

actual stall length and then becomes progressively shorter as the parking angle flattens past a particular angle. Stall depth must be known to determine parking module width at angles of parking less than 90 degrees.

Figure 8.2 illustrates how stall depth can be calculated for any given angle of parking. For the 215-inch long large-car design vehicle, the calculated stall length is 221 inches or 18'5" when a 6-inch bumper clearance is added to the vehicle's length. Many successful parking designs, however, use 17'6" or 18'0" stall lengths. The 175-inch small car design vehicle requires a 181-inch or 15-foot long parking stall. The 7'6" x 15'0" small car parking stall is one of the most commonly used configurations.



$VP_W = W \cos\theta + \sin\theta\,(L + c_b)$

$VP_I = 0.5W \cos\theta + \sin\theta\,(L + c_b)$

Figure 8.2. Calculation of projected stall length as a function of design vehicle length and bumper clearance for car-to-wall stalls (VPw) and interlocking stalls (VP_I)

Aisle Width

Driving aisles must be wide enough to allow comfortable parking maneuvers, and to permit safe and unobstructed movement of both vehicular and pedestrian traffic. Parking patrons should be able to drive into and back out of parking space easily, without objectionable effort. If tight parking stall and aisle dimensions prevent significant numbers of drivers from entering parking spaces in one continuous movement, then the parking facility will operate inefficiently. This inefficiency could lead to slower operation (congestion) during peak periods, greater incidence of vehicle accident damage, and parker exasperation.

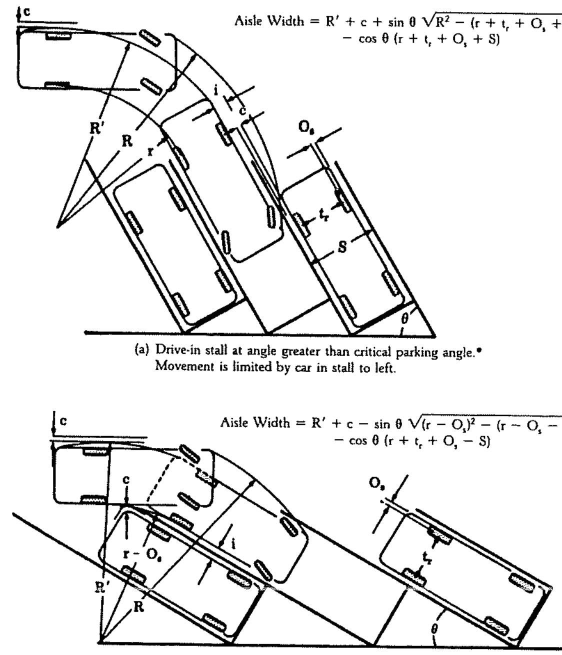
To some degree, aisle width is influenced by stall width. Generally, wider stalls need less aisle width, and narrower stalls require more aisle width. Aisle width also depends on the angle of parking selected and on whether the aisle provides one-way or two-way vehicular traffic movement. Parking spaces at less than 90 degrees require less aisle width than those arranged perpendicular to the aisle at 90 degrees.

Aisles width must usually provide for pedestrians walking to and from their parked vehicles. Under most conditions, the aisle width that is sufficient to handle vehicular movements also is adequate for pedestrian needs. Exceptions may occur when the parking angle is relatively flat (less than 60 degrees) or when pedestrian traffic is anticipated to be quite high. In such instances aisle width may have to be expanded beyond what would suffice for the sole consideration of vehicle maneuvering space. Other factors such as zoning requirements and emergency or maintenance vehicle access may influence aisle width choice.

While the determination of an appropriate aisle width will rely more on judgement than on analytical calculations, analytical equations have been used to derive aisle width. Equations, however, are no substitute for experience and judgement. In part, this is because they are unable to accurately account for varying driver behavior and ability.

Aisle width design equations are predicated on a driver proceeding along the driving aisle, coming to a full stop, turning the vehicle's wheels for as tight of a turn as possible, and then proceeding into the parking space. In practice, the driving path is conditioned by continuous vehicle movement along a spiraling turn, as opposed to a straight line path of tangency, connecting a constant radius turn into the stall. This inability of equations to simulate driver behavior is most apparent with 90-degree stall layouts. Equation-derived aisle widths for 90-degree parking usually exceed the minimum aisle width actually required by the design vehicle operated with average driver ability. For relatively flat angles of parking, equation-calculated aisle widths may more accurately reflect the minimum width needed for vehicle maneuvering, but the width may not be adequate to provide for other influences on aisle width, such as safe pedestrian movement or emergency vehicle access.

Aisle width equations do have some value. They can be used to help gauge the adequacy of selected designs, if the correct assumptions are made in respect to design vehicle dimensions and performance characteristics, and if the equations' limitations are realized. Thus, aisle width equations can be a tool for parking design. Equations (shown in Figure 8.3) are, perhaps, the most widely known and used formulas for calculating aisle width. These equations were used to derive the values shown in Table 8-3, using the large and small car design vehicle dimensions shown in Table 8-1 for an 8'6"-wide large car stall and a 7'6" wide small car stall at four different parking



$$\text{Aisle Width} = R' + c + \sin\theta\sqrt{R^2 - (r + t_r + O_s + i - c)^2} - \cos\theta\,(r + t_r + O_s + S)$$

(a) Drive-in stall at angle greater than critical parking angle.* Movement is limited by car in stall to left.

$$\text{Aisle Width} = R' + c - \sin\theta\sqrt{(r - O_s)^2 - (r - O_s - i + c)^2} - \cos\theta\,(r + t_r + O_s - S)$$

(b) Drive-in stall at angle less than critical parking angle.* Movement is limited by car in stall to right.

* Critical parking angle is the angle at which the aisle width required for parking-unparking car to clear the car in the stall on the left is equal to aisle width required to clear car in stall on right. This angle is given by the expression:

$$\theta' = \cot^{-1}\frac{\sqrt{R^2 - (r + t_r + O_s + i - c)^2} + \sqrt{(r - O_s)^2 - (r - O_s - i + c)^2}}{2S}$$

Figure 8.3. Formulas derived for the aisle width required to maneuver into or out of a parking stall in one pass

Source: Edmund R. Ricker, *Traffic Design of Parking Garages* (Westport, CT: Eno Foundation, 1957).

angles. Aisle widths shown in the table for parking at 90 degrees have been adjusted (calculated values reduced by 15 percent) to better reflect actual driving practice. Calculated aisle widths of less than 11 feet for large cars and 10 feet for small car design are not shown, since these are the more commonly recommended minimum widths for one-way traffic aisles. Generally small car spaces should only be used in 90-degree configurations.

Parking Module Width

The parking module is the clear width provided for the parking of vehicles, including access aisle width. In most cases, the module contains two rows of parking with an aisle between. The parking module (dimensions W shown in Figure 8.4) is computed by adding the stall depths, derived

Table 8-3. Calculated Parking Dimensions
(Based on Ricker formula)

Parking Angle and Projected Vehicle Length		*Stall Widths*		*Aisle Widths*	*Module Widths*				*Clearances*	
		Sw	*WP*	*AW*	W_1	W_2	W_3	W_4	*c*	*i*
		Large-car Design Vehicle (77" by 215")								
90°	VP_w = 18.42' VP_i = 18.42'	8'6"	8.50'	24.04'	42.46'	60.88'	60.88'	60.88'	1.5'	2.0'
75°	VP_w = 19.45' VP_i = 18.62'	8'6"	8.80'	21.17'	40.62'	60.07'	59.24'	58.41'	1.5'	2.0'
60°	VP_w = 19.16' VP_i = 17.55'	8'6"	9.82'	14.09'	33.25'	52.41'	50.80'	49.19'	1.5'	2.0'
45°	VP_w = 17.21' VP_i = 14.94'	8'6"	12.02'	11.0'	28.21'	45.42'	43.15'	40.88'	1.5'	2.0'
		Small-car Design Vehichle (66" by 175")[a]								
90°	VP_w = 15.08' VP_i = 15.08'	7'6"	7.50'	22.27'	37.35'	52.43'	52.43'	52.43'	1.5'	2.0'
75°	VP_w = 15.99' VP_i = 15.28'	7'6"	7.76'	20.14'	36.13'	52.12'	51.41'	50.70'	1.5'	2.0'
60°	VP_w = 15.38' VP_i = 14.00'	7'6"	8.66'	13.9'	29.28'	44.66'	43.28'	41.90'	1.5'	2.0'
45°	VP_w = 14.20' VP_i = 12.26'	7'6"	10.61'	10.0'	24.20'	38.40'	36.46'	34.52'	1.5'	2.0'

a. Small car spaces normally are considered only for 90-degree layouts.

Note: See Figure 8.4 for definition of terms.

θ Parking angle
W_1 Parking module width (wall to wall), single loaded aisle
W_2 Parking module width (wall to wall), double loaded aisle
W_3 Parking module width (wall to interlock), double loaded
W_4 Parking module width (interlock to interlock), double loaded aisle
AW Aisle width
WP Stall width parallel to aisle
VP_I Projected vehicle length from interlock
VP_W Projected vehicle length from wall measured perpendicular to aisle
S_L Stall length
S_W Stall width

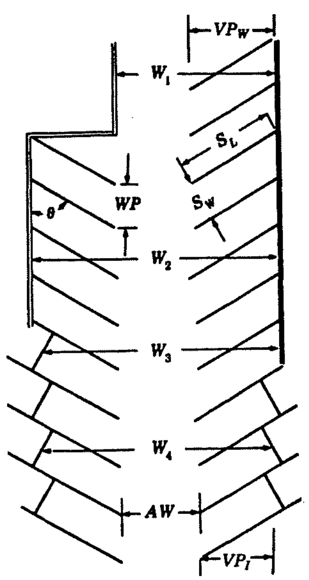


Figure 8.4. Dimensional elements of possible parking layouts

from the projected design vehicle length and bumper clearance, to the aisle width for the given parking angle. Projected design vehicle length has the same dimensional value as stall depth.

For angles of parking less than 90 degrees, the module width may be reduced by one interlock dimension for each row of stalls in a module that is interlocked with a row in an adjacent module. Calculated bumper-to-bumper interlock reduction dimensions vary depending on parking angle. Suggested bumper-to-bumper interlock reduction dimensions for various parking angles are: 90-degree angle, 0.00 interlock reduction (feet); 75-degree, 1.00; 60-degree, 1.67; and 45-degree, 2.33. Interpolation of values for other angles between 45 and 75 degrees will yield a reasonable result.

Typical ranges in parking module widths for different parking angles are shown in Table 8-4. The most appropriate module width for a given parking angle depends on (1) type of parking op-

Table 8-4. Typical Range of Parking Module Widths

Parking Angle	Aisle Width	Module Widths[a] (feet)			
(O)	(AW)	(W_1)	(W_2)	(W_3)	(W_4)
90°	24.0-26.0	42.0-43.5	59.0-62.0	59.0-62.0	59.0-62.0
75°	18.5-22.0	38.0-40.5	57.5-59.5	56.5-58.5	55.5-57.5
70°	17.0-20.5	36.5-39.0	56.0-58.0	54.5-56.5	53.5-55.5
65°	15.5-19.5	35.0-37.5	54.5-56.5	53.0-55.0	51.0-53.0
60°	14.0-18.0	33.5-36.0	53.0-55.0	51.0-53.0	49.0-5.10
55°	13.5-17.0	32.0-34.5	51.0-53.0	48.5-51.0	46.5-48.5
50°	12.5-16.0	31.0-33.0	48.5-51.0	46.5-48.5	43.5-45.5
45°	12.0-15.0	29.5-31.5	46.5-49.0	44.0-46.5	41.0-43.5
Small Cars Only					
90°	20.0-22.0	35.5-37.5	51.0-52.5	51.0-52.5	51.0-52.5

a. See Figure 8.4 for module width boundary conditions denoted by (W).

eration and user to be served, (2) available site dimensions, (3) how the vehicle size mix is anticipated, and (4) local zoning requirements.

Possible stall/aisle configurations are sketched in Figure 8.5. Pattern (e) in Figure 8.5 is the herringbone layout, suitable only for 45-degree parking. This layout is normally avoided because of the damage potential due to the necessary bumper-to-fender alignment of adjacent vehicles.

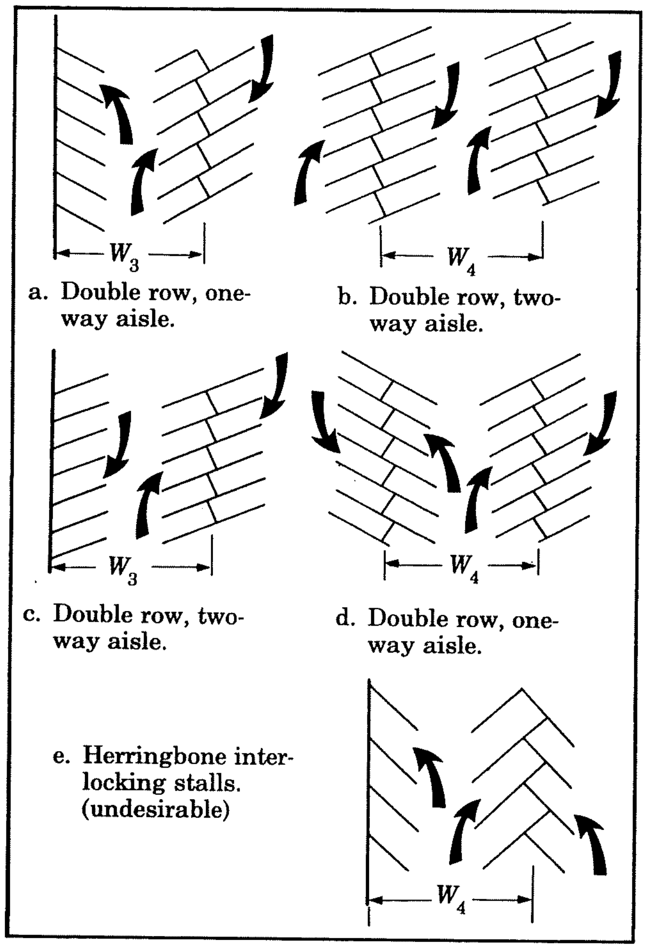


Figure 8.5. Possible parking module layouts with interlocking stalls

LAYOUT GUIDELINES

The efficient arrangement of driveway access, parking spaces, access aisles, internal circulation roads, and other parking lot features is influenced by many variables. The type of parker to be served, size of lot, and the type of operation are prime considerations. These considerations are further influenced by what is physically possible under constraints of the given site, what the owner-developer wants and can afford, what community regulations require or will allow, and the access opportunities on surrounding streets.

Driveway Access Design

The location and number of driveway access points is normally limited by local regulations, and are critical concerns in designing the parking layout and circulation system. For these reasons, the location of possible access points to the site is of primary importance. Access design usually proceeds simultaneously with the parking layout design. Local regulations and officials should be consulted to determine what access driveway points would be permissible and specific design requirements. Public regulations are principally concerned with assuring adequate stopping sight distance, minimizing pedestrian/vehicular conflicts and disruption to through traffic, and providing adequate driveway geometry.

Driveway openings should be located far enough away from street intersections to avoid or minimize traffic interference. Generally, driveway locations should favor entering traffic over exiting traffic. Exiting traffic moves slower and is less likely to affect through street traffic if backed up in traffic queues.

The number and location of access points depends on the lot size and access frontage; expected peak-hour entering and exiting traffic volumes by direction of approach; method of access control; and nature of the surrounding street system. For very large lots (as those serving regional shopping centers), access should be provided from as many surrounding streets as possible. In contrast, a small lot might need only one access point. Driveway access for large lots should be designed to separate potentially conflicting left-turn movements.

Access Design Procedure. Developing driveway lane and reservoir requirements is a straightforward procedure.

1. It is necessary to identify characteristics of parkers who will use the lot. These characteristics can be determined from the experience of similar traffic generators and/or site-specific studies.

2. Based on user characteristics and/or the total number of spaces to be provided, the peak-hour entering and exiting traffic volumes should be determined.

3. An access control strategy should be selected. This involves deciding whether or not a fee is to be collected and the method of collection, and how access is to be controlled to assure authorized use as intended.

4. The vehicle service or processing rate for the specific method of access control should be determined.

5. The number of access points, number of driveway lanes, and the amount of entrance and exit reservoir space should be determined. This normally involves comparing peak-hour flow rates for the busiest 15-minute entering and exiting period with the service processing rate of the access point control.

Detailed information pertaining to traffic flows, control point service rates (capacities) and queuing are discussed in Chapter 9. Relevant guidelines for parking lot access design follow.

Number of Access Lanes Needed. The number of entrance and exit lanes needed depends on the anticipated volume of peak-hour traffic, the processing or service rate of the access control (if access control is used), and the capacity constraints imposed by the street system. Where patrons will be required to stop at a control (such as a gate), the number of lanes to provide also is influenced by the space available to develop adequate reservoir length, driveway width, and acceptable waiting times for queued traffic waiting to be processed through the control point.

Where there is no entrance control that requires patrons to stop, 500 or more vehicles per hour per entrance lane may be able to enter the lot. The actual design capacity depends on difficulty of the entrance approach (sharp turn, pavement grade and roughness), patrons' familiarity with the entrance approach, and the capacity of the feeder street to deliver and maintain approach volumes. Parking lots without exit gates may call for design exiting capacities of 250 to 400 or more vehicles per hour per lane, depending on intersecting street traffic, type of intersection control and the turning movement desires of exiting traffic.

Many parking lots use gate access to collect parking fees and/or assure authorized use. Since gated access momentarily delays vehicles for a processing transaction, fewer vehicles per hour can enter or exit than for non-gated access. In such cases, design capacities or service rates vary, depending on the specific type of control and length of reservoir space between the street and control point, as well as the other factors cited earlier as influencing non-gated access. (See Chapter 9, Table 9-2 for service rate ranges of various access controls.)

The number of entrance or exit lanes can be estimated by dividing the anticipated peak 15-minute traffic flow rate (expressed in vehicles per hour) by the design service rate (capacity) of the particular type of access control (expressed in vehicles per hour).

Reservoir Space. Sufficient reservoir space must be provided at the lot entrance to prevent queued entering vehicles from spilling back across sidewalks or onto public streets. Exit reservoir space is usually needed to prevent queued exiting traffic from blocking gate control points and/or interfering with entering traffic or internal lot traffic circulation and parking manuevers.

The amount of reservoir space depends on lot size, the likely peak-hour traffic flow rate per lane, service rate of any control point (such as gated exit lanes), and the traffic conditions and controls of the street accepting exiting lot traffic.

For large lots without gated access control, adequate reservoir space (at least one to two car lengths) should be provided at primary entrance points to enable drivers to become oriented to parking area options without slowing other entering traffic. If entrance lane gates are used, sufficient reservoir space should be provided between the street and gate control point, as well as between the gate and parking area, the latter for driver orientation and traffic capacity purposes.

Ideally, the required reservoir lengths should be calculated according to the parking facility's operating characteristics, size, location and use. This is possible by using queuing theory formulas and/or derived design curves (see Chapter 9).

Traffic Circulation and Layout Orientation

The design and arrangement of parking modules to facilitate traffic circulation and space efficiency is largely a function of available site dimensions and accepted traffic engineering practices.

Pedestrian Circulation. It is desirable to arrange parking aisles perpendicular to the building face or pedestrian destination. This enables pedestrians to use driving aisles or parallel sidewalks to move between parking spaces and destination entrance. It requires a building setback of approximately 400 feet to provide adequate driveway entrance queuing space and parking aisles of reasonable minimum length.

When aisles are placed parallel with the building face, pedestrians are forced to move between parked vehicles to reach their destination. The parallel arrangement may be acceptable on narrow sites where parking stalls are arranged at 90 degrees and pedestrians are not forced to cross more than two parking module widths.

Raised sidewalks inside the parking lot have both advantages and disadvantages. If constructed parallel to driving aisles and located between rows of parking spaces, they must be sufficiently wide to accommodate vehicle bumper overhang and the possible placement of lot lighting standards, parking meter and/or sign poles. This suggests a width of 10 feet or more for sidewalks with vehicle parking on either side. While raised sidewalks imply pedestrian safety from vehicle operations, this is true only if sufficiently removed from vehicular areas or protected by barriers more substantial than curbing or wheelstops.

Disadvantages of sidewalks on medians separating parking rows include added space requirements, construction and maintenance costs, and the liability associated with pedestrians tripping or falling on raised curbing. When sidewalks are provided to serve rows of parking spaces, pedestrians often do not use them, finding the driving aisle more direct and convenient.

Vehicular Circulation. Traffic circulation should favor arriving traffic. Delivery and service vehicle traffic should be routed outside the boundaries of principal parking areas, and provided sufficient turning radii and vertical clearances.

Regardless of parking angle, the most efficient arrangement usually is found with aisles parallel to the long dimension of the lot. Circulation within the lot should provide a consistent search pattern that enables vehicles to circulate and recirculate as needed. Circulation aisles should be laid out to reduce travel distances and the number of turns. Dead-end aisles should be avoided.

Aisle length should not exceed about 350 feet without a cross aisle for vehicle circulation. This reduces driving time and length of travel inside the parking lot. It also discourages speeding. For larger lots, parking aisles should connect to a circulation roadway on which parking is prohibited. For two-way traffic circulation roadways (not providing direct access to individual parking spaces) it is common practice to use a minimum width of 22 feet (11-foot traffic lanes) plus 11 feet for each additional lane. One lane, one-way traffic generally requires a minimum width of 15 feet; two lanes of one-way traffic requires 22 feet plus 11 feet of width for each additional lane.

Shopping centers and other large traffic generators typically provide vehicular circulation at the building perimeter. Depending on circumstances, it may be desirable to limit this roadway to traffic circulation only, prohibiting parking. Except for very small lots or narrow sites, it is not desirable to locate parking spaces against building fronts. This enhances pedestrian circulation along building frontage, preserves architectural amenities of the building, and provides access for passenger loading and emergency vehicles.

Parking Angle. The choice of parking angle depends on available site width, owner/developer preference and traffic circulation objectives. Right-angle, 90-degree stall layouts provide wide aisles and allow two-way traffic circulation. Angled stall layouts at 45 to 75 degrees generally require a little more space than 90-degree layouts, but the difference is often negligible. Angle parking with one-way traffic flow is normally designed with alternating traffic directions.

For shopper parking, some major chain stores prefer angle parking with one-way aisles, which provides easier parking maneuvering. Others prefer 90-degree parking with two-way aisles, because it offers shorter travel distances, less driver regimentation and wider vistas of both parking opportunities and destination attractions. An industrial plant or special event lot may prefer angle parking to facilitate pull-through filling of stalls to expedite peak-traffic flows.

Primary advantages of 90-degree layouts include: greater choice for vehicular circulation, less travel time and distance, and wider aisles. Collectively, these advantages tend to decrease pedestrian-vehicular conflict as compared to flatter angle, one-way traffic layouts. Disadvantages of 90-degree parking are primarily associated with the greater effort required to maneuver into parking spaces.

Angled parking is easier to use and minimizes maneuvering delays. Angled parking also can be used on narrow sites. The disadvantages of angle parking tend to be the converse of the advantages cited for 90-degree layouts.

Generous turning radii should be provided throughout the circulation system. End islands should be developed at the ends of parking rows to assure sight distance and adequate turning radii. Figure 8.6 illustrates typical end-island layouts for different parking angles. Raised curbed end islands are far more effective than striped pavement islands in discouraging use of these areas for parking.

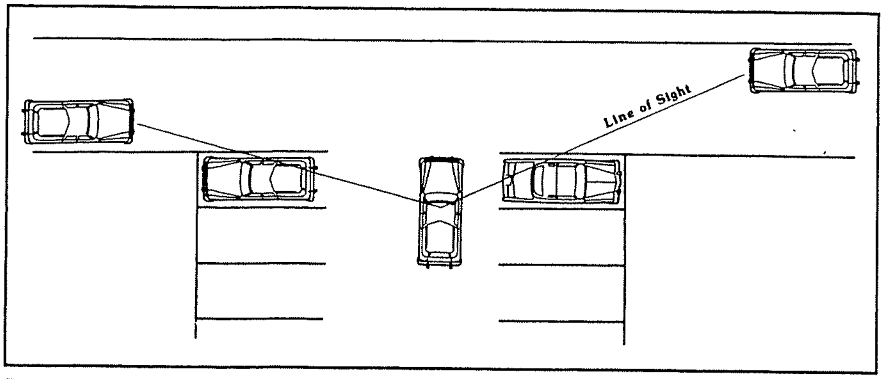
Special-Use Parking Spaces

Most parking lots must provide for some type of special-use parking. Special-use parking includes spaces with adequate dimensions and access for use by the physically handicapped, and may include space for bicycle/motorcycle parking and delivery or service vehicle parking.

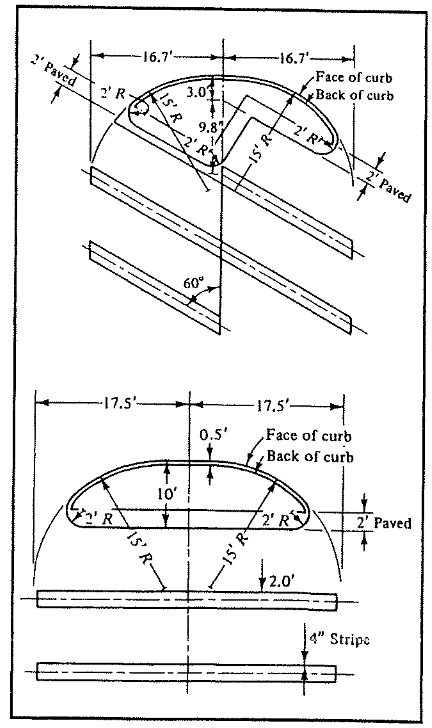
To gain greater space efficiency, many local zoning codes allow the use of small-car-only parking spaces to satisfy some portion of the needed parking. Problems associated with controlling the use for small car spaces tend to discourage their use for many types of parking; but this design approach is often the only alternative to obtain the needed number of spaces under constraints imposed by site-specific conditions.

Small-car-only spaces are allowed in many local zoning codes to provide some portion of the needed parking supply. Problems of controlling the use of these spaces, among other difficulties, limit the application of small-car-only spaces to very specific circumstances. An often more workable approach has been to slightly downsize overall parking stall and aisle dimensions to reflect the influence of smaller cars in the vehicle population. Downsized stalls are capable of parking most vehicle sizes, and control is not a problem. This approach is relatively new and has not been reflected in many zoning codes, which tend to lag development trends.

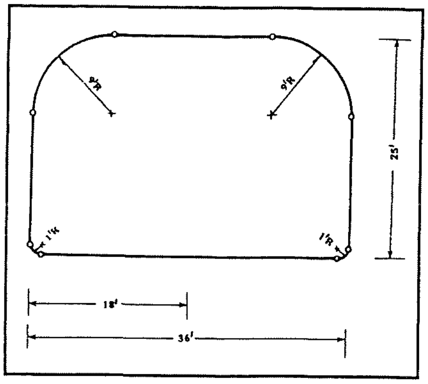
Layouts With Small-Car-Only Stalls. Special small-car only parking spaces became common after 1975 as the small car population increased. This led to various design approaches for dealing with small cars such as the illustrative approaches shown in Figure 8.7. They include (1) complete separation of small car and full-size spaces, (2) cross-aisle separation, (3) placing small car and full-size spaces in the same rows, or (4) alternating small and full-size car spaces.



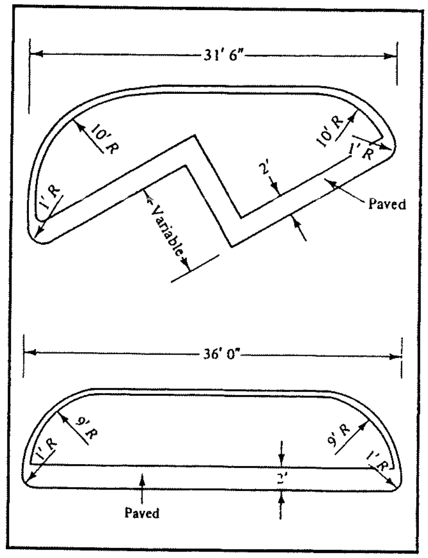
Sight distance is blocked in absence of end island.



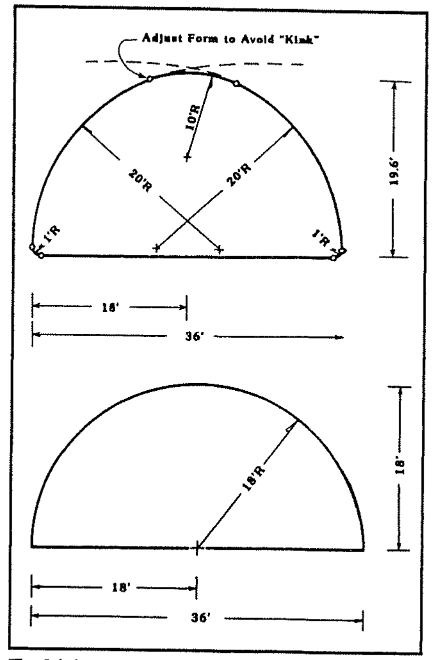
Dimensions for modified end islands to increase curb radius for 60- degree parking (*top*) and 90-degree parking (*bottom*).



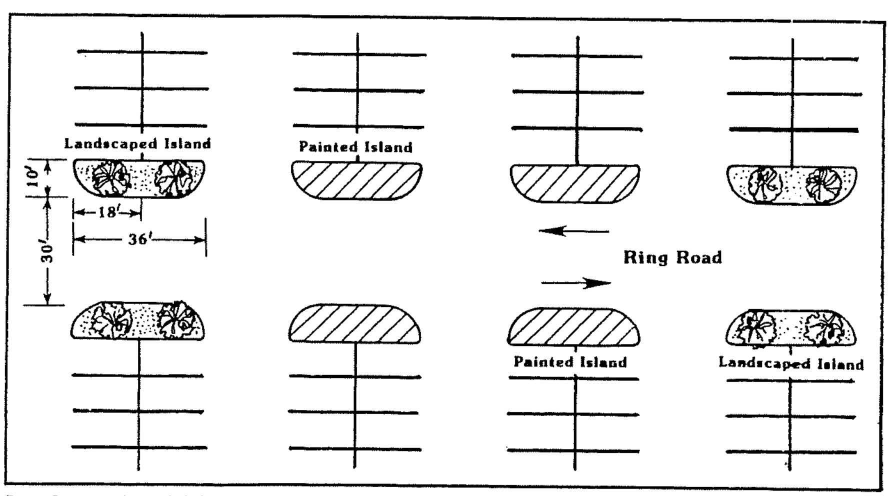
Dimensions of an extra wide end island with traditional radii.



Dimensions for typical end islands for 60-degree parking (*top*) and 90-degree parking (*bottom*).



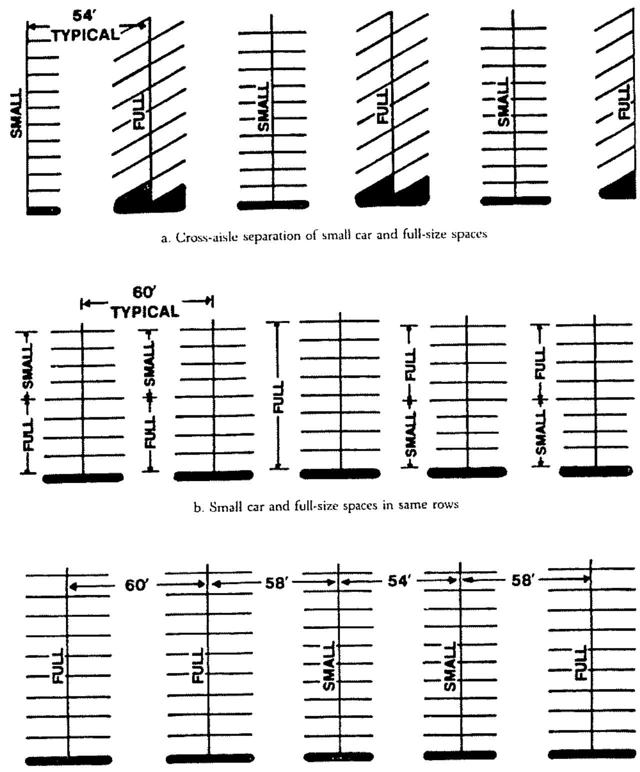
End island dimensions for 18- foot parking stalls: suggested compound curb radii design (*top*), and simple curb radius design (*bottom*).



Landscaped end islands used for roadway delineation.

Figure 8.6. Typical end-island layouts and applications

Source: Vergil G. Stover and Frank J. Koepke, "End Islands as an Element of Site Design," *ITE Journal*, November 1989, p. 33.



a. Cross-aisle separation of small car and full-size spaces

b. Small car and full-size spaces in same rows

c. Alternating two or more small car parking rows of full-size spaces

Figure 8.7 Parking layouts combining small-car and full-size spaces

Several problems emerged with these practices: (1) how to estimate the proportion of small car spaces over time, (2) how to allocate small-car-only space and (3) how to enhance proper usage.

Accordingly, some parking consultants have suggested that space dimensions be "weighted" by the fleet size mix. On balance, the preferred practice is to utilize standard-size spaces.

Handicapped Parking. Nearly all states and many municipalities have established design and space requirements for handicapped (HC) parking. These requirements vary by locale but are gradually being ammended to follow the Uniform Federal Accessibility Standards (UFAS). The federal standards require accessible parking spaces be at least 96 inches (8 feet) wide and have an access aisle of 60 inches (5 feet) wide minimum along one side of the parking space. Figure 8.8 illustrates general paramenters for handicap parking space layout, marking and signing.

The number of HC spaces to provide is normally a percentage of the total number of regular user spaces provided. The required number varies depending on ordinance and site-specific demand circumstances.

Handicapped spaces should be located as near as possible to destination entrances. Convenient and HC accessbile pathways must be provided between HC parking and destinations.

Parking Lot Space for Bicycles and Motorcycles. In a growing number of municipalities, bicycle parking is required by ordinance for certain types of new land-use developments. Very few cities have specific requirements for motorcycle or moped parking facilities. Where there are inadequate facilities for cycle parking these vehicles are parked on sidewalks and pedestrian malls, and frequently chained to trees and parking meter or sign posts. This situation is generally unattractive and may represent safety and traffic circulation problems. Cycle parking in automobile spaces is not space efficient or desirable to most cyclists for reasons of convenience and security.

Bicycle and motorcycle parking facilities should be located in an area of the parking lot convenient to destination entrances. Cycle parking facilities should be located in highly visible areas to minimize theft and vandalism. Cycle parking facilities placed behind walls or high shrubbery are not conducive to security. Wherever feasible, the parking should be visible to persons within the building. Cycle parking facilities should be placed on paved surfaces and well lit. Cycle parking should not interfere with pedestrian traffic, and should be protected from potential damage by other vehicle traffic.

Most bicycle parking ordinances require the parking space to be at least 2'6" wide by 6'0" long. Motorcycle and moped parking typically requires parking space dimensions of 3'4" by 7'0'. Figure 8.9 illustrates a few of the various types of storage racks and layout configurations available for cycle parking. Local ordinance requirements typically specify bicycle rack performance standards in regard to security.

Cycle parking is more likely to be used if it looks like cycle parking. Signs can help bicyclists to locate and identify unfamiliar kinds of racks. The racks themselves should be easy to understand and operate. For safety, racks should be easily visible to pedestrians; eye-level signs can help avoid tripping hazards.

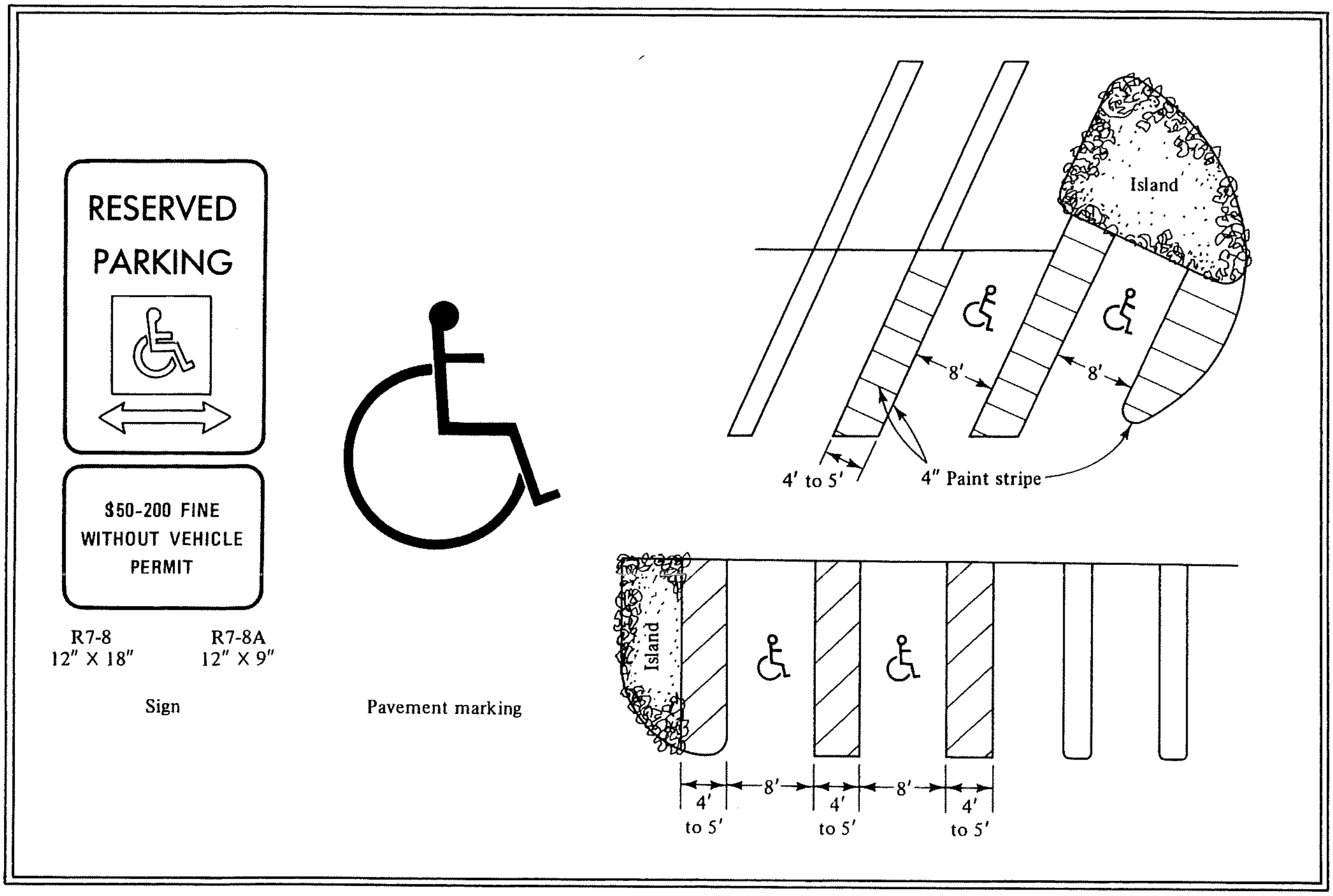


Figure 8.8. Handicapped signing, pavement marking and parking stalls

Truck Delivery Facilities. Large activity centers should be designed with separate access for truck delivery vehicles. The truck circulation system should be designed to avoid interference with automobile and pedestrian movements or with high turnover parking. Truck loading docks should be located away from the areas of pedestrian movement and screened from view of parking areas, adjacent properties, or adjacent streets. Rear access is commonly used for deliveries.

Over-the-sidewalk delivery and service may be adequate for some types of development where delivery activity is minimal. Where delivery activity is likely to be substantial, over-the-sidewalk delivery should be considered only as an auxiliary method. Where the traffic generator building is surrounded by parking, truck delivery courts are commonly used. Truck delivery tunnels, once popular, are now rarely used because of development and maintenance expenses. Figure 8.10 illustrates various options for providing truck delivery facilities.

The truck circulation pattern and loading position should be designed for counter-clockwise entry and for a left-side backin maneuver (see Figure 8.11). This allows the truck driver to see along the driver's side of the truck when backing. The truck maneuvering apron space should be designed to allow trucks to be backed in and pulled out in one continuous maneuver. When tractor-trailer trucks are expected, the WB-50 truck design vehicle is normally used for design. Dimensions for common loading angles are given in Table 8-5 for both a WB-50 and a WB-40 design truck vehicle.

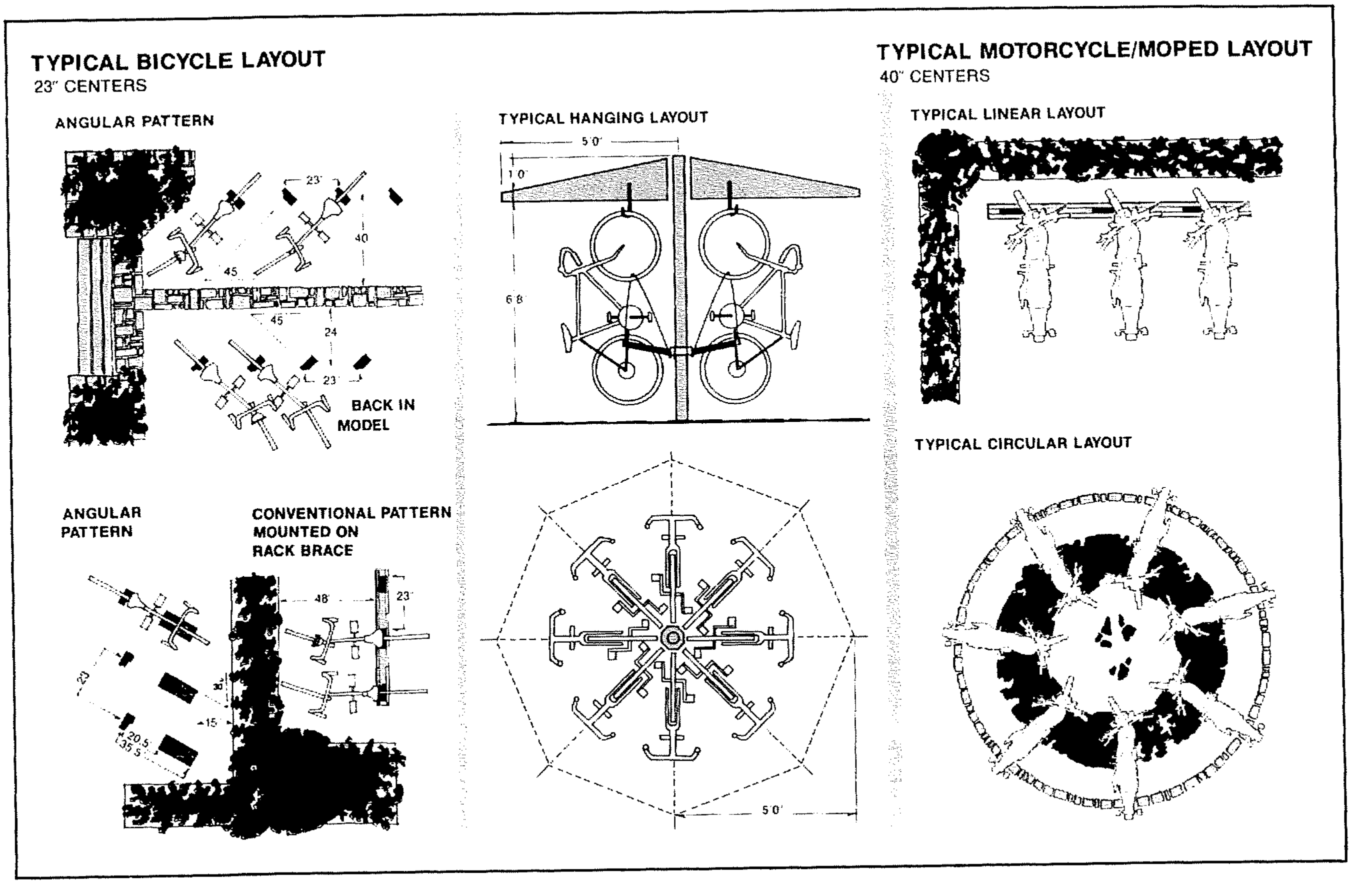


Figure 8.9. Typical bicycle and motorcycle rack layouts

Source: Rally Racks, Sonoma, CA.

DESIGN DETAILS

Parking lots should be paved and well drained. Pavement markings, signing and lighting should be coordinated. Landscaping and lot boundary elements, such as visual screening and fencing should be designed to be as maintenance free as possible, yet functional in serving their intended purpose.

Pavement and Drainage

The durability of an open parking lot depends on the quality of paving, as well as drainage. A paved surface is desirable for efficient operations and maintenance. It facilitates proper drainage, routine cleaning and snow removal. A paved lot surface also reduces dust, enables stalls to be marked, and provides an improved surface for walking.

The pavement should be sloped to drain properly. A minimum grade of 1 percent for asphalt and 0.5 percent for concrete is desirable. Grades should not generally exceed about 3 percent in the direction longitudinal to parking stalls, or 5 percent for cross-slopes or driving aisles.

Generally, cross-sloping small parking areas in one direction is the most efficient and visually least disturbing method of directing surface drainage. In some instances it may be more advantageous to pitch the paved surface from any two opposite sides towards the middle, either creating a ridge or a valley across the mid-section of the parking surface. Site-specific conditions will indicate cross-slope designs that are both efficient and cost effective.

Where necessary, underdrainage should be

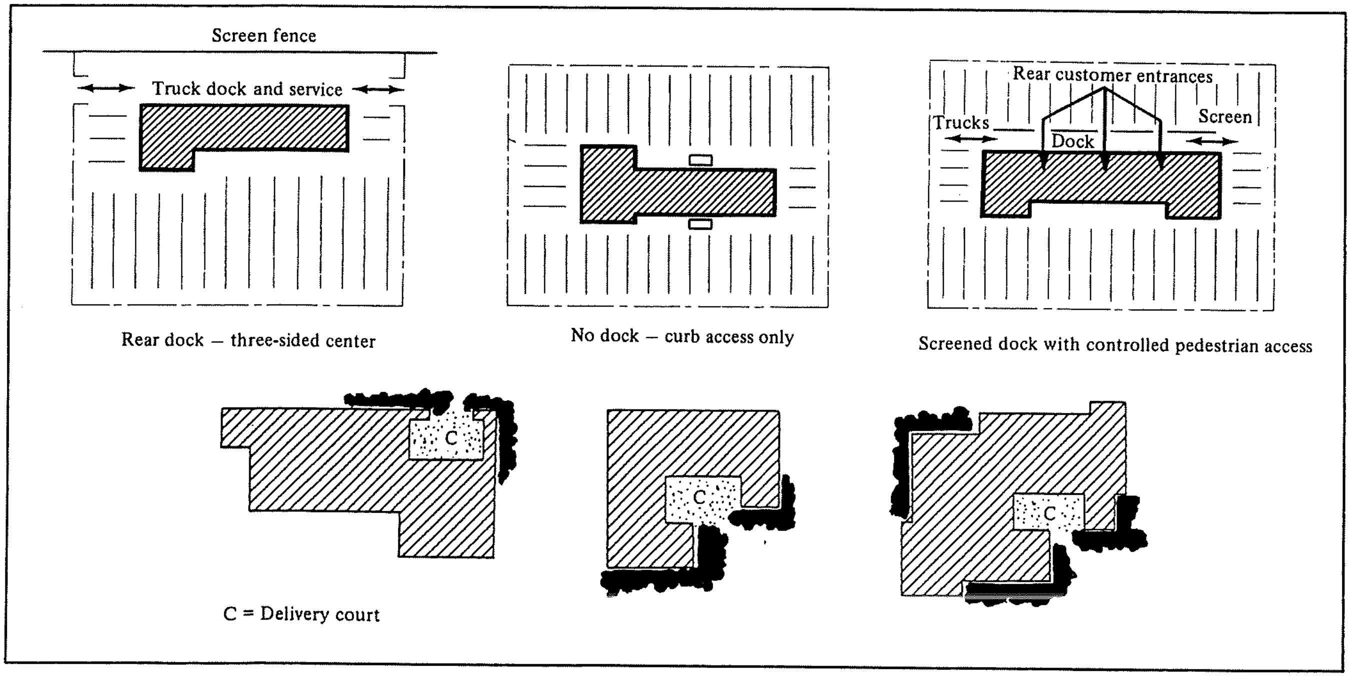


Figure 8.10. Examples of truck delivery and service docks and interior courts

Source: Vergil G. Stover and Frank J. Koepke, *Transportation and Land Development*, Institute of Transportation Engineers (Englewood Cliffs, NJ: Prentice Hall, 1988).

used to collect and dispose of groundwater before it can reach the foundation soil of the parking lot. If the need for underdrains is not recognized and provided for in the initial design, premature failure of the parking lot's surface will occur above the undrained subsurface. Surface repair of a pavement defect caused by poor drainage will merely be a temporary solution, since it treats only the symptom, not the cause of distress.

Curbs, Wheelstops and Bumper Barriers

Curbs are used in parking lots to help control drainage and to discourage vehicles from leaving areas designated for vehicular activity. Curbing may also be used to delimit parking end islands and to encourage proper traffic circulation. Wheelstops are frequently used to help limit vehicle overhang encroachment beyond parking stall limits. Bumper barriers are used where more positive vehicle restrain is necessary to limit vehicle encroachment or to help protect buildings, walls and other improvements from vehicular damage.

Curbs are effective in discouraging drivers from parking on the end island at the ends of parking rows. This preserves sight distance and provides an area that can be landscaped, improving lot aesthetics. Large lots often invite some drivers to drive across rows of empty spaces to shorten their travel. To discourage this type of hazardous traffic circulation, raised curbed medians can be placed parallel to driving aisles, extending along the ends of stalls and separating one or more parking modules. Such medians should be sufficiently wide and delineated to be visible, especially at night and during inclement weather. For reasons of maintenance convenience, it is desirable to make these medians sufficiently wide to allow for vehicle overhang, eliminating the need for free-standing wheelstops in front of the median curbing.

Design and layout should minimize the need for using free-standing wheelstops. Wheelstops interfere with people walking between cars, provide traps for debris, and impede snow plowing. Moreover, since they are placed out of the driver's line of sight, drivers must depend on impact to know when their vehicle is fully positioned in the

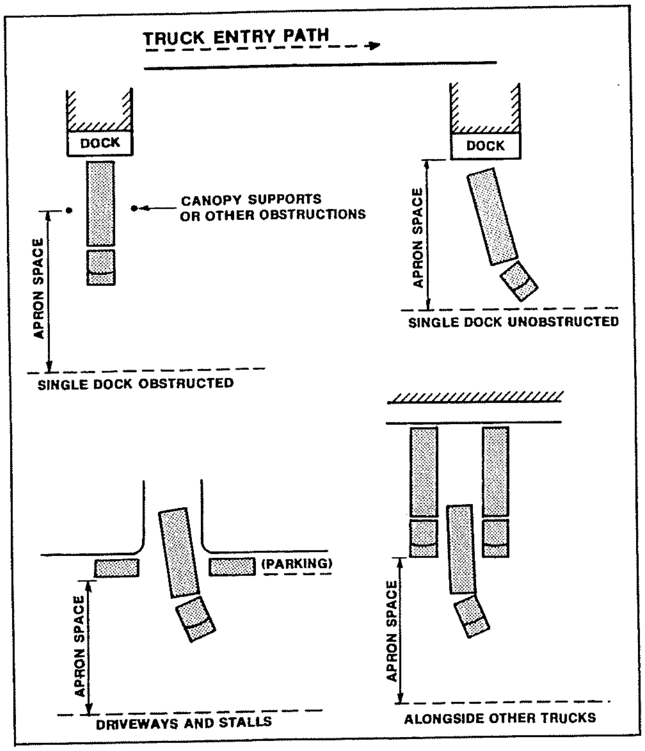


Figure 8.11. Loading-dock configurations and approach

Source: Vergil G. Stover and Frank J. Koepke, *Transportation and Land Development*, Institute of Transportation Engineers (Englewood Cliffs, NJ: Prentice Hall, 1988).

parking stall. Constant wheel impact causes the wheelstops to break and move out of place.

Curbing should normally be used to provide a wheelstop to help assure vehicle overhang protection for buildings, sidewalks, landscaping, and other properties. The setback allowance for vehicle front overhang is typically about 2.5 feet, and 4.0 to 4.5 feet for rear overhang. Back-in parking, however, is not usually a design consideration in North America because it is not generally practiced or encouraged. When positive setback clearance is essential to protect improvements from bumper contact, a bumper clearance factor of 6 inches or more should be added to the setback, or suitable guard railing should be installed.

Signing and Pavement Marking

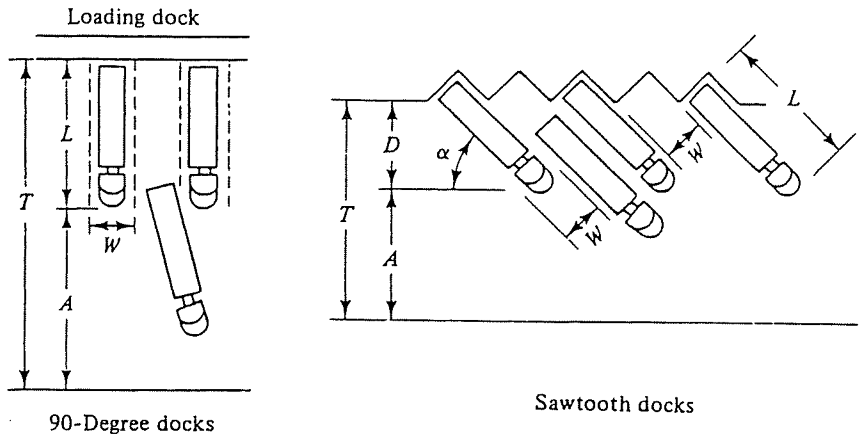
Parking lots should be signed and marked clearly to assist drivers and pedestrians. Traffic regulatory signing, such as Stop, Yield or speed limit signs are rarely effective when overly used. These regulatory signs should be used sparingly, and generally limited to the primary internal circulation roadways of large parking lots. Stop signs should be used where there is inadequate sight distance for intersecting traffic. "No Parking" signing may be helpful or required for enforcing this prohibition in fire lanes or along internal circulation roadways. Regulatory signing should be in compliance with local and state standards. Signing and pavement markings to designate handicapped parking are typically a requirement of local and state codes.

Large lots may benefit from signing that identifies specific areas of parking. This helps patrons to locate their parked vehicles and special users to identify their designated parking areas. Raised directional signing may also be desirable to help drivers and pedestrians locate points of exit. Where parking fees are collected, signs displaying the terms and conditions should be displayed near the entrance.

Sign placement should consider visibility factors such as nighttime lighting, sun glare, landscape overhang and the effect of parked or queued vehicles on sign visibility. Signs should be large enough to be read by the intended traffic; messages should be simple and expressed in customary terminology. Signing sometimes can be attached to light poles or walls. Signs should be mounted high enough to be visible and clear of pedestrian and vehicular traffic. Signing plans are best completed as construction of the project is nearing completion. This better enables the designer to determine the functional and aesthetic impact of sign design and placement.

Parking stalls should be striped with white or yellow paint. Customary practice for the locale usually suggests which color to use. Double-line stall striping encourages better vehicle positioning in stalls than single-line stripes (see Figure 8.12 for striping details). Marked pavement arrows indicating traffic flow direction may be desirable for one-way traffic aisles. Major circulation roads should provide centerline striping. Where warranted by multiple traffic lanes in the same direction, lane striping should be provided along with pavement edge striping when there is no curbing. Pavement striping should conform with state and local standards.

Table 8-5. Loading Dock Dimensions



Design Vehicle	Length in Feet (L)	Dock Angle (a)	Clearance in Feet (D)	Berth Width in Feet (W)	Apron Space in Feet (A)	Total Offset in Feet (T)
WB-40	50	90°	50	10	63	113
				12	56	106
				14	52	102
		60°	44	10	46	90
				12	40	84
				14	35	79
		45°	36	10	37	73
				12	32	68
				14	29	65
WB-50	55	90°	55	10	77	132
				12	72	127
				14	67	122
		60°	48	10	55	103
				12	51	99
				14	46	94
		45°	39	10	45	84
				12	40	79
				14	37	76

Source: Vergil G. Stover and Frank J. Koepke, *Transportation and Land Development*, Institute of Transportation Engineers (Englewood Cliffs, NJ: Prentice Hall).

Curb painting is most commonly used for regulatory purposes. Painting may help to delineate curbing for pedestrian and vehicular traffic, but represents a significant maintenance effort to preserve.

Lighting

Adequate lighting is essential where there is evening or nighttime use to improve safety and security. Ample mounting heights of luminaries, and proper ratios of spacing to mounting height should be used to distribute reasonably uniform amounts of light to the entire parking lot. Use of spotlights or luminaries of a sufficient intensity to illuminate all dark corners, while desirable, usually is impractical.

Lighting Levels. Illumination levels are measured in "footcandles" — a standard measure of illumination over a surface of one foot. The levels of illumination depend on the amount of

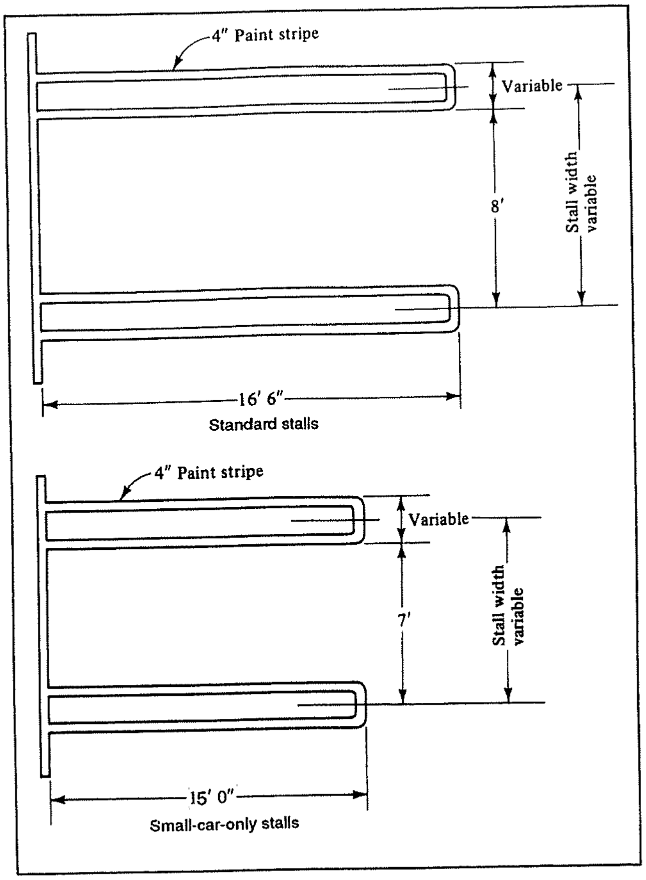


Figure 8.12. Striping of parking stall

activity within a lot during evening hours. Lighting levels recommended by the Illuminating Engineering Society of America (IES) are shown in Table 8-6. Areas of high activity include major league athletic events, major cultural or arts events, regional shopping centers and fast food facilities. Parking lots for these uses typically provide illumination of at least 2.0 footcandles. Sample zoning requirements are shown in Figure 8.13.

Areas of medium activity include community shopping centers, office parks, hospital parking areas, park-and-ride lots, and residential parking areas. These parking lots typically provide illumination of at least 1.0 footcandles. Areas of low pedestrian activity (at night) include industrial employee parking, school parking, and church parking. These facilities typically provide illumination of at least 1.0 footcandles.

Generally, higher lighting levels should be provided at vehicular entrances and exit areas, facilities used exclusively by pedestrians, passenger loading zones and areas of particularly intense traffic. These areas might require twice as much light (or more) than used in the general parking lot. A minimum intensity of 5 footcandles is suggested. Where security is a major concern, lighting levels should be increased.

Locations and Types. The spacing of light pole standards depends on type of fixture, height of pole, number of fixtures on the pole and the desired lighting level. Mercury vapor or sodium vapor light fixtures are commonly used.

Every lamp manufacturer provides a scale from which parking lot illumination requirements can be determined. There are, however, several guidelines that can be used for making preliminary estimates. For reasonably even illumination, most lighting can be placed at intervals that equal four times the mounting height. Some high pressure sodium and metal halide fixtures must be placed closer together to compensate for the loss of light output over the life of the lamp. Generally, wall-mounting requires around 40 percent more fixtures than pole-mounting to provide one footcandle of illumination over a horizontal area.

Table 8-6. Parking Lot Lighting Guidelines

	General Parking and Pedestrian Area[a]			*Vehicle Use Area (only)*[b]		
Level of Activity	*Lux (Minimum on Pavement)*	*Footcandles (Minimum on Pavement)*	*Footcandles Uniformity Ratio (Average/Minimum)*	*Lux (Average on Pavement)*	*Footcandles (Average on Pavement)*	*Uniformity Ratio (Average/Minimum)*
High	10	0.9	4:1	22	2	3:1
Medium	6	0.6	4:1	11	1	3:1
Low	2	0.2	4:1	5	0.5	4:1

a. Where pedestrians and vehicular conflicts are likely to occur.
b. Where conflicts with pedestrians are not likely to occur.

Source: *Lighting for Parking Facilities* (Illuminating Engineering Society of America, August 1984).

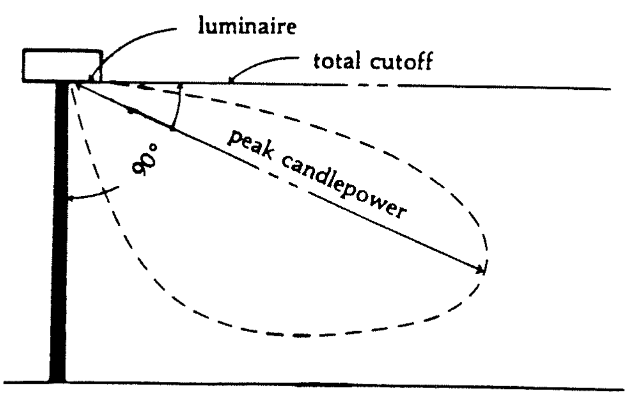
1. When light source or luminaire has no cutoff.[1]

Use/Density Category	Maximum Permitted Illumination[2]	Maximum Permitted Height of Luminaire
Residential	.2	10 ft.
Low-density nonresidential	.2	15 ft.
Medium- and high-density nonresidential	.3	20 ft.

2. When a luminaire has total cutoff of light at an angle of 90 degrees or greater.

Use/Density Category	Maximum Permitted Illumination[2]	Maximum Permitted Height of Luminaire
Residential	.3	15 ft.
Low- and moderate-density nonresidential	.5	20 ft.
	.75	25 ft.
	1.0	30 ft.
High-density nonresidential	1.5	35 ft.
	2.0	40 ft.

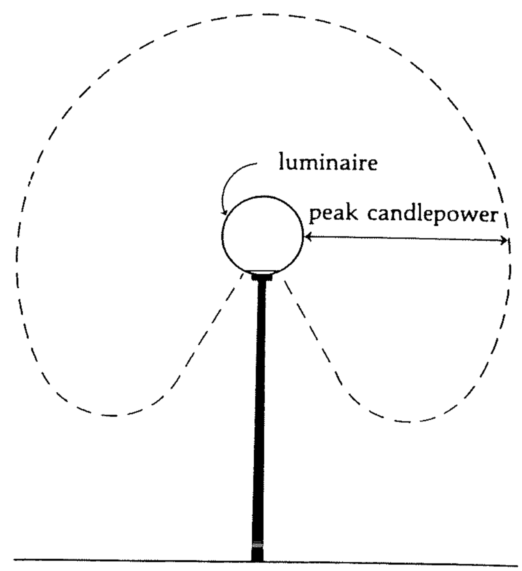
2. CUTOFF LUMINAIRE



1. The cutoff is the point at which all light rays are completely shielded.

2. The maximum permitted illumination is measured in footcandles at the interior buffer yard line at ground level. Lighting levels must be measured in footcandles with a direct-reading, portable light meter. The equipment used must allow accurate measurements, and all measurements must be made after dark with the lights on and then again with the lights off. The difference between the two readings must be compared to the standard for maximum permitted illumination.

1. NO CUTOFF LUMINAIRE



3. When a luminaire has total cutoff of light at an angle of less than 90 degrees and is located so that the bare light bulb, lamp, or light source is completely shielded from the direct view of an observer five feet above the ground at the point at which the cutoff angle intersects the ground.

Use/Density Category	Maximum Permitted Illumination[2]	Maximum Permitted Height of Luminaire
Residential	.5	20 ft.
Low- and moderate-density nonresidential	1.0	25 ft.
	2.0	30 ft.
	3.0	40 ft.
High-density nonresidential	4.0	50 ft.
	5.0	60 ft.

3. LUMINAIRE WITH LESS THAN 90 CUTOFF

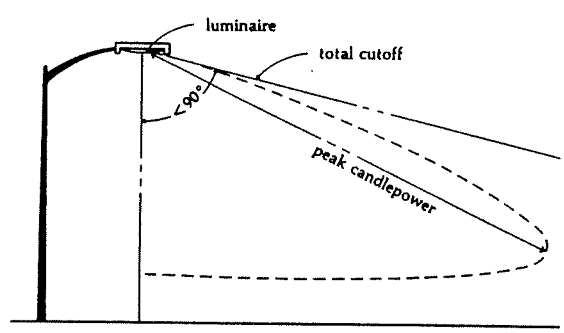


Figure 8.13. Sample exterior lighting standards

Source: Thomas P. Smith, *The Aesthetics of Parking* (Chicago, IL: American Planning Association, 1988) p. 18.

Pole placement, mounting height and fixture design should minimize glare to drivers and excessive spillover of light onto neighboring areas.

Poles to mount light fixtures generally range from 20 to 50 feet or more in height. Higher mountings distribute light over a wider area, require fewer poles and produce less glare. Accordingly, to minimize the effect of the glare and to provide the most economical lighting installation for most lamp types, luminaries are typically mounted at heights of at least 30 feet. Lighting uniformity is improved with higher mounting heights, and in many cases, mounting heights of 35 to 50 feet are preferable but limited by local zoning code.

High mast lighting, using special luminaries on masts of 100 feet or more in height, are used for roadside rest areas and in parking lots serving some types of recreational parking. This type of lighting furnishes uniform and economical lighting; however, it also has a disadvantage in that the visual impact from spurious light is increased for surrounding land uses.

Breakaway poles should not be used in parking lots. Poles should not be erected along the outside of roadway and ramp curves or where vehicles must make sharp turns. Poles should not be located where they would be especially susceptible to collision strikes. Poles located behind longitudinal traffic barriers (guardrail, for example) should be offset enough to allow for barrier deflection under impact.

Pole locations must be coordinated with stall and aisle layouts. Where practical, poles should be kept near ends of parking rows or around the perimeter of the lot. When located at parking stall boundaries, light poles can be mounted on concrete pedestals to protect them from bumper damage. Perimeter locations are desirable since the light poles are removed from the lot and allow flexibility for possible future changes in stall widths or layouts. Where raised medians or islands are used to separate adjacent stalls, light poles can be placed in these areas.

In large lots, however, light standards generally must be placed between parking rows in the interior of the lot. They should be located on the center line of double rows of parking stalls, and also on the center line of the two opposing stalls (see Figure 8.14). They should *not* be placed on the stall line between cars where fender damage might occur. Nor should they be placed where pedestrian traffic might be inconvenienced.

All wiring should be located in buried conduits before the paving operation is started. Lighting controls can be located in an approved outside control box or in a nearby building. The controls also can be placed on a timing device.

Landscaping

Landscaping of parking lots is desirable for many reasons. It screens lots from adjacent areas, and it breaks up the wide expanse of paved areas. It helps to separate pedestrians and vehicular traffic, and it can delineate different parking areas. Consequently, a growing number of communities have zoning ordinances that require landscaping for surface lots. These ordinances govern the amount of landscaping buffering and screening and the treatment of interior areas.

The amount of landscaping calls for balancing aesthetics, community appearance and costs. Some communities have called for a specific percent of the lot area to be used for landscaping, ranging from 5 to 15 percent.

Buffering and Screening. Screening parking lots from the street or nearby residential properties is desirable to maintain community appearance and property values. Screens come in many shapes, sizes and types, and are effective in shielding automobiles from view outside the parking lot. Commonly used screens include berming, evergreen plantings, fences and densely planted hedges.

Berms and graded slopes can be excellent screens. Although berms may be costly to construct, they are easy to maintain and are more

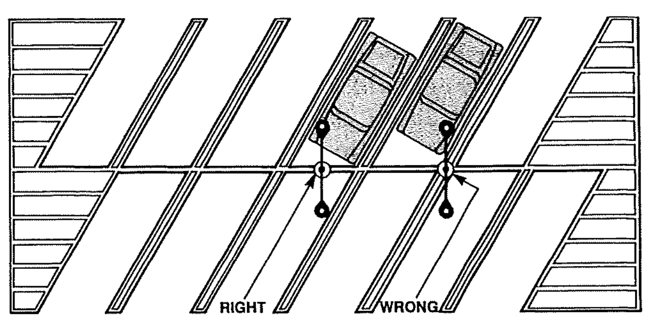


Figure 8.14. Light standards (poles) should be located on center lines of stall end boundaries

visually pleasing than fences or walls. Low height berms (three to four feet) effectively screen most automobiles, especially when the parking lot is placed a few feet below street level.

Small hedges or fences (three to four feet in height) also can be effective. These screens can be maintained on small landscaped strips of five to ten feet in width and built at low cost. Some communities in northern climates require non-deciduous shrubs to be used to ensure screening throughout the year.

Screens typically are required along street fronts and adjacent to residential areas. Landscaping setbacks may not be necessary along perimeter areas that abut commercial or industrial buildings. Trees may be required along a lot's street frontage, but not along other parts of its perimeter.

Fencing may be needed where security is a concern. It should be located so that cars do not strike and damage it.

Design Considerations. Landscaping should be coordinated with roadway and parking area layout. After the required (or desired) landscaping setback along property lines is determined, the parking lot should be designed for maximum capacity. Landscaping within the lot can be used to help compartmentalize large lots. It can be located within raised end islands, or medians separating parking modules. Proper clearance from parked cars should be maintained. The positioning of trees should be coordinated with the locations of signs and light standards.

Shade trees sometimes are required to satisfy interior lot landscaping requirements. They also moderate heat from asphalt parking lots in warm climates.

Shrub, plant and tree types should be selected that can withstand auto fumes and the concentrated heat from a large paved surface. Sufficient setback is essential so that landscape plantings do not interfere with the overhang of parked vehicles. Care should be exercised in locating shrubbery and other plants near entrances and exits to avoid restricting sight distance. Accordingly, the growth pattern of plants must be taken into account.

When choosing trees for parking lots, the primary concerns are longevity, crown size (for shading purposes), aesthetics, and nuisance factors. Trees that drop sap should be avoided, and trees that drop large amounts of blossoms, seeds, and pods that might clog drains also may have to be avoided. Deciduous trees that drop leaves can be used if parking lots are periodically cleaned. Hearty trees resistant to motor exhaust fumes, dirt, and soot should be used. Trees that are susceptible to insects and disease should be avoided, and trees with expansive roots that could disrupt paving and underground lines should be discouraged. In cold climates, the use of trees that are tolerant of road salt and deicing compounds should be encouraged.

Landscaping also should be coordinated with grading and excavation plans. This is particularly important when some of the existing trees and plantings are to be retained. When retaining existing trees, enough ungraded area around the tree should be retained for its survival. Grading should not encroach on a tree's roots in ways that threaten the tree's survival.

Based on the level of paving, sprinklers and valves should not extend over 6 inches above the ground in any area where a car bumper could hang over the planting area. To ensure proper visibility, the area from about 2 feet to at least 5 feet above ground must be clear of growth except for tree trunks; cars and pedestrians then will be fully visible. High hedges and cone-shaped trees with heavy growth reaching down to the ground should be avoided if they interfere with visibility. However, such foliage can be used as a visual screen around the perimeter of the parking facility.

Proper maintenance of landscaping is essential. Safeguards may be required to keep plants alive – especially in areas with insufficient rainfall.

SUMMARY

Parking lots provide important services to adjacent properties. They also can be a profitable business when commercially operated. It is good business practice to make them attractive to users. Wide aisles, ample stalls, protected walkways, paved surfaces, and adequate lighting will result in safer and more efficient operations. Sensitive landscaping will enable the lots to blend with their surroundings.

Contemporary concerns for urban aesthetics, as well as for traffic and environmental impacts, are influencing parking lot design. In response to these concerns a growing number of communities have implemented higher design standards. They often require effective visual screening and internal landscaping of lots to conceal or soften the parking lot appearance and to reduce apparent lot size. Maximum time limits (3 to 5 years, typically) are increasingly imposed on interim or temporary parking lots that do not conform to urban design requirements. And, zoning incentives and bonuses are being used to encourage underground and mixed-use parking structures.

The highly competitive nature of real estate development prompts many developers and operators to take the initiative in improving parking lot design and aesthetics. Better functioning, more attractive parking lots make developments more marketable. Parking for office, residential, retail and many other types of new development is being placed at the rear of buildings or partially concealed in landscaped islands around the building site. Even some existing shopping centers are moving to conceal much of their parking in landscaped compartmentalized areas. In this way, the parking facilities became visually and functionally integrated into the surrounding environment.

CHAPTER 9

Garage Design

A parking garage should functionally and visually fit into its environs. It should provide simple, convenient and efficient access for its patrons. Entering and exiting should be accomplished with minimum delay; travel between floors should be clear and follow natural paths. Parking and unparking should be easy; and pedestrian circulation should be safe and direct. Signing, lighting, drainage and ventilation should be adequate. Ample safety and security must be provided. Successful operation depends in large measure on how well a garage is designed.

This chapter overviews the many facets of parking garage design. It discusses design concepts, access requirements, parking layouts and ramp systems, and interior design details. The guidelines it sets forth help to illustrate how efficient garage design can be achieved.

DESIGN CONCEPTS

A wide range of parking structure design concepts deal with the type of facility, method of construction, and treatment of facades. In developing a facility, it is important to select the appropriate concepts for specific sites and environments.

Garage Types

Garages may be classified by their means of interfloor vehicular travel — elevator (mechanical), or type of ramp; or by their method of operation — self-park or attendant-park.

Most garages are built above ground, either as free-standing facilities or as part of multi-use buildings. Provision of parking with leasable commercial and/or residential space in the same building is increasingly common in urban centers.

Underground garages are built where environmental or land-use factors make it impractical to provide parking space above ground. Landscaped areas, plazas, or some type of development may be built above the below-grade parking. Development and operating costs of underground parking are usually much higher than for above ground development.

Ramp garages predominate. Straight, circular, and sloping floor ramp systems are used to provide travel between floors.

Mechanical or elevator garages have been used on very restrictive sites or as "temporary" parking facilities. They are used in many major cities of the world, but their use in the United States has not been popular due to operating costs and public acceptance.

Self-parking is provided in most garages. *Attendant-parking* is used where space is extremely scarce, or where "valet" parking service is necessary. While attendant parking is more space efficient, its high labor costs, and storage requirements for waiting vehicles limit its general application.

Building Systems

Parking garages use structural systems of either poured-in-place steel-reinforced concrete, precast concrete, post-tensioned concrete, structural steel, or combinations of two or more of these material systems.

The relative economy and adaptability of various structural and material systems reflect:

1. local building code requirements;
2. availability of materials, fabricators, and experienced contractors;
3. costs and shipping distances;
4. future maintenance requirements;
5. erection time and future facility expansion plans; and
6. responses to atmospheric and environmental conditions.

One structural or material system cannot be better than another, or more economical, in all locations and under all conditions. Choice of the most appropriate structural and material system only can be made after a comparative economic analysis that considers site-specific circumstances and influences.

Consideration also must be given to alternative building systems. Choices can involve some form of modular or demountable design concept. Alternatives also exist in structural span lengths between supporting columns.

Modular Systems. The modular building system concept is based on maximum off-site fabrication of components prior to actual on-site erection. Components are prefabricated units as large as possible, with each component being complete in structural integrity.

Modular systems can have advantages as compared to the historically more conventional concept of building-in-place. Faster on-site erection through factory fabrication serves to reduce costs. Modular structures also can have a high degree of demountability for reuse at a different site.

Transportation of modular components to the construction site is a possible disadvantage. State and federal laws limit maximum weights and dimensions for over-the-highway movements. The large size usually associated with modular components can make handling during transport and field erection more difficult, sometimes requiring heavier equipment than might be needed for building-in-place.

The modular concept is well suited to parking structures since parking modules are generally uniform and repetitive. Many architects, however, consider modular construction aesthetically undesirable because of design monotony and the limits imposed on design by rigidized systems.

Demountable Systems. Demountable (temporary) structures are designed and constructed to allow future disconnection of components and removal from the original erection site. This building concept uses structural systems that have the design and construction capability to be moved from one site to another.

Theoretically, the concept of demountable parking structures is ideal for an interim land use, where future higher use is anticipated but where current parking demand exceeds the available spaces.

Demountable parking structures have been suggested for use where land is leased, with the landowner anticipating a different use of the land; and where the lessee will not have sufficient time under the life of the lease to amortize the structure, and therefore wants reuse capability for a future date at another site. The demountable concept also can be applied for temporary parking where construction has reduced the available parking supply, or where temporary parking is needed to facilitate a temporary demand for parking space.

A large West Coast city, for example, acquired land in anticipation of developing it for a public office building at a later date, which would also include provisions for underground parking. The land became available for purchase several years before the office building need was expected. The city was able to lease a demountable parking structure and have it erected on the newly acquired site. This action resulted in several benefits to the city. First it permitted land acquisition when the land was first available, and probably at a lower cost than at a future date. Second, by providing a temporary parking facility, the city was able to begin recovering expenses from parking revenues while supplying needed parking. Finally, judicious use of land prior to permanent development helped avoid blighting effects and social problems that associate with vacated or undeveloped land in urban areas.

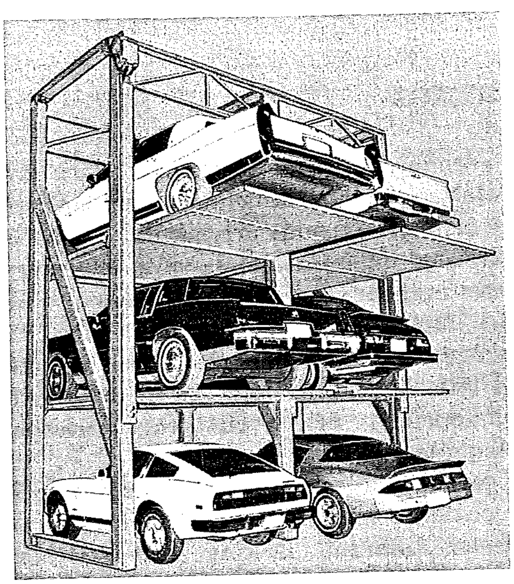
Demountable structures have been built in several cities since the mid-1960s. However, many remain in use as garage structures on their original site. There are inherent problems in reusing a demountable structure. It is difficult to locate a site with similar conditions, and many garage components are not economically salvageable-such as electrical wiring, plumbing, and to a large extent, floor slabs, which are subject to a high mortality rate due to damage when moved.

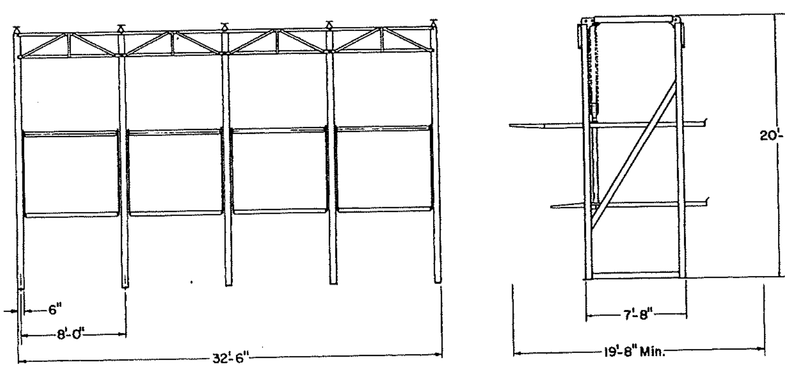
Structurally, demountable structures are as strong as permanent structures; although if left in place, some garage designers believe maintenance problems may become more pronounced than those of a permanent structure. Another commonly expressed disadvantage is that demountable structures lack certain aesthetic values. Appearance can be improved or made to blend with desired tastes by enclosing the structure in decorative masonry or anodized metal facades.

There are structural devices designed to increase storage capacity of surface parking by providing a partial decking above surface parking stalls (see Figure 9.1). These garage-like parking devices generally share a high degree of demountability and reusability. They can be advantageous for expanding surface parking lots or for providing parking space on very limited land area; however, they usually require attendant parking.

Clear-Span Design. Improved materials and construction techniques have reduced the cost of longer clear-span beams between supporting columns. Clear-span beams of 48 to 64 feet can eliminate columns within parking areas, thereby benefiting parking operations.

Obvious advantages of longer spans include column-free space for parking, greater space efficiency and greater parker acceptance, less sight-





SPECIFICATIONS	
Frame Height	20' 6"
Frame Width	8'
Frame Depth	7' 8"
Minimum Operating Depth	19' 8"

Figure 9.1. Structural devices are available to increase the number of vehicles that can be parked in limited space.

Source: Car Stacker Incorporated, Forth Worth, Texas.

distance obstruction, and fewer obstacles to impede vehicular movement. Clear-span designs enable some flexibility to change parking stall sizes and parking angles if future needs change.

Clear-span parking garage construction has become more cost-competitive with shorter spans, but clear-spans are still generally considered more expensive—with some comparative estimates placing costs at 5 to 10 percent more. Operational advantages permitted by the flexibility of clear-span designs must be weighed against the probability of higher construction costs. Other disadvantages include more complex construction where a building is located above the garage, and greater floor-to-floor heights because of deeper beam requirement.

Short-Span Design. Functional parking design favors clear-span construction. Other structural considerations, however, such as heavier loading due to construction of nonparking uses above the parking levels, may require closer column spacing for economic reasons. Short-span construction permits shallower beam depth, thereby reducing floor-to-floor heights, and this may be a critical consideration under severe zoning code restrictions. Dimensions of column grids that allow efficient parking operation depend on type of operation, characteristics of the parking demand, and circulation patterns between the street and parking spaces. Column spacing should allow a minimum of three parking spaces between columns. Columns should be set back from the aisles far enough to allow free and easy movement.

If clear spans cannot be achieved, a 30 to 50 foot column grid spacing provides a feasible alternative. Figure 9.2 shows how a 35 by 35 foot column grid can accommodate either 90 degree attendant parking or self-parking with angle stalls.

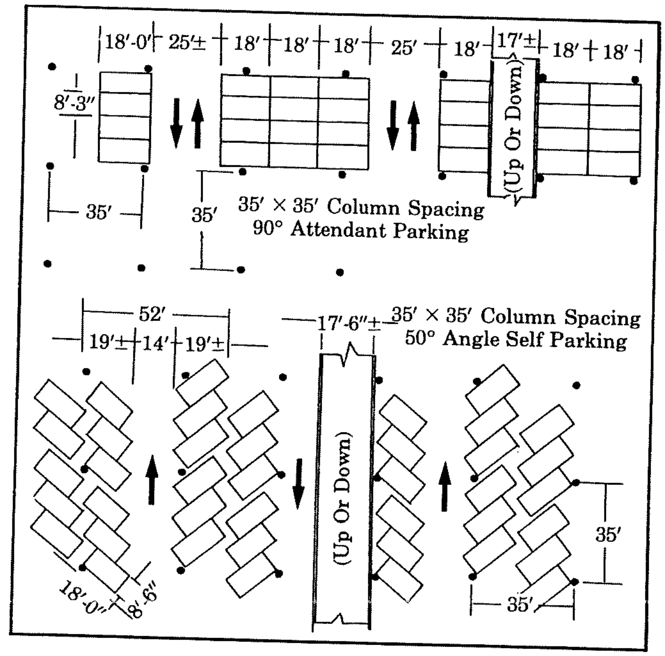


Figure 9.2. Contrasting parking arrangements, using a 35' by 35' column grid, facilitates angled parking for self-park operations and flexibility to stack park with attendant-park operations.

Aesthetic Considerations

Parking facilities should be located and designed so they are compatible with their environs. This can be achieved by sensitive architectural design and/or by city policy.

Local ordinances frequently regulate new development. Height limitations, building setback requirements, architectural standards, visual screening of parked cars, and landscape requirements are used to improve land-use compatibility. (See Figure 9.3.)

GARAGE ACCESS

Parking garage access must provide space for traffic circulation and parking manuevers. Stall and driving aisle dimensions are similar to those used for parking lots. Garage layout, however, normally uses mid-range dimensions rather than those at the upper and lower extremes. This is because garages are far more expensive to construct than lots, and more difficult to modify if selected dimensions or layout configuration prove inadequate.

Parking garage access must consider vertical circulation patterns and the means to move vehicles between different parking levels. Other primary considerations include access for both vehicles and pedestrians, vertical clearance, column spacing, and the placement of various auxiliary facilities necessary for garage operations,

Figure 9.3. Charleston's East Bay/Prioleau Street Garage, with street-level retail and office space, was designed to blend with the Exchange Building (background), which is one of four buildings still standing where the original U.S. Constitution was ratified.

including maintenance storage and machine rooms, manager's office, employee restrooms, and access controls.

The vehicular circulation system should be readily apparent to users. It should move entering traffic in a counterclockwise pattern where possible. It should minimize travel distance and should provide recirculation opportunities. Maximum aisle length should not exceed about 400 feet without providing a cross aisle. Adequate turning radii and ramp slopes must be provided, as well as sufficient distance for moving traffic and for security and orientation purposes. Distance between parking spaces and nearest exit stairwell is normally dictated by local code, ranging between 100 and 200 feet. Elevator location is a matter of garage orientation to the traffic generator and walking distance that the particular type of user will accept. Distance between parking space and elevator generally should not exceed about 350 feet.

Parking garages have a main floor and storage floors. The main floor's principal function is accepting and delivering vehicles to and from the street system. Access controls (gates, cashier booths, etc.) and space for operations support are normally provided on the main floor, as well as space for parking.

While located generally at street level, the main floor can be one level above or below street level. The most important main-floor design consideration involves location and capacity of vehicular entrance and exit points on surrounding streets.

Access Design for Vehicular Traffic

Garage access design should enable vehicles to enter and leave the facility with minimum delay, and with minimum queuing across sidewalks and onto public streets. This requires adequate entrance and exit capacity and reservoir space. Design calls for relating peak-hour traffic flow rates to the capacity of the specific access control strategy to determine the number of lanes and length of queuing space needed.

Typically, the peak 15-minute flow rate (converted to vehicles per hour) should be used as a basis for estimating access requirements. Traffic flow rates are compared with the *design* processing or service rate of the access control means to estimate the number of lanes needed. Peak traffic flow rate is compared to the *maximum* service rate of the control point to estimate length of queuing space needed.

Design Traffic Volume. Traffic arrival, accumulation and departure characteristics are generally reflected by the trip purpose of the parker and type of traffic generator the garage is to serve. Most land uses exhibit regular peaks of activity for arriving and departing traffic. Peak-hour volumes can be expressed as the ratio of entering or exiting vehicles per hour to the total number of parking spaces in the facility. Thus, if the inbound morning peak-hour vehicle volume is equal to half the number of parking spaces provided, the entering ratio is 0.50. For a 400-space garage this means that 200 vehicles would enter during the morning peak hour. (There also may be vehicles leaving the garage during the inbound peak hour.)

Typical peak-hour traffic volume percentages for parking facilities serving common land uses are shown in Table 9-1. This table, drawn from numerous traffic and parking studies, provides a basis for preparing initial estimates of peak-hour traffic. Site-specific study may be necessary for large garages or special situations.

During the peak hour, there are surges of traffic. Accordingly, a peak-hour factor (PHF) is used to upwardly adjust peak-hour volumes to account for periods of traffic surges. This factor is obtained by measuring traffic volumes in 15-minute intervals within the peak traffic hour, selecting the highest 15-minute volume and converting it to an equivalent hourly rate of flow (v). The resulting hourly flow rate becomes the design hour volume.

Thus, the design volume can be estimated based on the following formula:

$$v = V/(PHF)$$

where:

V= Volume of vehicles during peak hour.
PHF = Peak-hour factor.
v = Design hourly flow rate of peak-hour traffic.

The appropriate peak-hour factor can be determined from field observations or assumed based on experience. Peak-hour factors will generally range between 0.75 and 0.90. However, special events and employee parking typically call for a factor of 0.50 to 0.65. For example, if special event parking were to empty 50 percent of its capacity in 15 minutes, the peak-hour factor would be 0.50. Employee parking, where all employees are expected to start and end work at the same time, may require a factor similar to special event parking.

In general, the higher the traffic volume the more access lanes are required, and the higher the peak-hour factor that can be used. This is because the peaks and valleys in activity tend to be moderated as overall activity increases, and because the surges in traffic can be distributed over several lanes. At access points where only one entrance or exit lane is provided, the peak-hour factor should be no higher than 0.75. As additional lanes in the same direction are added, the PHF can be increased, to about 0.85 for two lanes and to 0.90 for three lanes or more.

Access Servicing Rates. Either a gated or non-gated system is used at points of parking access. Gated systems typically require parkers to stop at both the entrance and exit to perform some type of transaction in connection with paying for parking and/or assuring authorization to use the gated parking facility. Traffic flow is interrupted by these stops and the volume of traffic passing through the gate is a function of the gate's service rate, approach geometry, and traffic conditions beyond the gate, as well as patron's familiarity with the control.

Typical service rate capacities, measured in vehicles per hour are shown in Table 9-2 for various types of access control. The *design capacities*,

Table 9-1. Typical Peak-hour Volumes as a Percentage of the Total Parking Spaces

Type of Activity	*AM Peak Hour*		*PM Peak Hour*	
	In	*Out*	*In*	*Out*
Hotel-motel	30-50	30-50	30-60	10- 30
Residential	5-10	30-50	30-50	10- 30
Office	40-70	5-15	5-20	40- 70
Medical office	40-60	10-20	10-30	60- 80
Hospital				
Visitor	30-40	40-50	40-60	50- 75
Employee	60-75	5-10	10-15	60- 75
Retail-commerrcial	10-30	10-20	30-60	40- 65
Central business district	40-60	10-20	10-30	40- 60
Airport-All	40-65	30-50	70-90	70- 90
Short-term (0-3 hours)	50-75	80-100	90-100	90-100
Mid-term (4-24 hours)	10-30	5-10	10-30	10- 30
Long-term (more than 24 hours)	5-10	5-10	5-10	5- 10
Special events	Before event — (in) 80-100		After event — (out) 85-200[a]	

a. Maximum assumes a 30-minute departure.

Source: Adapted from: Robert W. Crommelin, "Entrance-Exit Design and Control for Major Parking Facilities," a seminar presentation (Encino, CA: Robert Crommelin and Associates, Inc., 1972), and Anthony P. Chest, Mary S, Smith, Sam Bhuyan, *Parking Structures Planning, Design, Construction, Maintenance and Repair*, (*Van Nostrand Reinhold*, New York: 1989).

which approximate 85 percent of the maximum service rates, should be used in determining the number of lanes required.

The *maximum* service rate capacities should be used only for queuing analysis. This is because the various queuing models are based on maximum service rates.

Table 9-2 gives values for conditions of easy and difficult access lane approaches. The difficulty of the approach is a function of drivers' familiarity with the facility, approach geometry and pavement surface condition. The length of reservoir space and traffic conditions beyond the entrance and exit gate also affect capacity.

Number of Access Lanes. The number of lanes required to provide garage access depends on the expected peak-period flow rate and the method of access control. An estimate of the number access lanes needed (n) can be made by dividing the expected peak-hour traffic volume (V) by the product of the peak-hour factor (PHF) and the service rate (u) of the access control to be used.

$$n = V/(PHF \times u)$$

Fractional lanes resulting from this calculation should be increased to the next highest number (i.e., n = 2.1 would require 3 lanes).

Lane requirements also can be estimated based on the number of spaces provided, given the likely number of vehicles to arrive or depart in the peak hour. The formula is as follows:

$$n = \frac{S \times R}{(PHF)\, u}$$

where:

n = Number of lanes.

R = % of garage capacity entering or leaving in the peak hour. (See Table 9-1)

S = Number of spaces.

(PHF) = Peak-hour factor.

u = Service processing rate (design capacity).

Similarly, the number of spaces that one lane can accommodate can be estimated as follows:

$$s = \frac{(PHF)(u)}{R}$$

where:

s = Spaces per access lane.

Based on a peak-hour factor of 0.80, and 60

Table 9-2. Typical Parking Control Service Rates per Lane

Type of Control	Vehicles Per Hour			
	Design Service Rate		Maximum Service Rate	
	EA[a]	STU[b]	EA[a]	STU[b]
Entrance				
Ticket dispenser-automatic	525	300	650	400
Ticket dispenser-push button	450	250	525	300
Ticket dispenser-machine read	375	200	450	250
Coded-card reader	350	225	400	275
Proximity card reader	500	275	550	325
Coin/Token operated gate	150	100	200	125
Fixed fee to cashier-wtih gate	200	150	250	200
Fixed fee to cashier-no gate	250	200	350	275
No required stop	800	550	1,050	700
Exit				
Coded-card reader	350	225	400	275
Proximity card reader	500	275	550	325
Token operated gate	150	100	200	125
Fixed fee to cashier- with gate	200	150	250	200
Fixed fee to cashier-no gate	250	200	350	275
Variable fee to cashier	150	100	200	150
Validated/Pre-cashiered ticket	300	200	350	250
Machine read ticket	375	200	425	250
with manual license plate check	100	100	125	125
with camera license plate check	75	75	85	85
No required stop	375	250	475	300

a. EA = Easy or straight approach to control service position.
b. STU = Sharp turn within 100 feet of either side of the control position and/or patrons unfamiliar with facility

Source: Estimated based on various sources including Robert W. Crommelin's research and A. Chrest, M. Smith, S. Bhuyan, *Parking Structures*, 1989.

percent of the parkers departing in a peak hour, the following numbers of spaces per lane result:

Design Service Rate (Vehicles per Hour)	Spaces Per Lane (rounded)
200	270
250	330
300	400
350	470

Reservoir Requirement. Storage areas for entering and exiting traffic should be sufficiently long to minimize backups of traffic onto surrounding streets or within the garage. A minimum of two-vehicle lengths of storage should be provided between the street and the garage, but more is often necessary.

Estimates of needed reservoir storage space can be obtained by applying standard queuing formulas. These formulas indicate the expected queue lengths and delays for various "traffic intensity" conditions. They define the traffic intensity as the ratio between the peak flow rate and the maximum service capacity rate.

The queuing model assumes random arrivals of traffic and exponentially distributed service times. For uniform service times, the queues would be half as long. Thus, there is a factor of safety in the queuing analysis.

The "single channel" queuing formulas apply to access points providing a single entrance or exit lane. They produce a reasonable (conservative) approximation of queues resulting where there is more than one lane in the same traffic direction and at the same point of access; in such cases, the flows are assumed to be divided equally among the available lanes.

The queuing formulas work well where the traffic intensity ranges from 0.50 to 0.85. Beyond 0.85, they give unrealistically high results, since they are based on steady state conditions.

The basic formulas are as follows:

Average length of queue

$$Lq = \frac{i^2}{1 - i}$$

Average wait before being served

$$Wq = \frac{i}{u - v}$$

where:
i = Traffic intensity = ratio of peak flow rate to maximum service rate.
u = Maximum service rate, vph.
v = Design flow rate, vph.
Lq = Average length of queue, (number of vehicles behind control point service position).
Wq = Average wait before being served (hours).

For example, if u = 300 vph and v = 200 vph, i = 0.66, the average queue length would be 1.3 vehicles. The average delay would be 24 seconds.

Average queues would be exceeded about 50 percent of the time. Therefore, it is customary to introduce a probability value that represents the frequency that the design reservoir length will be exceeded. For example, a 95 percent probability suggests that the reservoir length would be exceeded only five times in 100. For parking design purposes a 90 or 95 percent probability is typically used, this results in a failure of not more than 10 and 5 percent respectively. Figure 9.4 gives curves for the average and 90 and 95 percent probability conditions.

Introduction of a probability factor increases the reservoir space indicated by the calculated average queue length. For a traffic intensity between 0.6 and 0.8, a 90 percent probability increases calculated average queue length by about two vehicle lengths; a 95 percent probability increases average queue length by nearly three vehicle lengths.

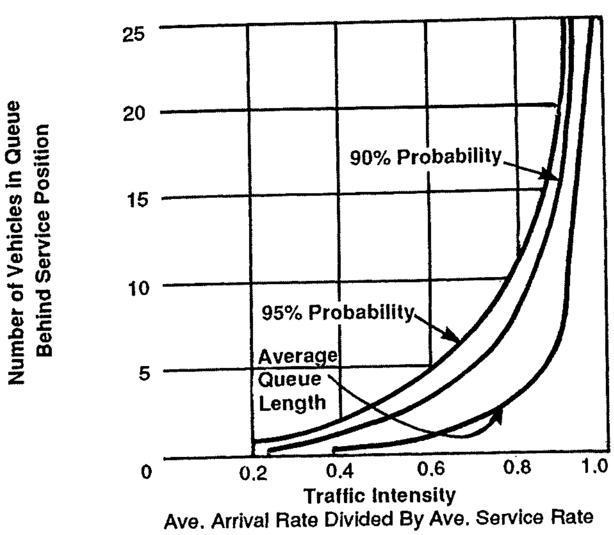


Figure 9.4 Reservoir needs versus traffic intensity based on single channel queuing theory.

RAMP SYSTEMS

Vehicular travel between different levels in a parking structure can be provided in several ways. A sloping surface (ramp) permits vehicles to be driven between parking levels, direct street connections can be provided to various levels from a sloping site, or mechanical conveyances can be used to transport vehicles between levels.

General Considerations

Safety, convenience, and traffic operating efficiency are principal ramp design concerns. Circulation travel distance should be as short as possible, with minimum turns and traffic crossings. Ramp arrangements should be as consistent and simple as possible to facilitate driver comprehension.

Ramp design and arrangement is influenced by (1) orientation of ramp traffic flow to the street entrance and exit points and to other ramp systems that might exist in the same garage; and (2) needed traffic capacity. The choice is further influenced by site shape and dimensions, parking demand characteristics, and development type (integrated-use structure or free standing garage). Thus, no single ramp system is best for all applications.

In some instances, site topography will allow direct access to more than one parking level from the street system. This is a desirable arrangement, since it leaves more floor space for parking and provides better flexibility for traffic distribution between the street system and parking facility. It may not be convenient for patrons to easily circulate to other levels in search of a parking space.

Time and convenience are important to ramp travel and should be considered in any comparison of ramp types. Actual travel time on ramps varies little among different ramp system types; however, some ramp systems have more potential for delay caused by conflicting traffic movements that limit ramp capacity. Other factors influencing ramp design include accident hazards, construction cost, and ability to conveniently accommodate vehicles and, in some designs, pedestrians.

Ramps may be designed for one-way or two-way traffic movement. One-lane ramps generally are not designed to operate on a reversible traffic basis.

The ramp system includes any portion of storage floors used by vehicles to move between levels. Nearly every successful ramp system requires vehicles to follow an approximate circular path when traveling between parking levels. The number of 360-degree rotations required to circulate through the garage and parking structure height are design concerns, particularly in self-park facilities. It generally is desirable to limit the maximum number of complete rotations to five or six. Depending on the type of ramp system, this will control the maximum desirable number of parking levels.

The number of up or down ramps will depend on size and parking characteristics of the garage, which influences capacity requirements.

Drivers sometimes are distracted by the awareness of height when traveling on upper levels — a condition that can be accentuated if parking levels extend higher than adjacent buildings. To reduce driver distraction, parapet walls along driving ramps should be designed to limit the driver's view of surroundings outside the parking structure.

Types of Ramps

Various types of interfloor ramp systems can be used to enable vehicles to traverse the approximate 10-foot elevation differences between floor levels in parking structures. Ramps may be removed from the parking aisles, or they may make use of these aisles for all or a portion of the interfloor circulation system. They may be straight, curved, or a combination.

Ramp systems may be grouped into two broad types that reflect the amount of interference between ramp traffic and parking-unparking operations: (1) ramp systems designed on the *clearway principle* provide interfloor travel paths completely separated from potentially conflicting parking-unparking movements; (2) ramp systems where part or all of the ramp travel is performed on aisles that provide direct access to adjacent parking spaces are called the *adjacent parking* type.

Clearway ramp systems provide for the safest traffic movement with the least delay. They are well suited to providing express entrance or exiting in large parking facilities. They are seldom feasible for small garage sites because the ramp system would preempt a relatively high proportion of the available space.

An *adjacent ramp* parking layout requires less area per parking space. Consequently, it can be used to advantage on small land parcels. Parkers generally find it easier to use adjacent parking ramp systems. This system, however, is more susceptible to traffic delays because of parking and unparking maneuvers. Delays, while difficult to measure must be recognized. They will be greater on the parking levels nearest the street level since these levels always will have more vehicles on them. For larger garages, it may be desirable to provide combinations of *clearway* and *adjacent* ramp systems. Usually, adjacent parking ramp systems are provided for entering traffic and clearway ramps for exiting traffic (see Figure 9.5).

Vehicles traveling on a ramp system may be directed to move in either a clockwise or counterclockwise travel direction. Counterclockwise rotation is generally preferred in the United States, and other countries where drivers customarily sit on the left side of vehicles, since it places drivers on the inside of turns, enabling better vehicle control. It is not always possible to obtain this pattern.

Ramp systems also can be classified as *concentric* or *tandem*, depending on whether the travel paths of vehicles moving up and down between parking levels revolve about the same or separate circles. Helically-curved (spiral) ramps are usually built concentrically (same centers) to save space and to provide flatter grades. Straight ramp systems are designed in either concentric or tandem (different centers of rotation) configurations.

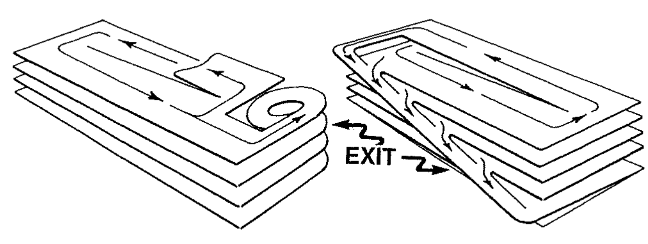


Figure 9.5. Parking garage examples that incorporate adjacent-parking ramp systems for traffic entering, and clearway ramp systems for traffic exiting the facilities.

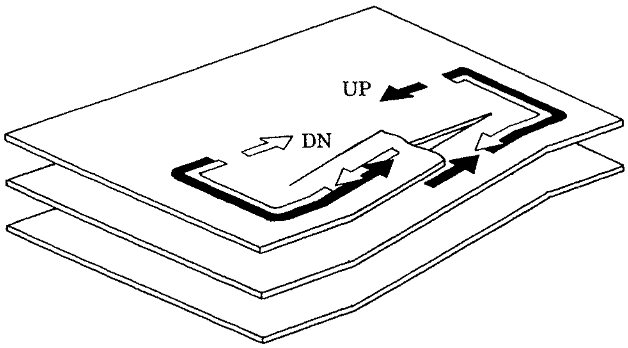


Figure 9.6. Straight-ramp system with one ramp-well

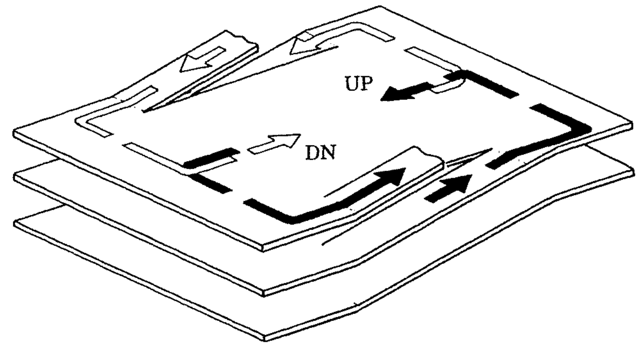


Figure 9.7. Parallel straight-ramp system with ramp-wells on opposite sides of structure

For vehicle movement to rotate in the same direction on a ramp system, up and down ramps must slope in opposite directions, requiring ramp surfaces to be opposed. Where up and down ramps slope in the same direction, ramp surfaces are parallel and vehicles must rotate in opposite directions. While no significant differences have been observed in operational ease, opposed ramp types are safer, since all vehicles must travel in the same direction. However, parallel ramp systems are less expensive to construct.

Straight-Ramp Systems. Ramps within a straight-ramp system usually should be "stacked" one over another for construction economy and shortest traffic circulation pattern. Stacking of ramps creates a "ramp-well." From a plan view, the sum of the system's ramp-well areas and the floor area containing aisles used by ramp portal-to-portal traffic is the ramp system's area. This extends vertically through the parking structure (with the possible exception of roof and/or basement levels). The ramp system is usually rectangularly shaped (ignoring curved ramp ends), with the ramp well(s) along the structure's longer-side dimension, giving more horizontal distance to satisfy ramp grade criteria.

Figure 9.6 illustrates a basic straight-ramp system having a ramp-well on one side only. In this system, vehicles follow an elliptical path, most of which is on flat surfaces, even when parallel up and down ramps are separated as in Figure 9.7. Figures 9.8 and 9.9 show opposed straight-ramp systems. In Figure 9.9 turning movements for the up and down ramps are performed in different areas, while the floor travel is a two-way movement; floor travel could be performed along the same aisle or separated. The parallel systems represented in Figures 9.6 and 9.7 can permit entrance and exit points on the same street. Opposed straight ramp systems enable interfloor circulation to take place through the same parking aisle, eliminating traffic crossing conflict.

Figure 9.9 illustrates a clearway type opposed straight-ramp system. Ends of opposed ramps on the main floor are pointed in opposite directions, making this design suited to structures with entrance and exit points on separate streets. This design can be adapted to entrance and exits points on the same street, but requires a 180-degree turn on the main floor, necessitating additional space and travel length within the structure.

Straight-ramp systems are advantageous in relatively narrow buildings. They require less floor area than helically-curved ramps and are less expensive to construct. Sharp turns, necessary to get on and off straight ramps, are disadvantages, and structure columns may pose layout

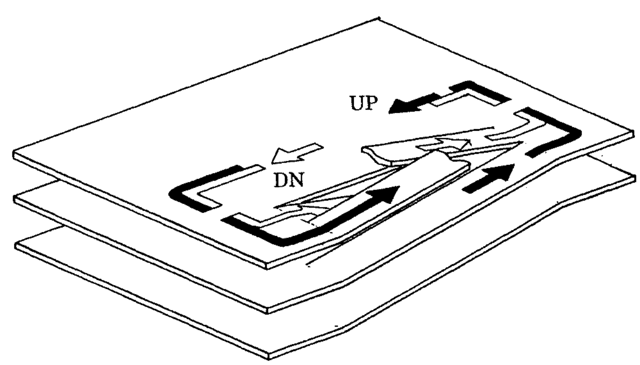


Figure 9.8. Adjacent-parking type opposed straight-ramp system

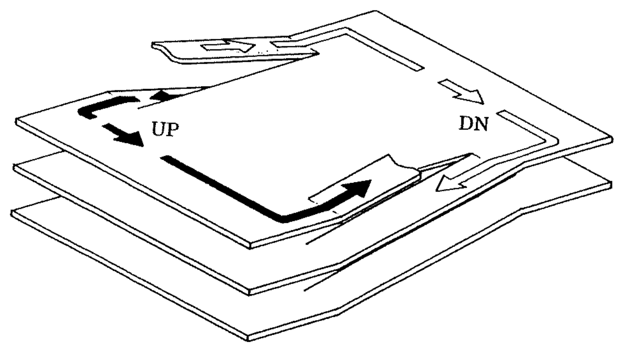


Figure 9.9. Clearway type opposed straight-ramp system

problems for providing sufficient turning radii.

Split-Level or Staggered-Floor Systems. The staggered-floor parking garage, generally referred to as a split-level garage, is constructed in two sections. Floor levels in one section are staggered vertically by one-half story from those in adjacent sections and overlapping by several feet to maximize the floor space within a given site. Short straight ramps, sloped in alternate directions and separated by the distance required to easily make a 180-degree turn between ramps, connect the half-stories.

Any combination of straight ramps can be applied to the split-level floor design. Traffic rotation direction may be the same, in which case the aisles are one-way, thereby reducing conflicts. Turning paths may overlap, requiring less space for the ramp system. Rotation can be provided also in opposite directions, which simplifies ramp construction by having up and down ramps in the same plane.

The division between split-level structure halves may be perpendicular to the street or parallel. In the latter case, either the front or back half may be elevated. Split-level floors can overlap as much as 5 to 6 feet to increase space efficiency and make narrow sites workable; however, floor overlaps of more than about 1 or 2 feet cause problems for van-type vehicle parking.

Figures 9.10 through 9.13 illustrate various types of split-level configurations. Figure 9.12 is the most common type.

Split-level garages are particularly applicable to small, high-cost sites where maximum use of space must be achieved. Construction is relatively simple, and the design fits well on rectangular sites. This system is efficient in terms of floor space per parking stall but, like all ramp systems employing adjacent parking, frequent conflicts may arise between circulating traffic and parking-unparking vehicles. Relatively sharp turns may be required.

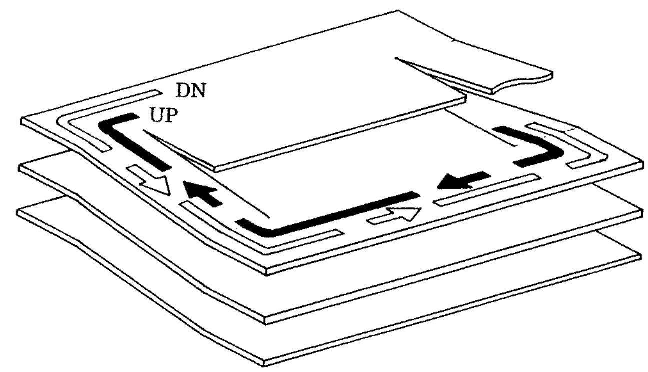


Figure 9.10. Two-way staggered floor ramp system. Ramps are placed at the ends of the garage to minimize turning conflicts.

One variation in the split-level system uses three separate sections, with the two end sections at equal elevations and staggered one-half story with respect to the center section (see Figure 9.13). Fifty percent fewer turns are required, thereby reducing travel time. However, vehicles parked on the end sections must be driven an extra half-floor when entering or leaving. "Wrong way" ramp travel is also a greater possibility with this types of design, and a larger site is required.

Sloping Floor Systems. The sloping floor parking garage, in its simplest form, contains two adjacent parking modules tilted in opposite directions, with cross-aisles at each end so that vehicles traveling the length of both aisles make a 360-degree turn to move up or down one complete

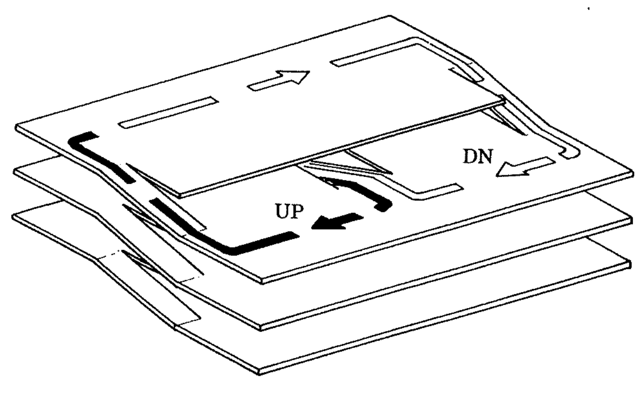


Figure 9.11. Tandem staggered floor ramp system. Ramps provide a clockwise circulation system.

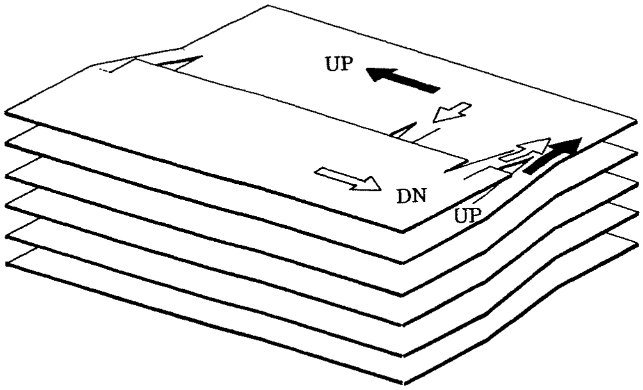


Figure 9.12. This staggered floor system provides parking on level floors and desirable one-way traffic flow.

parking level (Figure 9.14). Thus, there is no area set aside for ramps in the ordinary sense. The cross-aisles may be sloped or nearly level. Where site width allows development of a structure at least three modules wide, outside modules may be constructed as flat floors.

Parking industry experience indicates that the sloping floor design is well suited to self-park operations. The relatively flat floor slope (customarily ranging between 3 and 5 percent) permits comfortable parking and pedestrian walking. Because parking is adjacent to the interfloor circulation system, each entering customer has an opportunity to park in the first available space. Parkers do not feel confined to narrow ramps. However, the operational problems due to adjacent parking can cause congestion during

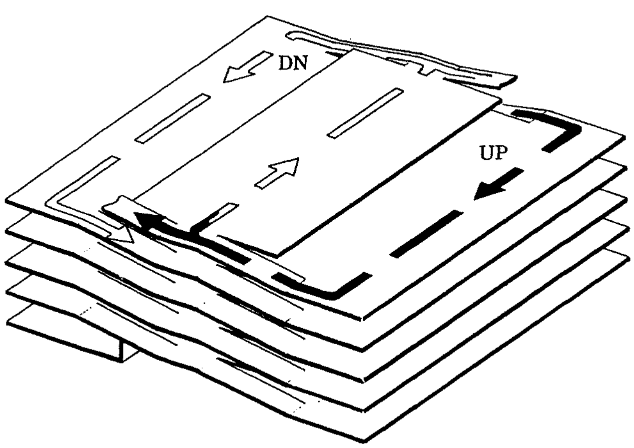


Figure 9.13. Three-level staggered floor ramp system

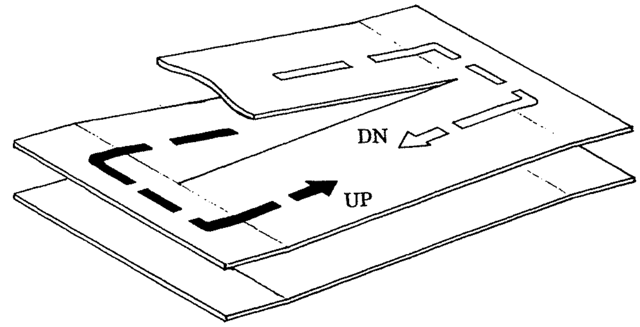


Figure 9.14. Basic sloping-floor concept

peak outbound movements if clear-way type express ramps are not used.

Floor-to-floor travel distance is greater in sloping-floor garages than in other types of ramp garages. This disadvantage is offset somewhat by the opportunity for greater travel speeds due to flatter slopes and longer tangents.

For longer structures it is possible to slope floors in opposite directions from a flat aisle in the center, connecting two modules. Ramp connections at mid-points of opposite sloping floors permit one-way traffic circulation (Figure 9.15).

It is possible to achieve one-way traffic circulation in sloping-floor layouts, with parking along aisles on every level, by using two sloping-floor garage units placed end-to-end. In the level center section where the two units meet, traffic flow can change from up to down and vice versa. This permits flexibility for angled parking, limited only by available site dimensions (Figure 9.16).

Continuity is important in the design of a sloping floor system. This is necessary to avoid the roller coaster effect that is created for the driver when the floor slope in a parking module varies from one end to the other.

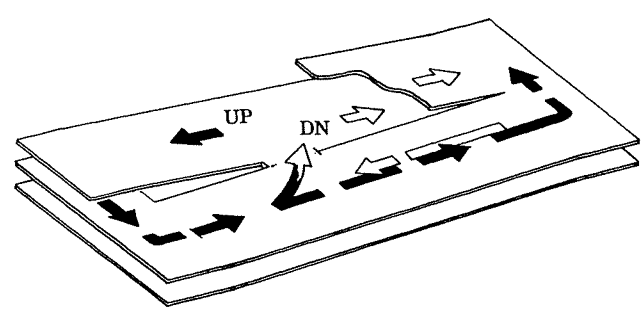


Figure 9.15. Sloping-floor system with cross over ramp at mid-point

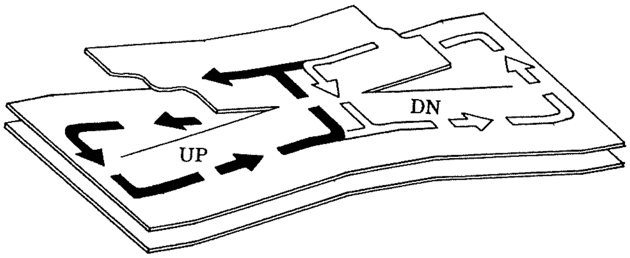


Figure 9.16. Double sloping-floor system with mid-point crossover

A sloping-floor garage should not exceed six continuous circuits. This is because drivers become confused and displeased by the repeated turning movements.

Helically-Curved Ramp Systems. The helix (spiral) ramp can be a single surface that permits vehicles to travel on a continuous helical path between parking levels. When two-way traffic is handled on a single helix, the outer lane is used for up movements since it has a larger radius of curvature and lower grade. Up movements are usually counterclockwise and down movements clockwise.

Helical ramp entrance and exit points can be located on the same side or opposite sides of the ramp coil. In either case, ramp access points to each level are located directly above each other on each succeeding floor. Helically-curved ramps typically are of the clearway type. There is no parking directly off of the ramps. Examples are illustrated in Figures 9.17 and 9.18.

A double helix system uses two helical-path surfaces that can be sloped in the same or opposite directions. One surface is used for up movements, the other for down movements. The two sloping helical surfaces may be separated as in Figure 9.18 or they may be interwoven.

Interwoven double helix systems are popular in tall structures because the number of 360-degree turns can be reduced by using two separate helical surfaces to serve alternate parking levels. Curving ramps are said to be continuous where they provide 360 degrees of rotation between two parking levels.

Helically-curved ramps usually are located at corners of rectangular structures to minimize floor space loss. They are located outside the structure when additional site area is available. Helically-curved ramps require more space than straight ramps, and they are more difficult and expensive to construct: but they can offer good traffic capacity.

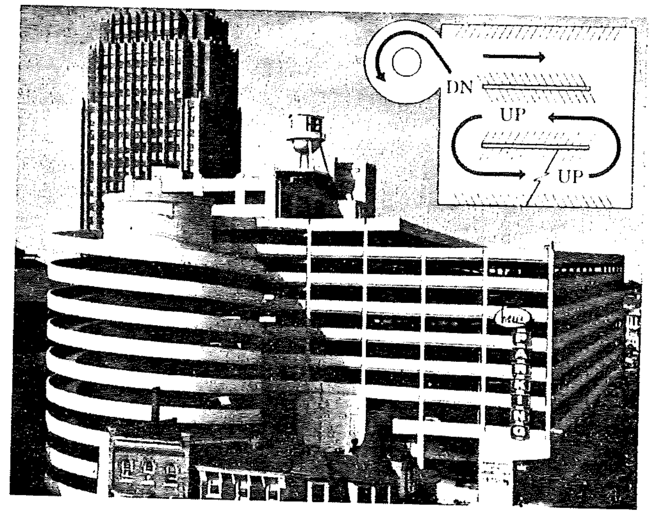


Figure 9.17. Helical ramps such as this one serving an 8-story, 750-car structure, can be used effectively for express exiting.

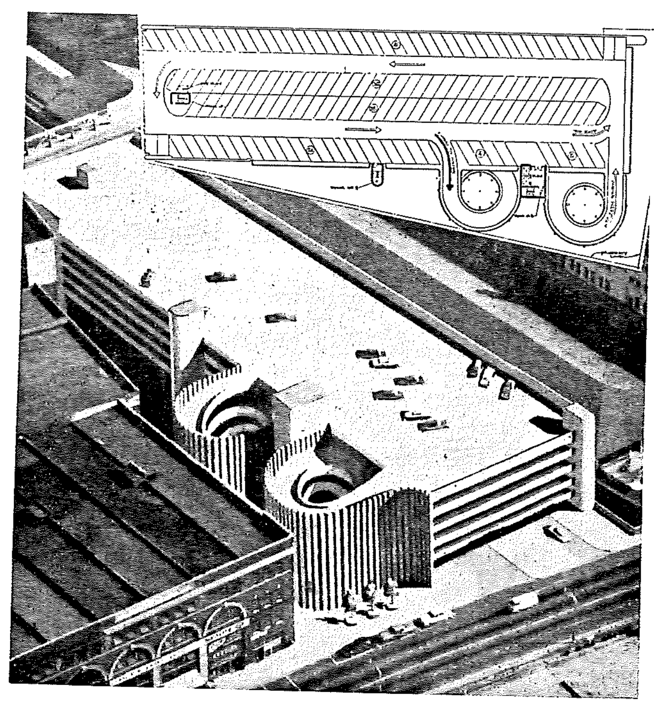


Figure 9.18. Helical ramp systems can often be advantageous for structures situated on odd-shaped sites.

Some designers consider five to six complete turns as the practical maximum for circular ramps that service self-parking garages.

Express Exit Ramps. Large parking structures with high-turnover or special peaking conditions may be served best with an express ramp for exiting traffic. Express exit ramps can be curved or straight, and they are designed always on the clearway principle, providing one-way traffic movement (Figure 9.19). They improve operating efficiency by reducing travel time (especially if adequate exit control point and street capacity exists), but add to structure costs.

Interfloor Circulation Capacity

The circulation capacity inside parking structures can be a critical consideration, especially for large garages. Capacity is reduced when vehicles must flow through a turn, intersect with other traffic, travel up or down steep gradients, or pass adjacent parking spaces.

Circular helixes and straight clearway express ramps may have the ability to move 1,000 or more vehicles per hour per lane if traffic acceptance conditions at the end of the ramp do not cause traffic to backup. For circulation systems that have adjacent parking along all or a portion of their lengths, flow capacity is limited to the capacity of the adjacent parking sections or the entrance/exit control point, whichever is the lowest capacity link in the system.

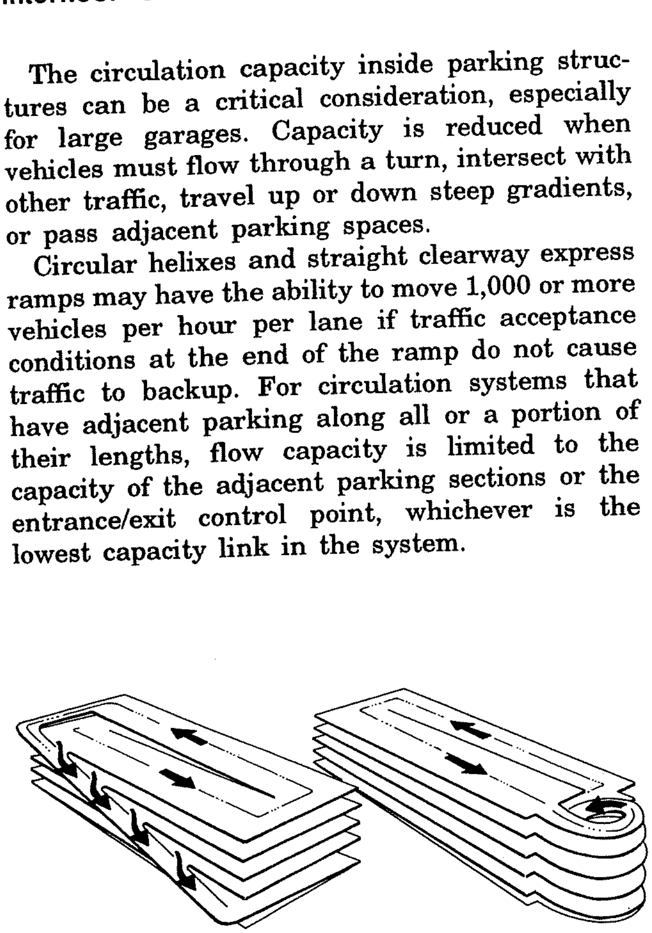


Figure 9.19. Examples of straight and helical shaped express exit ramps

Parking Module Circulation Capacity. Research has shown a relationship between stall and aisle dimensions and traffic flow capacity of adjacent parking circulation systems.[28] Tighter parking stall and aisle dimensions reduce flow capacity. Flow capacity is theoretically reduced by 90-degree parking because of increased maneuvering time to enter and leave parking spaces, and because of two-way traffic movement in the aisleway. In some cases, however, the two-way traffic flow associated with 90-degree parking may increase traffic flow capacity by reducing travel distances.

Traffic flow capacity also is reduced by short-span structural systems because closer column spacing tends to interfere with sight distances and maneuvering ease. As the number of parking spaces that must be passed along the interfloor circulation system increases, it poses greater opportunity for delay, reducing capacity especially for exiting traffic.

The adjacent parking circulation system's capacity for peak exiting traffic is normally not as great as its capacity to handle peak entering traffic. This is because the unparking maneuver requires more time than pulling into a parking space, and entering traffic is not required to travel further than the first available parking space. In many cases, the in-bound traffic peak is accompanied by a certain amount of out-bound traffic activity, and vice versa during periods of peak out-bound traffic. The in-bound/out-bound split may affect circulation system capacity, depending on design and magnitude of traffic.

Theoretically, during periods of peak-parking activity, minimum circulating vehicle headways may be as short as 4 to 5 seconds if capacity is available to sustain this flow at the circulation circuit's points of entry or exit. This is equivalent to 720 to 900 vehicles per hour per circulation circuit. In reality, this large of flow capacity is difficult to achieve throughout the circulation system, especially for exiting traffic. A more realistic design capacity of 400 to 500 vph is suggested.

There are numerous variables affecting garage circulation capacity. Site-specific traffic study is the best way to determine capacity needs and pro-

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[28] P.B. Ellson, *Parking: Dynamic Capacities of Car Parks* (Crowthorne, Berkshire, UK: Road Research Laboratory, 1969) TRRL Report LR221, and *Parking: Turnover Capacity of Car Parks*, 1984, TRRL Report 1126.

visions to assure the needed capacity is provided.

Guidelines for Maximizing Internal Traffic Flow. There are a number of design approaches to achieve maximum traffic flow capacity inside the garage. Some approaches may not be practical in specific cases because of site constraints or other reasons. The following are among the most commonly used design approaches.

1. Provide separate one-way inbound and outbound routes, even when there is little or no opposing traffic flow.
2. Shorten travel distances and the number of spaces that must be passed, especially for exiting traffic.
3. Provide clearway routing (no adjacent parking) for the primary circulation routing.
4. Arrange as many parking modules as possible off of the primary circulation routing.
5. Merge intersecting traffic, rather than create traffic crossings or opposing flows.
6. Remove principal pedestrian access points from the primary vehicular circulation route to avoid high-volume pedestrian/vehicular crossings.
7. Provide counterclockwise circulation for the most critical (entering or exiting) traffic movement.
8. Provide multiple entrance and exit points to distribute traffic and shorten travel distances.
9. Provide adequate exit control point capacity and accessible reservoir lanes behind each control point.
10. Provide adequate parking geometry, sight distances, and driver information systems (signing, pavement markings).

RAMP DESIGN PARAMETERS

Ramp design parameters governing the acceptability of ramp features such as maximum gradient, minimum width, and radius of curvature have evolved from garage operating experience. Since the efficient and safe design of driving ramps are largely influenced by the characteristics of the parking demand to be handled, it is impossible for any one set of dimensions to be best for all circumstances. Therefore, there are general ramp design guidelines and criteria but no absolute standards. Site-specific study should determine acceptable dimensional values for ramp features. The following discussion gives general parameters followed by the parking industry, however, unusual or special circumstances may suggest other values for efficient and safe design.

Ramp Grades

Ramp grade (slope) is computed by multiplying floor-to-floor height by 100 and dividing by the ramp length. The difference between ramp length measured along the slope or horizontally is negligible. Grades on curving ramps are steepest along the inner ramp pavement edge.

Maximum practical ramp grades are principally limited by safety considerations and the psychological effect on drivers, with hill-climbing and braking abilities of automobiles being a secondary factor. Steep or sharply curving ramps slow traffic movement and can be particularly hazardous when wet.

Straight Ramp Grades. Generally, straight ramp grades in self-park facilities should not exceed 10 to 15 percent; flatter grades are preferable. For attendant-parking garages, grades up to 20 percent are acceptable. Short ramps in split-level structures typically have gradients of 12 to 15 percent. Unless provided with proper grade transitions, some vehicles could scrape when pulling on and off ramps in the 12 to 15 percent grade range. Comfort and safety considerations suggest the need for proper grade transitioning, even on flatter grades (discussed later in the chapter).

Figure 9.20 graphically relates ramp grade and length with floor-to-floor heights. For example, this graph shows that for a slope of 13 percent and a rise of 10 feet (floor-to-floor height), a ramp 77 feet long is required. Similarly, a floor-to-floor height of 10 feet and space for a 90-foot ramp would result in a little less than an 11 percent grade.

Sloping Floor Ramp Grades. Maximum preferable grades for sloped floor parking structures are 3 to 5 percent. Parking on a sloping floor garage is normally at an angle of 60 degrees or greater to minimize the possibility of gravity rollback of vehicles. Slopes of 5 to 6 percent sometimes are used in self-park garages when the parking angle is 70 to 90 degrees. Steeper grades (up to 10 percent) may be acceptable for special use self-park situations and attendant-park op-

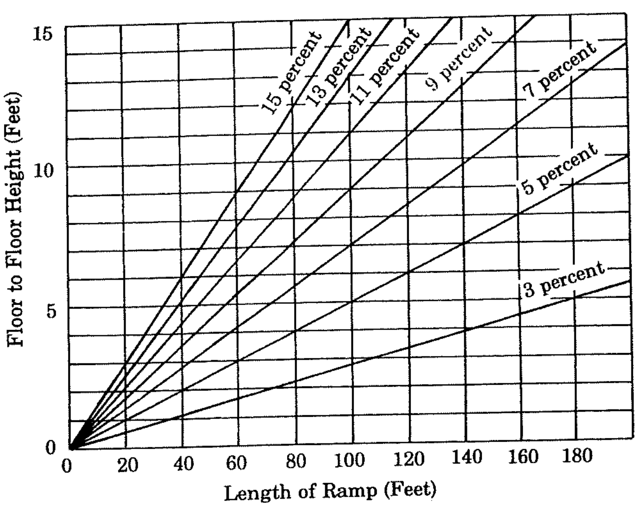


Figure 9.20. Relationship between floor-to-floor height, ramp grade, and length.

Source: Edmund R. Ricker, *Traffic Design of Parking Garages* (Eno Foundation, 1957), p. 115.

erations. Suitable gradients generally can be achieved in sloping floor structures whose outside dimensions are as small as 125' by 200'.

Circular Ramp Grades. The grade of a circular ramp will vary with the floor-to-floor height, the width of the driving path, the number of drops per revolution, and the overall diameter of the ramp. The percent grade is usually calculated at the outer ramp wall (outside ramp pavement) edge; the center line of the drive path, and the inner wall. The maximum grade criteria apply to the inner pavement edge. For driving comfort and predictability, the gradient of a circular ramp should be constant throughout its length. Superelevation of one-half inch per foot is typical for most circular garage ramps. Circular ramps may have grades as steep as 15 percent; however, grades of 10 percent or less are preferable.

Ramp Grade Transition Design

Critical vehicle clearances, driver comfort, and safety considerations influence the design of ramp ends where they meet flatter floor surfaces. Ramp breakover angle (limited by vehicle wheelbase and ground clearance) and the angles of approach (affected by front overhang of vehicles) and departure (affected by rear overhang) are critical vehicle clearance points. These angles are established for stationary vehicles with normal equipment and load, including passengers and fuel.

The design vehicle's ramp breakover angle, which varies inversely with the wheelbase, is a measure of an automobile's ability to be driven over the crest created by two converging surfaces without scraping its underside. The angles of approach and departure determine an automobile's ability to roll over the sag point (lower end of ramp) formed by different grades without scraping or touching the pavement surface. The angle of departure is more critical because the rear overhang of vehicles is generally longer than the front overhang.

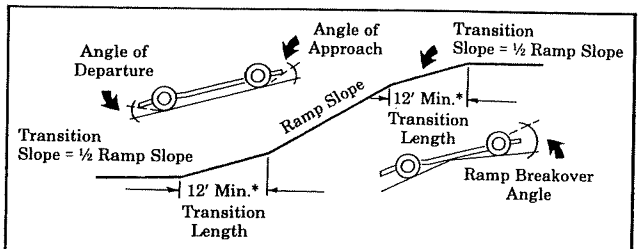
Standards established by the Society of Automotive Engineers limit the ramp breakover angle to no less than 10 degrees; angle of departure, no less than 10 degrees; and angle of approach, no less than 15 degrees. Vehicles designed to these minimum standards theoretically are able to traverse sag and crest sections at the bottom and top of a 17.6 percent ramp grade, and to move to flat floor grades without need for a grade transitioning (blending) area. Thus, most automobiles can traverse sag and crest pavement sections at the bottom and top of at least a 17 percent grade.

Centrifugal force can cause vehicle suspensions to compress at a sag point, even at a low speed; it can result in vehicles scraping the pavement surface. Without grade transitioning at the ramp crest, driver sight-distance can be limited momentarily, and crossing abrupt grade changes can be uncomfortable for drivers and passengers. Therefore, ramp grades should be blended gradually to flatter floor surfaces at the ramp end points.

Generally, the transition slope should be about half the ramp grade, with a minimum blending distance of 12 feet. Figure 9.21 illustrates this method of transitioning ramp grades. Ramp grades of less than 10 percent can be blended satisfactory with a transition length shorter than 12 feet.

Ramp Width and Radii

The minimum width of a straight one-way ramp normally ranges from 11 to 14 feet; two-way



*Ramp slopes (grades) less than 10 percent can be blended satisfactorily with an 8-foot transition length.

Figure 9.21. Method of blending ramp and floor grades
Note: Vertical scale is exaggerated to show detail.

straight ramps, where opposing traffic flows are not separated are usually 22 to 24 feet wide in parking structures. The narrowest ramp widths can be used when vehicles can make a straight approach to the ramp. Where the ramp entry will involve a turning approach, a wider ramp width may be necessary.

One lane ramp widths of 14 to 18 feet generally are needed for circular ramps. The outer lane of a two-lane curved ramp need not be as wide as the inner lane. The minimum outside wall radius of a circular ramp is 32 to 33 feet, however, a larger radius of 35 to 37 feet is more desirable.

The repeated turning movements of vehicles traveling between parking levels is a primary design consideration. The spiraling path radius must be kept minimal to conserve space and to reduce travel distance. However, very sharp and unrelieved turning will produce a dizzy effect on drivers. To minimize this effect, ramp systems can be laid out with sharp curves separated by short tangents or less sharply curved sections when possible.

Ramp Turn Super-elevation

Ramp curves should not be super-elevated too steeply, because very slow drivers may have difficulty in keeping away from the inside ramp pavement edge, and fast drivers may be encouraged to drive at speeds greater than conditions of grade and sight distance safely permit.

Garage ramp super-elevation should be approximately 1/2 inch per foot of ramp width at the point of sharpest turning, with lesser amounts adjacent to straight sections or storage floors. Straight ramps generally are crowned or pitched for drainage.

Ramp Appearance

Some motorists are reluctant to use ramp garages because travel paths combine narrow lanes, steep grades, and sharp turns. Even drivers accustomed to garage parking depend on appearance and "feel" in maneuvering their vehicles.

Consequently it is desirable to use architectural and optical effects that give drivers confidence and reduce possible adverse psychological effects of driving in restricted spaces. An obvious means is to make sight distances as great as possible and to provide abundant illumination.

The optical trick of obscuring horizontal and vertical lines of reference may be used to reduce the apparent steepness of ramp grades. Ramp walls can be painted with stripes contrasting to wall color, parallel to ramp surface or at steeper angles. The normal angles between vertical columns and the travelway can be obscured by paint markings, or adjacent structural features may be built with architectural lines parallel or perpendicular to ramp surfaces.

Ramp structures should be as open as practicable to provide sight distances and to reduce closed-in impressions. In locations where icing conditions are common, ramp systems should be placed in building interiors or otherwise protected from weather.

Ramp illumination should be given special attention. Wall openings should not be allowed where outside light sources could blind drivers. Artificial lighting should take the form of diffused illumination, and reflectors should be pointed away from the direction of travel.

MECHANICAL GARAGES

Vehicles in mechanical or elevator garages are moved to and from parking spaces mechanically. These garages are space-efficient, and traditionally have been built in areas of high land cost and limited space. There are many types of mechanical garages in existence; however, their use has been conditioned with problems of aesthetics, environmental compatibility, and traffic congestion caused by vehicles queuing outside of the facility. These problems, coupled with relatively high maintenance costs and the need for attendant-operation have limited their application.

Early Mechanical Garages

The early mechanical garages used freight elevators. However, since elevators could handle only one vehicle at a time (two in some garages), peak periods of arriving and departing vehicles required long waiting periods and large reservoir areas. Electrical and mechanical failures were common.

Multiple elevators, each serving a vertical bank of parking stalls and equipped with power-operated dollies to load-unload waiting vehicles, were a forward step in garage mechanization. These designs, as used today, have no storage floors *per se*, but have stalls — sometimes three deep on each side of an elevator.

Several large garages of this type were built in the 1920s — one 24 stories high, with each elevator serving over 100 stalls. Although a great improvement over single freight elevators, many disadvantages remained — such as high initial cost, inability to accommodate peak flows, and hazards of mechanical or electrical failure.

Modern Mechanical Garages

Electronic controls and faster, more reliable elevators have improved mechanical garages. Some lifting mechanisms move laterally to serve several banks of stalls. Horizontal movement capability permits improved reservoir operation and reduces the seriousness of individual elevator breakdowns, since each tier of stalls can be reached by more than one elevator. Some elevator lifting mechanisms also are counterbalanced to rise without power when empty, and to descend (with automatic braking control) once a vehicle is on the elevator. This provides a means to empty stalls in the event of power failure.

The newer mechanical garages are faster than their predecessors, and can store or deliver a single vehicle in less than a minute. When a

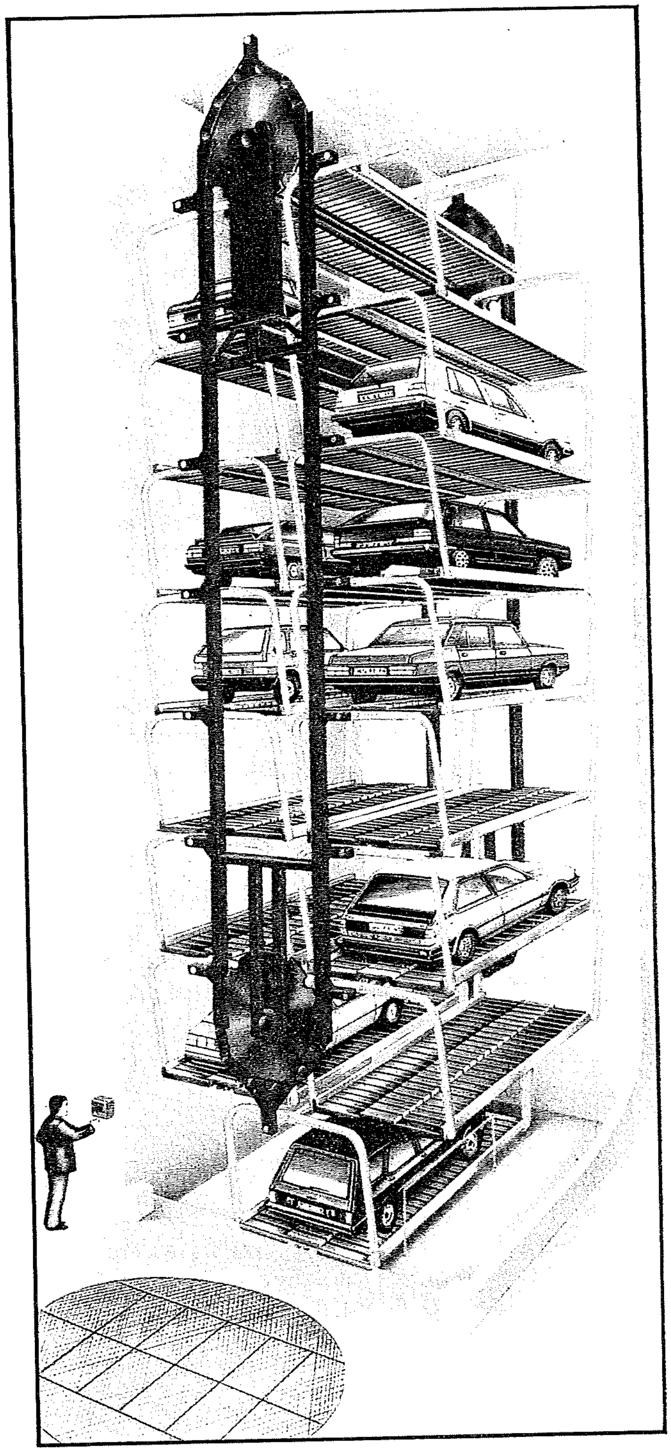


Figure 9.22. This vertical mechanical parking system provides 10 to 42 parking spaces on the amount of ground area required to park about 4 automobiles.

Source: Parking Systems of America, LTD, Vienna, VA.

vehicle is stored and another delivered on the same trip, the total time required can be about 90 seconds with some designs. The rate of handling vehicles is fixed by the speed of the mechanism and the number of elevators.

The demand for vehicle storage and delivery usually occurs in random patterns, with large numbers of customers arriving in short periods. Since elevators can store and deliver vehicles only at a fixed rate, the effect of a short interval of higher demand rate may extend over an appreciable time period.

An additional problem is that mechanical equipment has tended to wear out before the garage facility has paid for itself. Historically, maintenance costs have been higher than those experienced for ramp garages.

PEDESTRIAN CIRCULATION

Parking garage planning and design should provide attractive pedestrian circulation within the self-park garage and between the garage and final destinations.

In most parking garages, pedestrian regulations are difficult to enforce. Pedestrians tend to walk in a path representing the shortest distance, and they have a basic resistance to changing grades or following a prescribed path that is obviously circuitous to an alternative travel route.

Design Concepts

When possible, it is desirable to separate pedestrians from major vehicular movements. However, within a garage it is nearly impossible to separate the horizontal movement of pedestrians from circulating vehicular traffic. Raised or separated walkways on parking floors usually do not receive enough use to merit their expense and, when provided, are often discontinuous. The two basic design concepts involved are pedestrian-vehicular coordination and pedestrian-vehicular separation.

Pedestrian-Vehicular Coordination. Parking garage designs must anticipate moving pedestrians off of storage floors over the shortest possible distance, usually via the vehicular circulation system. This is accomplished by locating pedestrian access points around the structure perimeter. Garages with large floor areas, or garages located underground or under office structures or other types of activity centers, frequently provide centrally located pedestrian access points. It is desirable to have all parking spaces no more than 100 feet from the nearest pedestrian access point on parking levels.

Sight distance, adequate lighting, and well-marked pedestrian access points, coupled with signing for pedestrians, driver orientation, and clearly defined vehicular movements will aid pedestrian circulation on parking floors.

Pedestrian-Vehicular Separation. The physical separation of pedestrians and vehicles can be essential for a location where major flows of pedestrians and vehicles are likely to cross. Basically, pedestrians can be segregated from vehicular traffic by providing separate walkways or by pedestrian tunnels or bridges.

Pedestrian-vehicular separation measures increase costs and require more space. However, pedestrians must be afforded safe walking paths. Separated pedestrian systems offer the opportunity to provide direct, climate-controlled connections to adjacent buildings and/or other pedestrian pathways. In areas of intense pedestrian activity, separated systems are especially desirable from aspects of traffic safety, reduced walking distance, convenience, and comfort.

Walkway Widths

Minimum walkway widths for light pedestrian flows typically range from 4 to 5 feet, with the principal consideration being to provide enough space for two persons to walk abreast or to pass each other. If the walkway is obstructed laterally, effective width is decreased, and an extra 1.5 feet of walkway width should be provided. Walkways adjacent to display windows or sales counters should provide an extra 3 feet of width.

Wider walkways should be used for sidewalks along streets bordering parking facilities. A walkway having an effective width of 7.5 feet is considered a minimum for lightly used urban sidewalks. This width will provide free-flow pedestrian volumes up to approximately 200 persons per hour.

Pedestrian Grade Separations

Grade-separated walkways provide additional space for pedestrian movements, eliminate pedestrian-vehicular conflicts, permit opportunities for views and vistas, and offer more opportunities for people-interaction between multi-level structures. However, for grade-separated walkways to be justified on a traffic basis only, exceptional pedestrian travel demand is generally required at the structure levels to be served by the separated walkways.

Pedestrian bridges and tunnels may be desirable when the generator is separated from the parking garage by heavily traveled streets, where abnormal hazard or inconvenience to pedestrians would otherwise result. They also are feasible to control access to malls, shopping complexes, and major buildings. A desirable objective is to provide weather-protected and vehicular traffic-free connections to encourage use of both the garage and the surrounding land uses. Such an approach, carried to its ultimate, allows the garage system to be integrated with other existing and proposed pedestrian systems.

Pedestrian tunnels or underpasses, as compared to pedestrian overpasses, require less grade transition and less horizontal space on approaches. They also prevent less visual obstruction to the cityscape, while providing weather protection. Pedestrian overpasses, on the other hand, can generally be built at lower costs and provide greater visibility and a more positive sense of security for pedestrians.

Generally, pedestrians are more reluctant to use tunnel underpasses than bridge overcrossings. Pedestrian tunnel problems can be minimized by locating underpasses in line with approach walkways and gently ramping walkways to permit continuous vision through the underpass from walkway approaches. It is essential that the underpass be well lighted and designed to avoid sharp curves and concealed corners.

At pedestrian overpasses, vertical clearance over vehicular roadways should be slightly higher than the minimum vertical clearance required for vehicle structures, to reduce overheight vehicle impact possibilities. Typically, a minimum clear height of 17 feet is required, measured from the pavement crown to underside of structure. Small-opening screening (fencing), transparent wall panels, or complete enclosure should be provided for protection of vehicular traffic. Complete weather protection of the enclosure is desirable.

Pedestrian bridge or tunnel walkways should have widths no less than the approach walkway at each end. A width of 8 feet is a generally accepted minimum criterion, although greater widths — from 10 to 15 feet — are preferred, even though seldom justifiable on a capacity basis.

Pedestrian tunnels and bridges, when enclosed, should have a minimum clear height of 8 feet to minimize the restrictive nature of enclosed pedestrian walkways and to allow access for mechanized cleaning equipment.

Pedestrian Ramps

Pedestrian ramps are often more acceptable than stairs to persons who must carry packages or push shopping carts or baby strollers. They also can be used by the physically handicapped. Compared to stairs, short, gently sloping ramps appear to require less effort to travel; however, ramps use space less efficiently and require greater travel distances than stairs.

Pedestrian ramp gradients should not exceed 15 percent, and preferably should be less than 10 percent. Ramps should not exceed 120 feet in length, measured horizontally. Where greater lengths are required, level sections with a minimum length of 15 feet should be provided approximately midway in the ramp length. To reduce space requirements, ramps (and stairs) may be made more compact by reversing directions -- usually at a midpoint location — or by winding the alignment helically.

Neither walking speed nor spacing in a pedestrian stream is affected by mildly sloping ramp walkways (under 6 percent). However, some studies indicate almost a 30 percent reduction in horizontal walking speed on a 12 percent grade.

Provisions for access by handicapped persons are essential in most new structures. A nonslip surface should be provided on all walkways, including curb cut ramps — that should be at least 4 feet wide plus rounding near the curb. Gradients should be less than 12 percent.

Stairs

Stairways are usually used for grades exceeding 30 percent. Because of restricted walking space and the energy needed to overcome gravity, stairs reduce pedestrian speed in ascent to roughly one-third and in descent to roughly one-half of level walkway speeds.

Architectural standards for exterior stairs recommend a riser height of 6 inches and a tread depth of 12 inches, which provides a 50 percent grade (an incline of approximately 27 degrees). The optimum steepness of stairs is about 50 percent; however, inside parking structures, inclines between 58 and 70 percent are commonly used to conserve space. These steeper stair grades may be practical where stairs serve principally for emergency access, and where elevators are the normal interfloor access means. Stairs in multi-level garages are unattractive to pedestrians, particularly if pedestrians are expected to use them for traveling between more than two floor levels.

The adverse psychological effects of stairways can be improved by providing a landing every 5 to 6 feet of vertical elevation, which approximates eye level. This can be especially effective in reducing the appearance of stairway steepness.

Stairways in parking garages are typically 4.5 to 6 feet wide. Pedestrians need less room on stairways than on level walkways because their movement is inherently impeded. In special cases, comfort and convenience can be increased by assisting pedestrian movements with moving walkways, elevators, or escalators.

Moving Walkways

The moving walkway concept is often used for pedestrian movements in major urban trip-generating locations where large numbers of people must walk considerable distances between parking and trip destinations. Major airports have been principal users of moving walkways because passenger circulation involves walking and carrying luggage from parking spaces to terminal buildings, often requiring extensive walking distances.

Moving walkways are practical for distances under 1,000 feet. They allow pedestrians to add their own speed to that of the moving belt (tread) to save time and effort. Moving walkways (and escalators) are governed by the American Standard Safety Code. This code requires a handrail along each travel lane, and limits the maximum speed to 180 feet per minute and treadway slope to a maximum of 15 degrees. Most insurance companies will only underwrite moving walkway installations that are in accordance with the code. Table 9-3 presents moving walkway characteristics.

Escalators

Accepted standards limit maximum escalator speed to 125 feet per minute and to a maximum slope (angle of inclination) of 30 degrees. Escalator tread width is normally 32 or 48 inches, and escalator speeds in the United States are usually

Table 9-3. Moving Walkway Characteristics

Maximum Treadway Slope At Any Point On Treadway	*Maximum Moving Walkway Width in Inches*	
	140 fpm Maximum Treadway Speed	*140 to 180 fpm Treadway Speed*
0 to 3 degrees	Unlimited	40
above 3 to 5 degrees	110	40
above 5 to 8 degrees	78	40
above 8 to 12 degrees	40	N.P.
above 12 to 15 degrees	40	N.P.

Source: *American Standard Safety Code*, American Society of Mechanical Engineers, New York, 1965.
N.P. = Not permitted by Code.

90 to 120 feet per minute. At 90 feet per minute, capacity ascending is approximately 3,000 persons per lane per hour, and 2,000 persons per lane per hour on descending escalators. Generally, a 32-inch tread width is considered one-lane and a 48-inch tread width is sufficient to allow two people to stand side-by-side for two-lane operation.

Escalators are used in some parking garages, but generally are considered impractical for garage application when compared to elevators on the basis of cost, space-use efficiency, and reliability. They may be appropriate, however, for special high-turnover parking situations that produce large pedestrian volumes.

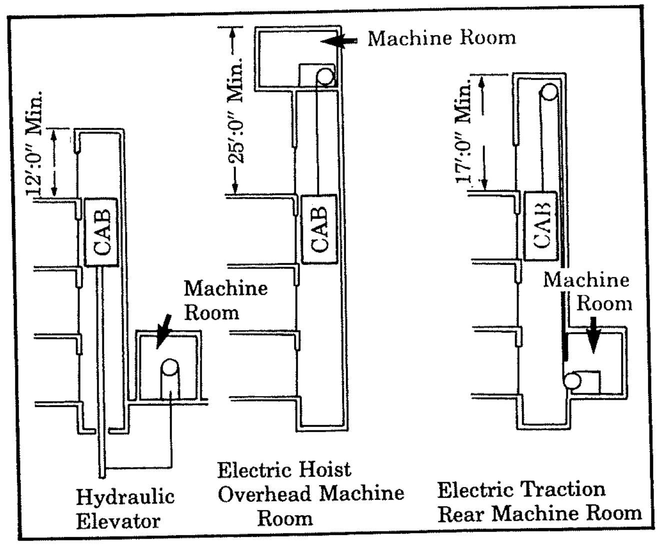


Figure 9.23.Types of elevators

Elevators

The modern passenger elevator has features such as automatic leveling and self-opening doors that permit self-service operation. Elevators are faster than stairs or ramps, require minimal effort to use, and are considered safer. However, they involve high initial cost and continual maintenance costs. When service demand is heavy, people must wait while the elevator is servicing other floor levels.

Elevators may be justified in parking structures of three or more levels. They are installed in banks (number of elevators located together) of two or more. They should be located as near as possible to the principal pedestrian generators. If the main pedestrian generator is located at one end of the parking structure, elevators should be located accordingly Generally, elevators should be located within 350 feet of all parking spaces.

Elevators are raised or lowered either electrically or hydraulically. Figure 9.23 illustrates typical elevator towers for a hydraulic elevator and electric hoist elevators, using either an overhead machine room or a grade-level machine room. Hydraulic elevators are limited to heights of approximately 50 feet, which is equivalent to about five parking levels. They generally have speeds around 100 feet per minute, and are considered slow compared to electric elevators having speeds up to 350 feet per minute.

The actual time of vertical travel in a garage elevator is a small part of the total travel time required for each pedestrian trip. For this reason, high-speed elevators are not usually necessary in garage applications serving fewer than five parking levels. Hydraulic elevators may be adequate for a two- to five-level parking structure; however, electric elevators are generally specified for higher structures. Above seven levels, higher speed (350 feet per minute) electric elevators should be considered.

Design elements for passenger elevators are fairly well standardized. The number and size of elevators to be installed is based on expected peak loads and the allowable maximum average waiting time. The actual number of passengers to be handled affects the time of operation only in the loading and unloading times. A garage with a large demand will normally have more parking levels, which increases the number of possible stops. The maximum average waiting time is more or less arbitrarily selected to meet the desires of owner and designer. One minute is the time usually selected as a maximum average waiting time.

In design of elevator systems for a particular building and passenger load, computations of total travel time should be made for each combination of floor heights and number of passengers, with special attention to multiple-destination trips to higher floors. The number and design of elevators should be such that the average waiting time for any expected trip will not exceed the selected maximum. If it exceeds the maximum, a need for additional elevators is indicated.

Such computations are best developed by elevator engineers, who should be consulted in establishing the number and type of elevators. The garage architect, engineer, and planner should be prepared to state the estimated flows of passengers per unit of time (usually by five-minute periods) and the maximum average waiting time selected.

As a general rule, two elevators should be adequate for parking garages up to 600 spaces, with another elevator for each additional 600 spaces or substantial fraction thereof. Elevators in parking structures are commonly rated for 2,500-pound capacity. Elevator cabs should be lighted to 20 horizontal footcandles, and should have all surface areas including floors and doors designed to be vandal-resistant.

If expansion capability is planned as part of the initial structure, provisions should be made for adding elevators to the existing elevator banks. This is accomplished by providing the structural framing and special knock-out panels when constructing the original facility.

In addition to adding new elevators, vertical expansion requires provisions for extending existing elevators. Hydraulic elevators are simplest to extend, requiring only additional elevator guide rails if the original installation provides for future expansion in the length of the hydraulic plunger. Electric hoist elevators with machine rooms at grade level are cheapest to extend compared to overhead machine room types, but are more expensive initially. The grade-level machine room type of electric elevator also offers expansion capability, with minimum downtime during the expansion period.

PLANNING AND DESIGN DETAILS

Remaining sections of this chapter describe current design practices for parking structure elements such as ceiling heights, drainage, ventilation and heating, lighting, floor and stall markings, signing, safety and security measures.

Ceiling Height

Ceiling heights have traditionally been designed to 7'0" minimum in recognition of local building height limitations and that parking garage storage levels seldom are converted to other uses. Consideration should be given, however, to increased ceiling heights on at least the ground level to accommodate vans used by handicapped patrons, or to provide potential for later conversion to commercial (nonparking) uses.

Minimum ceiling heights allow reductions in ramp grades and lengths. However, low ceiling heights have been a concern because they prohibit entrance by certain types of emergency vehicles. Many types of recreational vehicles — particularly light trucks with camper bodies or mounts that are increasing in usage as dual-purpose transportation vehicles — also are excluded by low ceilings. Other common objections arise from damage to automobile radio antennas and damage caused to garage fixtures. (Overhead clearance signing should be provided outside garage entrances.)

Minimum clear ceiling height should be 7.0 feet (9 to 10 feet floor-to-floor heights). However, 8'2" is desirable where handicap vans are to be accommodated; this may translate into floor-to-floor heights over 10 feet. A minimum vertical clearance of 12 feet should be maintained between the proposed floor level and the lowest point of the overhead structural framing system when commercial development is anticipated. Where commercial space is to be provided this translates into a height of at least 14 feet between the retail floor and the next parking level.

Low ceilings require careful placement of lighting fixtures and overhead signs so that these garage components can function adequately without high risk of damage from vehicles. Building components such as water lines, drainage lines, and air ducts, should not encroach on overhead or lateral clearances.

Drainage and Corrosion-Limiting Considerations

Parking structures require effective drainage, waterproofing and corrosion limiting features. Even though most of a parking structure is sheltered from direct rain or snowfall, much water can enter a structure. Storm-driven water can be blown in through wall openings, snow (often laden with salt) can be brought in on vehicles, subsurface structure levels may be subject to ground water infiltration, and the top level of a structure may be exposed to all elements.

Additionally, good maintenance procedures require that parking levels periodically be washed down with water. Water leakage through the floor slab is one of the major maintenance problems associated with parking structures especially as they age.

As the reinforcement rusts, it expands, causing internal pressures that are destructive to surrounding concrete (Figure 9.24). Once started, the cycle continues as long as all of the necessary elements are present: oxygen, water, and an anode and a cathode. Except with cathodic protection, the most controllable element is water. Thus, waterproofing and corrosion prevention are closely linked.

Damage to automobile finishes from oil and chemical-saturated water drippings leaching through structure floors onto vehicles parked below is a common customer complaint. This situation causes rapid and extremely expensive damage to the garage structure. The leakage may not appear to be causing structural problems during the early years of a garage structure's life, but after, perhaps as few as 5 years, water seepage can cause structural damage.

The drainage, waterproofing and corrosion-limiting systems should be considered during the design phase. All should be included in the initial design, even though for short-term economic reasons the waterproofing and corrosion-limiting systems sometimes are not provided during the original construction. A structure that is not adequately protected from the environment and maintained will require corrective rehabilitation and preventative measures. Most likely, these needed "retrofit" measures will be far more expensive than if effective waterproofing and corrosion-limiting measures were taken in the original construction.

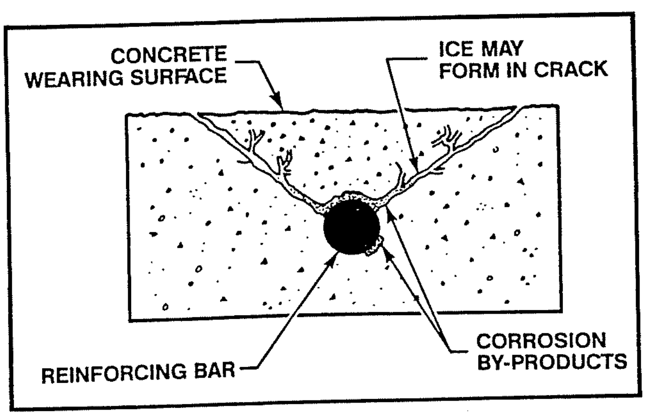


Figure 9.24. As steel reinforcement rusts, it expands, causing destruction to surrounding concrete.

Drainage. A well-designed drainage system, including proper floor sloping, removes water rapidly from the garage decks, helping to reduce water seepage and corrosion.

Drainage design should anticipate any special maintenance needs that could occur as a result of climatic conditions or other site-specific circumstances. Is snow melting equipment necessary? How will snow be disposed of? If on-site disposal is envisioned, is the drainage system adequate to handle the melt? Are convenient cleanouts provided in the leader system to provide access to remove blockages in the drain system? How will the leader system be kept free of snow and ice blockages?

Sloping floor garages have neutral drainage in the direction of the ramp slope, which may be over 4 percent. Cross-over aisles or end bays may have a flatter surface, but should be pitched to drain. Curbs typically are used along the sides of ramps and sloping floor levels to direct drainage flows to points of interception.

Storage floors of cast-in-place "flat" floor garages should be sloped about 2 percent (approximately 1/4 inch per foot). Precision manufactured (and installed) precast floors can provide positive drainage with 1 percent (approximately 1/8 inch per foot) slopes, although some designers prefer a 2 percent slope. Floor drainage slopes should be pitched to drain at right angles to the driving aisle, in long-span structures, deflection should be considered in computing drainage slopes.

Drainage should be directed toward the sides of the parking bay either by crowning the floor or by cross sloping from one side to the other (usually from the inside of structure downward, toward the outside wall). Crowning is preferable because it keeps the driving aisle (where pedestrians usually must walk) drier. However, crowning a floor is costlier to construct and may require additional drainage structures and plumbing. Drainage should lead away from elevators and stair platforms.

Floor and trench drains are commonly used to intercept runoff. These drains should be of adequate size and number, and placed to effectively intercept runoff. They should have grates suitable for carrying vehicular traffic loads. (If bicycle access and/or parking is anticipated, grates should be of a design that will prevent a bicycle wheel from dropping between grate rails.) Drains should be located outside of direct pedestrian pathways.

A riser system of drain leaders is used to connect drain inlets to common outfall pipes that carry drainage to the disposal system (storm sewer, natural or constructed open channels, or retention pond). Leader size and minimum gradient can be determined with hydraulic equations and/or nomographs. The drain riser system should be designed to handle at least a 10-year frequency storm.

Floor drains generally should be placed at 50 to 60 foot centers with the drains located in a diagonally staggered pattern along the length of each side. The drains should be placed in such a manner that water pooling caused by trash-clogged drains or unusually heavy runoff will not impede or endanger pedestrian traffic movements, or damage equipment controls housed in the structure.

Drain leaders must be located in such a way that they will not be susceptible to damage by vehicles. When they cannot be placed behind structural support columns, special protective measures, such as bumper guards, must be used. Drainage leaders should not protrude below the minimum ceiling height clearance (usually 7 feet or more) above vehicular and pedestrian travelways.

If future expansion is envisioned, the drainage conduction and disposal pipes should be constructed initially for the maximum runoff anticipated for the expanded facility. Standing puddles of water can be inconvenient and potentially dangerous to pedestrians. This condition is particularly apt to occur at entrances to elevators and stairs if proper detailing is overlooked. Since drainage slopes at these points may be difficult to construct, close construction supervision is necessary to assure proper installation. In general, drainage slopes should lead away from elevator doors and stairway entrances.

Elevator pits and other subsurface areas should have a means for positive drainage. This might involve sump pumps and backup systems (an extra-large sump reservoir, backup or spare pumps).

The site surrounding a garage should be graded to provide proper drainage *away* from the structure. Pedestrian sidewalks leading to and from the garage should have adequate runoff.

Provision of water supply outlets on each parking level should be provided to permit convenient washing of floor and ramp surfaces.

Waterproofing and Corrosion-Limiting Approaches. The application of waterproofing and corrosion limiting systems is essential to protect the parking space, structure, automobiles, and drivers. The specific solution method varies depending on the type of structure and the service environment.

Structural design considerations to prevent corrosion should include; (1) a quality concrete mix of at least 4,000-pound design; (2) adequate concrete clear cover over top of reinforcement steel of 2 inches or more; (3) good concrete curing practices; (4) good expansion joint seals; and (5) effective surface waterproofing.

Though good drainage and use of high-quality concrete along with an effective waterproofing system limit corrosion substantially, two other measures are increasingly used in parking garage construction: epoxy-coated reinforcement bars and cathodic protection.

The fusion bonded process of coating reinforcing steel is a firmly established and proven system of limiting corrosion; yet its adaption in parking garage construction is relatively new. The fusion-bonded epoxy coating insulates the reinforcing steel; and greatly reduces the possibility of rusting. It is more expensive than uncoated steel, however, the ability to withstand the deteriorating effects of deicing salt may justify the additional cost.

Cathodic protection is a proven corrosion control method. Cathodic protection systems have been used for years in the oil and gas industry to mitigate corrosion of pipelines, offshore platforms, fuel storage tanks, well casings and refinery equipment. It is only since about 1975 that cathodic protection has been adapted for control of steel reinforcing bar corrosion in concrete.

Cathodic protection is based on the principle that corrosion of any metal is a result of an electrical current flowing from one part of the metal to another. Corrosion (metal lost through oxidation) occurs where current leaves the steel. In the corrosion circuit, these points where current leaves the rebar are called anodes or anodic areas, as opposed to other nearby areas on the rebar, which receive current and are called the cathodes or cathodic areas. The cathodic protection process uses the application of direct current to the rebar through an anode material in sufficient quantity to reverse or counteract the natural corrosion current. When this corrosion current is eliminated, corrosion stops and the rebar is said to be under cathodic protection.

Lighting

Adequate lighting is necessary for the safe movement of vehicles and pedestrians and for the security of patrons and parked vehicles. The amount and quality of illumination also influences how well a parking facility is patronized, affecting the success of the traffic generator served by the parking. Lighting can impart a certain ambience that may be difficult to quantify, but it is widely recognized as an important influence on people's attitudes toward specific parking facilities and the land uses served by the parking.

Lighting levels vary among different parking facilities. These variances reflect obvious differences in designer interpretations of acceptable light levels, lighting layout, and lamp type. Less obvious reasons include dirty lighting fixtures, age of lamps, low ambient air temperature and other climatic conditions such as fog. These factors can significantly reduce lighting effectiveness.

Fluorescent lighting tubes, for instance, can lose 20 percent of their light output during the first 2,000 hours of operation. Output of fluorescent tubes, normally measured at 25 degrees Centigrade, will be reduced by nearly 30 percent when operating at the freezing point. Ambient temperature and weather conditions also can affect the light output of other types of lamps.

Many factors influence the type and amount of lighting to be provided. These include (1) lighting standards, such as those established by the Illuminating Engineering Society of North America (IES), and *de facto* standards resulting from what has been accepted practice in the parking industry; (2) what lighting is to accomplish in terms of illumination levels and uniformity to achieve the desired degree of function and ambience; and (3) how much lighting costs to install, operate, and maintain.

Lighting of a specific garage depends upon (1) hours of operation (2) interaction among factors such as visibility, visual comfort, light distribution; and lighting system geometry, and (3) type of garage construction. Many garages need illumination throughout the day — especially underground facilities and above ground structures with large covered areas. Rooftop parking and garages that are more than 50 percent open may not need extensive daytime lighting.

The *quality* of lighting is determined by four characteristics: (1) lighting level; (2) lighting level uniformity; (3) restriction glare; and (4) the degree to which lighting delineates garage pavement and wall surfaces.

Since there are a variety of factors to consider and many specialized products and techniques available to provide the illumination, lighting systems should be designed by qualified professionals to satisfy a given parking facility's unique needs.

Desired Light Levels. Guidelines for parking garage illumination — largely based on IES standards — are shown in Table 9-4. A high light level is needed just inside vehicular entrances and exits to avoid sudden and sharp differences between outside sunlight and inside garage light-

Table 9-4. Garage Lighting Guidelines (In Footcandles)

Area	Day	Night
General parking and pedestrian areas	5	5
Ramps, aisles, and corridors	10	5-10[a]
Parking storage areas	3-5[a]	3-5[a]
Entrance areas	50-80[a]	5-10[a]
Elevator areas, walkways, cashiers booths	20	20
Stairwells	20-50[a]	20-50[a]

Source: Adapted from *Lighting for Parking Facilities* (Illuminating Engineering Society, August 1984).

a. Higher values are based on information compiled by J.M. Hunnicut Associates and discussions with parking authorities.

ing, and to facilitate cashiering operations. Entrance and exit areas should be provided with at least 50 footcandles of illumination for the first few seconds of driving time after entering and before leaving a parking structure during the day.

General practice in parking garage lighting is to concentrate light on aisles and ramps, with spillover lighting often being adequate to illuminate parking stalls. A minimum of 5 to 10 footcandles should be provided. Higher levels of illumination may be advisable for areas where drivers are expected to follow a turning path, or where driving aisles intersect.

Higher levels of illumination also are desirable for remote areas that may be subject to security problems, including stairways, elevators, and other pedestrian access points (20 to 50 footcandles). Parking storage areas should have at least 3 to 5 footcandles of intensity.

Depending on site-specific circumstances, it may be desirable to provide more that the above minimum lighting. Good judgement must prevail in lighting decisions. Minimum lighting levels should be measured on new installations with no cars in the parking spaces.

Lighting Methods. Incandescent vapor-tight fixtures, mercury vapor, pressurized sodium vapor, and fluorescent lamps have been used in parking garage operations. Fluorescent tubes have been the most common type of fixture because of their low cost to obtain and install. However, there appears to be a trend toward sodium vapor because of the greater efficiency achieved in many situations.

One common arrangement is to mount fluorescent fixture tubes parallel and across from each other along sides of aisles or above the center line of aisles. The latter arrangement generally requires fewer fixtures, but may be more susceptible to damage from vehicular traffic.

Placement and Controls. Lighting fixture placement should consider economy, and protection against vehicular damage, vandalism, and weather. Fixtures must be located to minimize glare and obstruction of driver vision while maximizing servicing convenience. Fixtures should have an unbreakable exterior, tamper-proof hardware; and a vibration-free lamp mounting to prevent failure.

Roof-level placement of lights and supports is desirable at ends of parking modules and along boundaries of adjoining modules, where they do not impede traffic movement. Care should be taken to minimize glare that is created for drivers all through the structure and on adjacent streets. Excessive spillover of light to nearby properties should be avoided.

Lighting and other electrical controls should be placed in a central panel that is convenient to garage personnel and secure from unauthorized use or tampering. They preferably should be located near an attendant's station or in the main control room.

To minimize electrical utility costs and conserve energy, controls can be designed so that floor areas not in use, or not requiring illumination, can be deactivated while others in the system remain lighted. For security reasons, however, it is necessary to physically prevent pedestrian and vehicular access to levels or areas that are not illuminated. Photoelectric switches or timer controls have application for open-top deck levels and other areas of the garage; however, manual override may be necessary on holidays or when the facility is not used.

During nighttime operations, all lights must remain on until every car has left the garage, or the parking levels are closed. Exit lights, however, must remain on 24 hours, unless local codes dictate otherwise. Circuits and switches should enable partial lighting during daytime periods.

Signage

Signage is essential for a parking garage, especially where customers park their own cars. The signs should be clear and concise. They should direct parkers to and through the garage. More especially, they should be used to (1) identify the garage for approaching street traffic, (2) direct motorists to parking spaces, (3) identify parking areas, (4) direct motorists to the most convenient exit, and (5) advise motorists about clearance, oncoming traffic, potential conflicts, and prohibited movements. They should direct pedestrians from parking space to stairs and elevators.

Signage System. Signing should recognize that a parking garage is essentially an extension of the street system. Directional and information signs should be consistent with standard street signs, although unique sign designs have been successful in some cities.

Signs at entrance points should identify (1) height restrictions, (2) parking fees and (3) when the garage is full. Vehicle and pedestrian paths within the garage should be marked by legible, well lighted signs. Where sign placement can take advantage of garage lighting, specially illuminated signs may not be necessary. Some garages paint signs on walls or other areas that have good target value.

Directional signs should be placed strategically to direct drivers in prescribed patterns to reach parking spaces and exits. Once drivers leave parked vehicles and become pedestrians, it is imperative for safety and good public relations that pedestrian access points, stairways, and elevators be visible from any parking stall location.

Open-wall design is a natural aid to pedestrian orientation, placing adjacent streets and buildings in view. Large parking garages with multiple parking modules, or underground garages, may require signing to orient properly both drivers and pedestrians.

In self-park facilities, parking stalls, sections and/or floors are usually identified by numbers, letters and/or symbols to facilitate easy retrieval of parked vehicles.

The design and placement of signs should reflect good graphics and traffic engineering standards:

- Signs should be easy to read from a moving car.
- "International" symbol signs and standard highway signs have good clarity.
- A "P" symbol to indicate parking is easily identified.
- Both too few signs and too many signs should be avoided.

Use of Color Coding. Color coding, often in conjunction with numbers or letters, is used in some facilities to help customers find their parked cars. Color coding can be used in several ways, including color strips around columns, colored doors and elevators buttons, floor strips, and actually spelling out the color by name in conspicuous locations. An important consideration in color coding, or number/letter systems, is that the patron be made aware of the existence and purpose of the identification system. Color coding also can be used to differentiate "To Parking" from "Exit" signs within a garage.

Changeable-Message Signs. Internally illuminated "blank out" type signs that provide changeable messages are increasingly used. This type of sign, coupled with automatic vehicle sensing and counting systems, can signal drivers when certain parking sections become full. Changeable message signs can save travel time within parking facilities, improving operations as well as public relations.

Timing of Decisions on Sign Plans. Difficulties are often experienced in determining an effective signing plan from parking garage construction plans. Some designers make it a practice to postpone sign plans until garage construction is nearly complete. This enables field investigations to determine and assess sign locations and needs on the basis of actual conditions encountered in a parking structure. The delayed timing helps to assure that sign locations will not be obstructed by parked vehicles or building components. Field investigations also afford the opportunity to evaluate required size and lighting for sign graphics.

Floor Markings and Stall Delineation

Floor pavement markings should delineate parking stalls and give warning and directional messages.

It is nearly universal practice to delineate stalls in public parking facilities. Marking stall side boundaries aids drivers in positioning their vehicles, assuring efficient floor space usage. Single paint lines 4 to 6 inches wide are most commonly used to mark parking stalls. Double lines between stalls further aid drivers in correctly positioning vehicles. Parking stall delineations can be extended up walls giving drivers highly visible reference guides, but this is not commonly done.

General consensus of garage operators is that yellow paint lines remain visible longer than white, but no conclusions have been developed as to which color is actually best.

Shortening parking stall length delineations to 16 or 17 feet is one technique that encourages drivers to pull as far as possible into parking stalls. Vehicle restraining devices should be used at backs of stalls. These devices may be bumper stops or wheelstops.

Maintaining markings is important, since they become worn quickly and lose effectiveness. While painted stall markings are by far the most common form of stall delineation, other materials and methods have been used successfully. Striping tape and raised surface markers are used in some parking facilities. Low concrete islands were common in earlier garages to reduce labor costs of periodic restriping, but were found to hamper snow removal and floor cleaning, not to mention inflexibilities of modifying the parking geometry at later dates.

The use of curbing inside parking garages is declining because of inflexibility, cost, and maintenance. However, pedestrian safety islands are still used in very sensitive areas where pedestrian-automobile crossings are unavoidable or vehicular channelization is critical. Protection of stationary objects, such as cashier booths, requires barrier-type delineation.

Ventilation

Parking garages may be ventilated by natural means if they are above ground and open. If they are enclosed or partially enclosed, they should be ventilated by mechanical means. Therefore, most above-ground parking garages are ventilated naturally since they generally use open-wall designs. Mechanical ventilation to remove harmful automobile exhaust gases is essential for underground garages and for many garages built on part of multi-use development. The goal of ventilation, whether natural or mechanical, is to remove or reduce the pollutants to at least a safe and acceptable level, if not to the lowest level possible.

The buildup of automobile emissions within a parking facility depends on several factors. These factors include the number of vehicles operating at the same time, the maintenance condition of each vehicle, whether it has just been started or is running at its normal temperature, the speed, the length of time the vehicle operates between entering the facility and parking space (or between starting and exiting the facility) the ambient air temperature, and the altitude.

Carbon monoxide, the most voluminous of detrimental elements in automobile exhaust gases, is odorless, colorless, and tasteless. It can cause unconsciousness and death, although the more likely danger in parking garages is associated with impaired reaction time and visual acuity affecting driving coordination and ability to operate a vehicle.

Carbon monoxide, contrary to many opinions, is the same weight as air and usually concentrates about 2 feet above the floor — the approximate elevation of vehicular exhaust systems. It tends to collect heavily in parking garage corners that are not adequately ventilated and near curb lines at street levels.

The basic criterion is the maximum permissible amount of carbon monoxide (CO) in the air. There are variations in the standards set by public agencies. The Environmental Protection Agency (EPA) recommends a maximum average of 125 parts per million (ppm) of CO in a 1-hour period. The Occupational Safety and Health Administration (OSHA) sets an average limit of 50ppm of CO in an 8-hour period. The Uniform Building Code set maximum averages of CO in ppm at 200 for 1 hour and 50 for 8 hours. Thus, in general, ventilation should be sufficient to prevent accumulations of carbon monoxide in excess of 100 ppm per million.

Carbon Monoxide Detection. Ventilation equipment, operating and maintenance costs can be expensive. Recognizing the economies involved in operating ventilation equipment at partial capacity during slack periods of parking activity (in lieu of full capacity), many building codes allow partial capacity operation if monitored by an approved type of carbon monoxide detection system.

Three types of systems are employed to detect and measure carbon monoxide concentrations.

1. The "heat of reaction" method passes an air sample through a heated chamber containing a catalyst that promotes oxidation of carbon monoxide to form carbon dioxide. Generated heat from this reaction is in proportion to carbon monoxide concentration in the sample. Temperature change is measured by thermocouples and amplified to provide a signal to actuate alarm circuits if the reading is beyond prescribed limits.

2. A second method, the "infrared absorption" method works on the principle of carbon monoxide absorbing infrared radiation in proportion to

amounts of carbon monoxide in an air sample. Air sample comparisons are made against a reference cell containing a known standard gas to determine carbon monoxide amounts contained in the sample.

3. The "colormetric" analyzer is a third system. A sensing material responds to the presence or carbon monoxide by changing color. Color change is measured by instrumentation and relayed to activate a signal alarm circuit.

The economic feasibility of carbon monoxide detection systems depends on costs, including operation and maintenance, as compared to costs of operating the ventilation system at full capacity during operating hours. It generally is less costly to integrate a carbon monoxide detection system with initial construction rather than to add it later. Consequently, ventilation needs and controls should be determined in preconstruction planning and design stages.

Air and Exhaust/Intake Requirements. For open structures, it generally is accepted that natural ventilation is adequate if 20 to 25 percent of the perimeter wall area is open and the openings are well distributed. However, some codes require as much as 75 percent of two sides to be open. (If 20 percent of two opposite sides are open in open parking structures of standard dimensions, wind speeds of 1/2 mile per hour will provide six or more changes of air each hour.) Plan dimensions of more than about 400 feet require special consideration.

For enclosed parking structures, building codes frequently specify the number of air changes there should be each hour or they specify the capacity based on cubic feet per minute (cfm) per square foot of floor area. They often specify where air changes must be made, such as near the floor and/or ceiling. However, different operating characteristics of individual buildings prevent developing a rigid standard on how many air changes per hour are needed.

Generally, four changes of air per hour are minimal requirements, with seven or eight air changes per hour often needed for peak-operating periods. However, in some facilities, even 14 changes have proved to be insufficient. In practice, the quantity of noxious foul-smelling exhaust gases usually reaches an intolerable stage long before harmful amounts of carbon monoxide are present.

The ventilation requirements in cubic feet per minute (cfm) per square foot usually range from 0.75 to 1.5 with 1.0 being the most common. If the ceiling height of the garage is 7 feet, 1 cfm per square foot will provide an air exchange every 7 minutes or about 8.6 air exchanges an hour. These requirements generally have resulted in enclosed parking facilities that are adequately ventilated except for the few special situations in which a large percentage of the parkers leave simultaneously. Ventilation requirements would be increased by backups within the garage that result from inadequate street or cashier-booth capacity.

Improving Ventilation. There are three basic mechanical means of ventilation — (1) supply only, (2) exhaust only, or (3) a combination of the two. Effectiveness will depend on the distribution of supply and/or exhaust points and the geometry of the parking facility itself. Openings between floors, openings to the outside, or the proximity of supply and exhaust points can cause "short circuits" in the air flow that leave portions of the facility unventilated. Thus, it is important to consider the probable air flow throughout the entire enclosed parking facility. It generally is best to place the exhaust points near the floor, since polluted air tends to be heavier than clean air. A simplified flow system of air through the garage has proved most successful by introducing new air at a point approximately two feet above the garage floor.

Areas where employees work for extended periods, such as offices and cashier booths in a parking facility, should be ventilated with an air supply separate from the rest of the facility. The air supply for the whole facility should be located where it is least likely to be contaminated from the system's exhaust or other outside sources.

Ducts must be located so that overhead space and other dimensions crucial to the use of a facility are not impaired. Numerous small fan units often are preferable to a few large fan units. The smaller units allow more flexibility in the fan control system. Also, should one unit be down for repair or maintenance, a small portion of the facility would be affected.

Parking Garage Heating

Once widely practiced, parking garage heating is now seldom considered necessary in vehicle storage areas. The manager's office, cashier booths, and enclosed areas for the exclusive use of pedestrians are the only places that generally are heated in parking garages.

In regions of heavy snowfall and low temperatures extremes, pavement heating has been used to free exposed driving surfaces of ice accumulations. It usually is limited to entrances, exits and exposed ramp surfaces.

Safety and Security

A safe, secure environment within a parking structure is essential. Safety and security are potential problems in self-parking facilities. Accordingly, new garages incorporate security in their planning, and some existing garages make post-construction modifications to limit pedestrian entry, to specific access points and to monitor movements. Electronic audio and/or visual equipment are other security devices typically added after construction.

Security techniques are classified as either *active* or *passive*. Active security is defined as any technique requiring a human response, such as security patrols, guards, or audio-visual surveillance. Any device or technique not requiring a human response, such as fencing, lighting, and locks, is defined as passive security.

Security begins with measures designed into a structure. Lighting, for example, is basic to safety and security and is a valuable deterrent to criminal acts and loitering. Overlighting of remote areas in a garage can be justified on a security basis. Architectural design should eliminate possible hiding places, and openings that could allow random pedestrian access. Open-wall garage design, used in most above-ground parking garages, is particularly vulnerable to security problems if the design does not provide fencing or small-opening screening that prevents random entry.

All fixtures and equipment should be reasonably secure from tampering and acts of vandalism. Painting garage interiors in light colors improves lighting effects while contributing to improves aesthetics and security.

Stairwell and Elevator Security. Most local building codes require smokeproof and fireproof stairwells. As a result, most stairwells are enclosed with masonry walls. These stairwells, and most elevator cabs, are virtually soundproof and visually obscure from other garage areas, representing potential security problems.

Where building codes permit, stairwells have been constructed using safety glass or transparent plastic as an enclosure, or as open stairwells, thereby reducing security problems. Elevators can have one or more walls of transparent material, but it may be more practical to monitor elevators with electronic surveillance techniques.

Nighttime Security. During periods when parking activity is substantially less than the garage capacity, as during night operations, there should be a means of securing unused parking levels from use, including stairwells and elevators. If the garage is not operated on a 24-hour basis, the entire facility should be secured from vehicular and pedestrian access when not in operation. However, many of the garage facilities that close in the evening either do not have the means to lock the facility, or do not believe it to be necessary.

Security Patrols and Surveillance. Most parking garages use some form of active security to supplement passive techniques. Publicly-owned parking garages often rely on city police patrols. Some garages with pronounced security problems use the services of professional security guards or off-duty policemen. Uniformed garage personnel can provide effective security by reassuring parking patrons and serving as a deterrent to unauthorized entry or loitering.

Use of electronic visual surveillance systems depends on adequate and uniform lighting. It usually requires the full attention of at least one employee if not used in conjunction with an electronic audio monitoring system. Electronic visual monitoring in parking garages generally is confined to elevator cabs and passenger waiting areas. In some instances, electronic visual surveillance systems can also monitor traffic movements.

Electronic audio surveillance systems consist of two different types: (1) sound amplification throughout the entire parking garage, or (2) sound transmission to a specific monitoring station, usually the manager's office or cashier's booth. To be most effective, an audio system should allow two-way communication.

The provision of closed circuit television is justified in some situations, even though it is an expensive technique. The cameras help monitor pedestrian activity, especially in remote sections and at entrances and exits.

Fake or dummy television monitoring cameras, both fixed and revolving, have been used as a psychological deterrence. Specific signing to the effect that electronic surveillance is used, or that security guards are on duty to patrol, are other popular psychological approaches. How much deterrence value these types of passive techniques have is difficult to establish, although most garage patrons appreciate the assurances offered.

Various provisions can be made to improve cash security. Using a drop safe is the most important since cash would be unavailable if a robbery were attempted. Exact change can be required for transactions. A silent (concealed) alarm, often foot operated, can be placed in the cashier's booth.

Fire Protection and Control. Fires in parking structures have not been a significant problem. The combustible material per square foot of floor area is considerably less than of nonparking structures. Parking garage designers and operators believe that many building codes require an inordinate amount of fire protection in garage facilities. Most building codes require sprinkler systems in underground garages.

Because of past experience with parking garages and the likely nature of any occurring fires, some cities have granted variances to eliminate sprinkler-system requirements in parking structures. Automobile fires usually consist of smoldering upholstery and electrical fires, both of which are contained or enclosed within the vehicle. Sprinkling of water or foam on the vehicle is, therefore, of questionable help.

The practice of locating fire extinguishers throughout a parking garage is generally not recommended, since they are frequently stolen or damaged by vandals. An acceptable practice is to use larger extinguisher systems, mounted on handcarts and situated at central locations in the garage. The larger size discourages theft and provide more fire-fighting potential. Locations that enable monitoring of equipment discourages vandalism.

Many newer parking garages have water or foam fire-fighting systems constructed integrally, with firehose connections located at strategic points on walls throughout the structure. Consideration should be given also to rooftop standpipes for firehose connections that can be used for fighting fires in adjacent buildings as well as in the parking structure.

Heat and smoke detector systems are commonly used. Heat detection systems are available that sound an alarm when temperatures rise beyond prescribed limits within a specified time period. These indicators usually sound an alarm when the temperature in an area rises 15 degrees in 1 minute.

SUMMARY

The following section summarizes various design parameters discussed in this chapter. Appendix L provides a further checklist to help assure optimum parking structure design.

Structure Size

A parking structure with 500 to 2,500 parking spaces, scaled to the capacity of adjacent street access, is most desirable.

Structure height may be limited by local building codes as well as interfloor circulation constraints. Generally maximum parking structure heights range between 5 and 9 levels (60 to 90 feet).

Location Guidelines

Accessibility is a principal factor in parking garage location. Parking garages exceeding 1,200 spaces should have nearby or direct freeway access.

Guidelines for maximum walking distance are: long-term parking, 1,000 to 1,500 feet; short-term parking, 500 to 800 feet; or urban population (under 250,000 population) — long-term parking, 600 to 700 feet; short-term parking, 200 to 350 feet.

Entrance/Exit Lanes

Maximum lane capacities for parking garage entrances range up to 700 or more vehicles per hour; for control entrance lanes, 200 to 400 vehicles per hour per lane depending on control. Discharge capacities range between 150 and 300 vehicles per hour for each gate-controlled exit lane. General requirements for number of access lanes and reservoir area are: *entrance lanes* — short-term parking, 1 lane per 300 to 600 spaces; long-term parking, 1 lane per 300 to 500 spaces; *exit lanes* — short-term parking, 1 lane per 250 spaces; long-term parking, 1 lane per 200 spaces; *inbound reservoir area* — free-flow entry, 1 space per entry lane; ticket-dispenser entry, 2 spaces per entry lane; entrance cashiering, 8 spaces per entry lane; and attendant parking, 10 percent of parking capacity served by each entry lane.

Parking Stall Dimensions

Minimum stall widths for self-park operations are 8.5 feet; for attendant-park operations, stall widths are 8.0 feet or less. Minimum stall length is 17.5 to 18 feet. Special compact-car stalls are 7.5 feet wide by 15 feet long.

Aisle Width

Minimum widths for one-way driving aisles range from 11 to 18.5 feet; two-way driving aisles, from 22 to 24 feet.

Column Spacing

Traditionally, columns have been spaced at intervals of three parking spaces. This results in a 28.5-foot spacing, assuming 90-degree parking and 18-inch columns. Because columns are located 3 feet in from aisles, a parking bay or module of 62 feet requires an overall minimum column spacing of 31 by 28.5 feet. Larger columns, angle parking, and/or more stalls between columns requires spacing to be increased accordingly to maintain adequate clearances.

Clear-Span Design

Column-free designs may provide structural support spans from 48 to 65 feet. A 60- to 62-foot span is desired for 90-degree parking.

Parking Layout Efficiency

Under 350 square feet per space is desirable; 350-400 is acceptable; over 400 is questionable.

Floor Heights

Minimum clear height is 7.0 feet; however, 8.2 feet may be more desirable, which provides a 9.5 to over 10-foot floor-to-floor height. Minimum clear height for ground floor commercial space is 12 feet.

Ramp Grades

A maximum grade of 5 to 6 percent may be used for sloped portions of sloping floor garages where ramps provide direct access to stalls. Where conventional interfloor ramps are used (either straight or helical), grades should not exceed 15 percent; grades of 7 to 8 percent are preferable. For attendant-parking, grades should not exceed 15 to 20 percent.

Ramp Width

Where ramps are designed for one-way traffic movement, 12 to 14 feet is desirable; for two-way movement, 22-24 feet is desirable. Greater width should be allowed on curved ramps.

Lighting

Adequate lighting is necessary to promote safety and to deter violence and vandalism. Most desirable are: 50 footcandles at garage entrances and exits; 20 to 50 footcandles for stairways; 20 footcandles for cashiering and watching areas, and elevators; 10 footcandles for travel lanes; and 3 to 5 footcandles for parking areas.

Passenger Elevators

Passenger elevators are recommended for parking structures of 3 or more floors. Needs can be generally equated to the number of parking stalls: two elevators for the first 600 stalls and one extra elevator for each additional 600 stalls or substantial fraction thereof.

Security

Security measures employed in parking garages include television surveillances, panic buttons, fencing closure of grade levels, access control, and two-way audio surveillance.

CHAPTER **10**

Off-street Parking Operations

A primary and highly visible goal of off-street parking operations is service to the parker. Less visible to parkers, but an equally important goal to the operator, is economy of operation. Maintaining a balance between service delivery and operating economy is the challenge of parking operations.

At minimum, operating parking space involves controlling usage and maintaining the space in good repair. Even for very small parking lots, controlling and maintaining the parking spaces can be a daily concern for the operator or owner served by the spaces. This operational concern expands in complexity as the number of spaces increases, when strict control of access is required, or when fees must be collected from parkers. For most parking a plan of operation is imperative.

A plan of operation is important even before the decision is made to actually construct the space. Basic assumptions about how a parking lot or garage is to be operated are made early during planning and preliminary design stages. Where the parking facility is the focus of a development, operating assumptions can be principal determinates of the project's financial feasibility.

Before opening a new parking facility to traffic, the plan of operation begins to be implemented. Maintenance arrangements are made, operating procedures are outlined, and employees or contracted personnel are staged to carry out the duties of delivering the parking service. After the parking is opened to traffic, there is a learning period during which the validity of earlier operating assumptions are tested, personnel gain training and experience, and adjustments are made to respond to unanticipated problems.

Operating plans usually require modifications. Other than for the simplest parking provisions, few preliminary plans of operation can anticipate all circumstances and demands that are actually encountered in operating the specific parking facility. Even the operating plan of established facilities should be assessed periodically to determine if the desired balance between service and economy is being realized, or to determine what must be done to bring the operation into better balance. Thus, the operating plan should provide some flexibility to accommodate changes or unanticipated circumstances.

Operational planning enables operating costs to be estimated and the cost/service implications of alternatives to be compared. Formulating a plan of operation examines what methods of operation will be most appropriate. Operating hours, policies and procedures are established by the owner and/or operator. The operating method selected and hours of operation will help indicate personnel and equipment needed to control and maintain operations. In some situations, it may be to the owner's advantage to have others operate the parking, either through a lease agreement or management contract.

Operating methods and procedures must reflect site-specific circumstances, including what the owner/operator wants. This chapter examines many of the considerations used to formulate operating plans. It discusses alternative methods of operation, operating procedures and costs, and other concerns of parking operation.

OPERATING PLAN CONSIDERATIONS

A plan of operation must assure the desired balance between service and economy. It must be responsive to the type of patron served, and it must reflect consideration for various circumstances of the operating environment. The plan of operation is always tempered by the philosophies of management and administration on how best to achieve service delivery and operating economies.

Influencing factors of patronage type include their parking demand characteristics and service expectations. Influences of the operating environment generally involve circumstances of public policy, regulation, parking facility type and condition, and the parking site's surroundings.

These influences have many implications for providing appropriate parking operations. They indicate service delivery needs and measure parking facility adequacy. They also provide a basis for estimating or anticipating the costs of operations and judging the opportunity for recovering costs.

Influences of Patronage Characteristics on Operations Planning

The type and mix of parkers varies, depending on land use or attraction generating the vehicular traffic and parking demand. Every land use exhibits typical peak-traffic activity periods and parking demand characteristics. Even though there may be variations in these characteristics, they are usually predictable.

Parking Demand Characteristics. Arrival and departure patterns, parking accumulation and turnover characteristics, type and mix of parkers, each have a fundamental influence on operations planning. These characteristics influence how many hours each week parking must be provided and indicate the amount of traffic and parking capacity needed. They also influence decisions on method of access control, vehicle handling and revenue collection. Most importantly, parking characteristics suggest the level of service necessary to be attractive to patrons, yet remain cost effective for the operator or owner to provide.

Longer operating hours generally equate with higher operating costs. Parking for airports, hospitals, some multiple-shift workplaces and residential developments is typically made available around the clock on a 168-hour per week basis to provide the service level demanded by patrons of these land uses. Major operating expense items, such as labor, lighting and security normally increase with longer operating hours. Many land-use activities demand less than 168-hour per week parking availability, but it still may be necessary to operate lighting and security during hours the facility is closed. The costs and benefits of staying open longer must be weighed carefully to determine the optimum hours of operation.

Demand characteristics are the basis for determining the size and operating capacity necessary to provide the desired level of service. Larger parking facilities generally cost more to operate even though the operating cost per space may be lower due to economies of scale. The method of access control, vehicle handling and revenue collection has a direct impact on the capacity that must be provided, as well as the costs of operation. Operations planning should consider peak-period demand surges when large numbers of patrons want to enter or leave; contingencies for system breakdowns and provisions for handling demands that occasionally exceed capacity. The larger the parking facility the more critical these concerns become to operations seeking to balance service and costs.

Parking characteristics also indicate the patron mix. The demand may be characterized by a mix of short- and long-term parkers, parkers that are to be given special treatment, and parkers who arrive in a variety of vehicle sizes and types. Operations planning must consider how the patron mix is to be handled to optimize service and economy. This may involve providing segregated parking areas or special parking fee rates for different user groups. It could require special operating procedures to control and enforce desired space usage.

Service Expectations. Service is conditioned by ease of access and parking convenience, special privileges extended to patrons, and what the parker is asked to pay. Service is measured by speed and ease of access, walking distance, reserved or guaranteed space availability, security visibility and facility features or service offerings that add amenities to parking.

The type of parking patron is an indication of the level of service that parkers will expect or accept. High-turnover parking generally needs a higher level of service than all-day or low-turnover parking to facilitate safe-expedient traffic operation. Patrons of convenience stores and various types of service establishments demand very fast parking access and very short walking distances. This normally precludes gated access, direct parking fee collection or attendant handling of vehicles. At the opposite extreme are most types of special event parking, where relatively long access waiting times and walking distances can be tolerated by most patrons.

Certain types of parking can be extremely time and convenience sensitive. For example, some hotel, airport, restaurant, shopper and special event parking may need or expect a valet or parking attendant to handle their vehicle between destination entrance and parking space.

Service expectations may extend beyond considerations of the time required for a patron to use the parking. Some types of parkers may expect special services, such as a high level of security for evening parkers and nightshift workers. Various operational amenities may be necessary to attract and retain patronage. Parking operations have courted their clientele with loaner umbrellas, maps, shuttle transportation, electrical outlets to recharge car batteries, and emergency repair services, among other amenities — often provided at little or no direct charge.

Influences of Operating Environment

The operating environment is a factor of government regulation and policies, parking facility type and condition, and circumstances imposed by the surrounding area of development. The successful operating plan anticipates and responds to the operating environment.

Government Regulation and Policies. Local government progumates and enforces zoning, building and fire codes that regulate the provision and operation of all off-street parking. Operations are typically limited to the maximum number of vehicles that can be parked and the minimum size of parking stalls and access aisles that can be provided. This effectively prohibits self-park operations attempting to maximize revenues by stacking or parking vehicles in access aisles or otherwise maximizing the use of available space in a manner deemed not in the public's best interest. Government also commonly regulates operations in other ways.

Parking operated as commercial ventures are required to be licensed. To combat traffic congestion and/or help attain air quality goals, local governments in some instances have imposed a surtax on parking receipts and enacted other transportation control measures affecting parking to discourage low occupancy private automobiles from entering downtown districts. A number of cities have levied sales or exise taxes on parking receipts simply to increase public revenues. Any sales tax approach implies strict record keeping and reporting procedures for parking operations.

Like most businesses, parking operations are concerned with the real estate and income taxes collected at various levels of government, handicapped access, labor laws and legal liability. Unlike some businesses, many parking operations must be concerned with spill-over lighting, public-side competition, government efforts to control or regulate the price charged for parking, levels of curb-parking enforcement, aesthetic appearance, signing, snow removal and disposal, mandatory structural inspections, storm water runoff and traffic detours and traffic diversions, caused by construction or changed public policy, that affect business.

Parking Facility Type and Condition. The type, functional design, and condition of the parking facility places physical limitations on how a facility can be operated, and affects maintenance requirements and costs. A well-designed and constructed facility aids service delivery and helps to maximize operating economies.

Functional design is intended to provide an accessible facility that facilitates economical operation. For gate-controlled access parking, the number and location of access points can be critical considerations for operations. Mechanical gate arms and associated access control equipment constitute operating investments and require periodic maintenance. If the operation requires access points to be manned with an attendant or cashier, operating costs will grow as the number of access points increase; however, access driveways are provided in response to traffic capacity needs rather than operating economy. Good design attempts to maximize operating economies by permitting all access points to be monitored from one cashier/attendant position.

Manned or attended parking operations introduce concerns for appropriate administrative and operational areas. Among these concerns are size and features of cashier booths, employee restrooms, employee lockers, and administrative office space. Storage space for supplies and maintenance equipment is another factor for operations to consider.

All parking facilities require periodic housekeeping and preventative maintenance. Adequate water supply provisions should be available for washing down garage floors and watering landscape plantings. Electrical controls should be centrally located and, in garages, provision for changing the level of illumination can help economize operations. Equipment manuals, and manuals for other design features requiring periodic inspection and servicing should be readily available.

Good design provides a facility that can be easily maintained without undue interference with traffic operations. Good design and construction also provides a parking facility that is as maintenance free as possible. This is reflected in use of materials and fixtures that are resistant to vandalism, drainage that works and is easy to maintain, and other design or structural features that are not liability nuisances or maintenance intensive.

Changes in circumstances sometimes make even the best functional parking designs less than satisfactory for maintaining the desired balance between service and economy. Flexibility for restoring this balance is usually sought first by modifying operating procedures and/or the method of operation.

Surrounding Area Conditions. Parking operation must reflect consideration for the environment in which it operates. Primary concern is for access, however, local practices and competitive offerings also influence operating plans.

Operations planning should anticipate change that is likely to occur in vehicular and pedestrian traffic characteristics and site access. Locational circumstances may indicate need for special security measures or special procedures to discourage unauthorized use of parking space or loitering. Competition in the area of influence can affect parking space pricing and choice of operating method or procedures. Local customary practice can even influence the choice of color (white or yellow) for parking stall striping.

METHOD OF OPERATION

Method of operation refers to how access is controlled and whether vehicles are handled by the parker or an attendant. It also can refer to how parking fees are collected. The method of operation must be an early decision in parking facility planning because it affects many important functional design provisions necessary to complement the chosen method of operation.

The purpose of access control is to discourage or prevent unauthorized use of space. Access control also provides a means to assure that parking fees are collected. Fee collection also can be accomplished with non-gated access points. In many cases where parking is provided without a direct charge and unauthorized use is not a problem, gated-access control is unnecessary.

Most off-street parking is the self-park operating type. Attendant or valet parking is used where available parking area is extremely restricted or to provide a high level of service. Normally, operating costs are higher for attendant-park operations because of the added labor costs. Experienced attendants, however, are able to park 10 to 25 percent more cars in a given space as compared to self-parking.

Most parkers prefer self-parking. This is because they can lock their vehicle and take the key with them; and they avoid possible delay or perceived vehicle abuses associated with attendant handling of vehicles. Self-parking reduces operating costs, but requires more space than attendant parking to accommodate drivers with widely varying driving skills. A self-park operation also must provide more directional information for drivers. Potentials for problems are increased further by the mix of pedestrian and vehicular traffic inside the parking facility.

Non-Gated Self-Park Operations

Non-gated access provides both convenience and economy when authorized use is not a problem. It encourages free-flowing traffic movement, limited only by the traffic capacity of surrounding streets and the parking facility's internal circulation system. Except where a parking fee is to be collected on-site from the parker, non-gated access eliminates most equipment and labor expenses incurred with other methods of operation. Disadvantages are primarily associated with controlling space usage.

Controlling Space Usage. In a non-gated parking facility it may be necessary to have operational control over who is allowed to use the spaces, where they should park within the facility, and when or how long they are allowed to park. Enforcement of parking restrictions requires identification of offenders and the legal ability to take effective corrective action.

Various enforcement measures are available for publicly operated parking (as discussed in Chapter 11) and for privately owned and operated parking. While the public side can often recoup parking enforcement expenses, the private side usually has more difficulty. Enforcement of space usage on private property typically relies on specific signing and other forms of communication. Agreements with the local police may enable towing and off-site vehicle impoundment, or on-site vehicle immobilization.

Where unauthorized parking is a particular problem, a parking attendant can be hired to direct traffic and parking space use. This type of an attendant does not actually drive patron's vehicles or have police powers. The intent is to encourage proper positioning of vehicles in parking spaces, facilitate traffic movement during surges of activity, and to discourage unauthorized parking before the driver has an opportunity to leave the vehicle. It is important that this individual be properly dressed to be recognizable as an authorized employee, and to wear high-visibility clothing and/or reflective markings. The individual should be trained in directing traffic and should be able to effectively communicate the parking policies and regulations governing space usage.

Pre-printed and official-appearing notices can be placed on the windshield of improperly parked or unauthorized vehicles. The message should be courteous, describing the violation and requesting compliance. Threats such as "violators will be towed at their own expense" are normally unnecessary and poor public relations; these messages are usually reserved for specific signing. For habitual violators, some parking operators have found success in getting the message across on rather difficult-to-remove adhesive backed stickers of phosphorescent orange or other distinctive color. The sticker is placed on the driver's rear side window or on another glass area in such a way as not to obstruct the driver's operating vision or damage vehicle finish.

Methods used to enforce parking time limits include chalk marking of tires and/or recording license plate numbers. Parking meters and several other variations on the meter concept are available to aid detection of parking time-limit violators and to collect parking fees. In most cases, these devices are activated by inserting coins or, in some other fashion, collecting a fee from the parker.

Collecting Parking Fees. Charging a fee for parking can be an effective control over space usage. Universities and other parking providers commonly collect pre-paid parking fees in return for a parking permit that is affixed to the vehicle or simply displayed inside the vehicle behind the windshield. Checkers periodically patrol parking facilities to identify unauthorized (unpaid) parking. This approach is commonly used to serve parkers that frequent the same facility or system of parking. The permit can be color-coded or otherwise marked to limit parking only in designated parking areas, and/or during certain time periods.

Several mechanical methods are available for collecting parking fees on-site in non-gated facilities. The parking meter is the most widely used, however, centrally located fee collection devices are growing in popularity. Since there is no gate or attendant to assure that the correct fee is collected, these systems are called honor parking systems.

The post-mounted parking meter at each parking space has traditionally been used primarily to discourage long-term parking and to help identify overtime parking violators. The reasoning is that short-term parkers are willing to pay a nominal amount for convenient parking and long-term parkers find it inconvenient to keep the meter current. Meters also can be used to collect payment from long-term parkers, but this application is less common. Parking meters are available in several variations (see Chapter 11).

Various alternatives to the more traditional meter are available to collect parking fees from centralized on- and off-site locations. These range from non-mechanical slot boxes to microprocessor-based electronic control devices. The basic slot box consists of numbered slots corresponding to each parking stall in the facility. Upon leaving the parked vehicle, the patron goes to the box and inserts the posted parking fee in the slot number that corresponds with the patron's parking stall number. Parking facility personnel, periodically check the box contents to determine who has not paid and to collect box contents. Electronic meter boxes offer more flexibility, enabling charges to be assessed on a variable fee basis and providing a receipt or parking fee voucher to the patron, as well as providing the facility operator with an audit record. Computerized meter boxes can be interconnected to enable parkers to purchase more time, if needed, from boxes located outside the parking facility.

Honor System Strengths and Weaknesses. Honor systems offer an alternative to using cashier/attendants to collect parking fees. They require fewer personnel on the collection side of the equation, but this is offset to some extent by the added personnel necessary to monitor and identify scofflaws, and to perform periodic collection and maintenance duties. Compared to gated operations, honor systems reduce traffic delays at access points and, because they are self-service, are perceived by patrons to be a less costly form of parking.

Traditional parking meters can represent significant expense to install, maintain and empty. Centralized collection devices are more economical in these respects and more aesthetic, but their use is less familiar to many parkers than traditional parking meters, and they may not be perceived as being convenient. Commercial operators were among the first to use the centralized slot box concept to collect revenue during off-peak periods (evenings, weekends and holidays). Municipal operations also have been adopting the centralized meter approach — even for on-street parking applications. Centralized meters are likely to continue growing in popularity.

With unattended honor system parking there is a greater need for customer understanding and visible enforcement monitoring. Clear and concise signs, located conspicuously, will promote the understanding of unattended honor system parking. Parkers must know what they are buying, how to pay, and what happens if they do not pay. When enforcement is inadequate or where private owners lack sufficient legal backing, even otherwise honest people may cheat the system. There is also the possibility of a substantial amount of paid-for but unused time at metered spaces being appropriated by subsequent parkers. Nevertheless, honor system parking accounts for a very high percentage of all-day parking. Most authorities believe its use is growing nationwide.

Gated Access Self-Park Operations

The parking gate keeps unauthorized users out and authorized users in until they have paid the appropriate fee. The parker can be charged based on actual length of stay, rather than an estimate made at the time of arrival. In general, gated systems are more expensive to operate but yield more parking revenue than non-gated systems.

Gated access operations involve a means of collecting a parking fee and/or recognizing that the parker is pre-paid or otherwise authorized to use the parking space. Most gated parking is cashier-attended. Unattended gated operation also is common, requiring the patron to use coded cards, keys, coins or tokens to open gates. Most modern gate operations are automated to some extent and provide various degrees of revenue control with means to compare revenues with other measures of parking activity — providing an "audit trail." Since parking is largely a cash business, the audit trail is an important revenue control feature to monitor employee and patron honesty, as well as to provide documented records.

There are three methods of cashiering: (1) exit cashiering — free entry, pay on exiting; (2) central cashiering — free entry, pay before exiting or prepay (free entry, free exit); and (3) entrance cashiering — pay on entry, free exit. Exit cashiering is most commonly used in self-park operations. Central cashiering may be suitable for self-park operations when parkers must return to the parking facility over a common path. Entrance cashiering is most suitable for collecting a flat fee.

Exit Cashiering. This cashiering method requires parkers to take a time-coded ticket upon entering, either from an automatic dispenser or an attendant to open the entrance gate. This ticket is then surrendered upon leaving to the cashier for payment calculation and fee collection before the exit gate is opened. Exit cashiering is typically more labor intensive than central cashiering and in most applications of entrance cashiering; however, it is often the only practical method to provide patron convenience.

Central Cashiering. There are two variations of central cashiering. The pay-before-exiting variation requires parkers to return to a central location (usually in the parking facility itself) to pay a parking fee before proceeding to their parked vehicle. In receipt of payment the parker receives a token or time-coded ticket that is used to activate the exit gate. Like exit cashiering, a time-coded ticket is received upon entering and charges are varied according to time parked. If a flat rate is charged, entrance ticketing and gating are unnecessary.

The second variation of central cashiering involves prepayment for a block of parking time. The pre-paid parker is given a receipt or some other form of proof-of-payment that is recognized for entry and exit. Prepayment also can be used in conjunction with other methods of cashiering.

Entrance Cashiering. This method requires the patron to pay the full parking charge upon entry, and allows the patron to exit without further transaction. Entrance cashiering is used to collect a flat parking fee. It is frequently used to collect fees for parking serving special event or recreational attractions and, in some cases, for spaces serving all-day or long-term parking. Usually, attendants collect the parking fee to speed entering traffic, reducing reservoir back-ups; however, coin/currency machines can be used. A serious disadvantage of entrance cashiering is that it requires a large entrance reservoir area to handle surges in vehicle arrivals.

Attendant-Park Operations

Attendant-park operations are labor intensive but enable more vehicles to be parked in a given space. This operating method may be justified when the gain in additional parking capacity produces sufficient additional revenue to offset the higher labor costs. It also may be justified for garages that cannot provide generous enough parking dimensions to make self-park operations feasible, or where mechanical devices are used to store parked vehicles. Normally, attendant parking is found where land values and parking demands are very high, and patrons are accustomed to paying for parking.

Entrance problems can be severe with attendant-park operation, since a change in vehicle drivers is required. During peak periods, traffic backups and delays can result if reservoir space is inadequate and/or if there are not enough parking attendants on duty. The entrance reservoir absorbs peak inbound movements when vehicles arrive at a rate greater than that at which attendants can store them. From an operating standpoint, it is the most important area in the attendant-park facility.

The number of attendants, the time needed to move each vehicle to the storage levels, and the size of reservoir space are closely related. The rate of storage varies directly with the number of attendants and inversely with the time to store each vehicle. More explicitly, the rate of storage per hour equals the number of attendants times sixty, divided by the time in minutes required for an attendant to make a round trip (driving a vehicle to the storage space and returning).

On average, the rate of storage must equal or exceed the rate of vehicle arrivals during the peak period. Reservoir space takes care of spurts that exceed the average arrival rate, and stores accumulated vehicles when attendants fall below their storage average. An inadequate reservoir can be partly compensated for by additional attendants, while a large reservoir will allow employment of fewer attendants. When an attendant-park facility is filled, the reservoir space also should be full since this area is valuable and usable for parking.

Vehicle Ticketing Procedure. Arriving patrons leave their vehicles in the entrance reservoir space and are given a claim check stamped with the arrival time. An attendant then attaches a second part of the ticket (vehicle identification stub) to the vehicle. This stub contains only the ticket serial number, printed in large enough type to be read at a distance of about 15 feet. An attendant moves the vehicle to storage, and a third ticket part (office stub) is retained by the central cashier. The vehicle storage location is usually noted on the office stub, but in some operations a fourth ticket part is attached to the office stub until the customer calls for the vehicle, at which time it is detached and placed in a rack to signify that the vehicle is wanted. The location stub contains the identification number and any other information necessary to locate the parked vehicle.

The operator of a parked vehicle must surrender the claim check when returning for the vehicle. The claim check is then stamped with the departure time and the fee is computed and paid. After delivering the vehicle to its operator, the attendant removes the vehicle identification stub from the vehicle and gives it to the cashier, who staples all parts of the ticket together as a completed transaction.

Some operations use a fifth ticket part (release stub) that is given to the customer after the parking fee has been paid as a temporary receipt to identify the customer with the right vehicle at delivery. If the vehicle is not delivered promptly, the release stub also gives the customer the identification number of the parked vehicle in asking for a recheck. Release stubs are collected at the exit to ensure against vehicle theft.

Vehicle Handling Procedures. Detailed procedures are developed for vehicle handling based on experience, physical design of the parking facility, and patronage characteristics. Vehicles are removed from reservoir space to storage areas in an orderly manner so that attendants can move without confusion to the next vehicle to be parked. It is customary to empty the reservoir space one lane at a time, in rotation. This allows maximum use of reservoir space and gives customers time to unload.

General rules of right-of-way within the parking facility are established to help prevent accidents and speed vehicle handling. The placement of vehicles may be left to the judgement of attendants or controlled by the manager through premarked tickets. Vehicles known to be stored for long periods or all day are placed in rear rows of stacked parking, or in stalls that are difficult to access. This leaves the most accessible stalls for shorter term, higher turnover parking.

Valet Parking

While valet parking is a unique method of operation, it is similar in many respects to attendant-park operation. Like attendant-park operations, valets park customers' vehicles, saving customers time and effort. Unlike attendant-park operations, valet parking picks up and delivers the customer's vehicle at the entrance of the customer's destination. Valet parking is usually paid for differently, often performed on a temporary basis, and usually has more flexibility for providing customized service. Valet parking is often operated as an auxiliary service, supplementing another method of parking. Valet parking provides the highest level of customer convenience possible. Customers arriving at the entrance of their destination turn their vehicle over to a valet for parking; the valet brings the vehicle back to the customer's entrance when requested by the customer.

Valet parking is provided for two reasons — convenience and/or to help offset a parking deficiency. It is used when image and reputation require the highest degree of parking convenience to help attract patronage to a traffic generator. Some restaurants, clubs, hotels, and upscale retail establishments rely on valet parking to provide some or all of their parking. Valet parking is available at some major airports and a small but growing number of hospitals. Valet parking is also used to help offset the lack of nearby convenient parking.

A parking generator may provide its own valets or contract with a valet parking service provider. Under contract arrangements, the valet parking service typically charges the traffic generator a flat fee. In some cases, the service provider also charges customers a minimum service charge. Widely differing payment arrangements are possible through negotiation. Usually, customers are expected to tip the valet handling their vehicle.

Operating procedures vary. Similar to attendant-park operations, valet parking must consider distance of parking space from pickup/delivery point and demand characteristics to determine how many valets are necessary. Revenues and parking space access control, may also be concerns to the valet parking operator, as is insurance coverage and projecting a professional image.

REVENUE CONTROL

Revenue control is an important concern whenever operations involve parking fee transactions. Honor systems depend on high visibility checking and enforcement to encourage patrons to make proper payment and use of space. Other types of operations use gates and/or attendants to discourage patrons from cheating the system. Parking facility employees also must be discouraged from cheating the system.

The primary purpose of revenue control is to help assure that the correct amount of monies are collected and retained. Revenue control also facilitates record keeping for purpose of taxation, management contract provisions and assessment of operations. Some or all of the following may be revenue control concerns, depending on circumstances and what the parking facility owner/operator wants: Controlling cash revenues, detecting theft by employees, detecting fraud by customers, minimizing transaction errors, and providing activity counts for auditing purposes. Revenue control must also encourage efficient operations by minimizing labor needs and traffic delays, and maximizing revenue generation.

Honor System

Sealed and unsealed coin boxes are available for parking meters. The unsealed coin box can be opened and emptied directly by the service attendant. With sealed box systems the box is removed, replaced by an empty box, and opened later under more secure circumstances. Portable collection units are available that accept contents of the sealed box, keyed so that the contents cannot be removed while being emptied into the collection unit. The attendant then replaces the emptied coin box in the meter. This prevents attendant access to money and eliminates need for additional meter coin boxes.

Aside from possible loss during the attendant collection process, there are several potential revenue control problems associated with most metered operations. Coin/currency box capacity is limited and, for higher turnover parking, this may mean boxes have to be emptied on a frequent basis — perhaps more than once each day. Under circumstances of unattended operation, meters/currency boxes may invite thieves. There also is inherent possibility of a substantial amount of paid-for but unused time at metered spaces being appropriated by subsequent parkers. Other than what operating experience shows as typical amounts of revenue collected, a box or meter system usually cannot automatically provide accurate information relating to number of parkers served, turnover and spaces available at any given time.

Gated Systems

Revenue control with gated systems varies depending on the degree of automation used. The simplest systems use a cashier and manually operated gate, which may provide virtually no revenue control or audit trail for record keeping. Most gated systems are automated to some extent to help provide an audit trail, as well as to reduce labor and errors. Computerization is used for larger or multiple parking facilities and to provide a higher level of automation.

Basic Automated Gate Systems. Basic automated gate systems use ticket dispensers with pavement loop detectors to electrically open and close gates. On entry, a loop detector senses the presence of a vehicle and causes the ticket dispenser to extend a time stamped, sequentially numbered ticket to the driver/parker. When the driver removes the ticket from the dispenser the entry gate receives an electrical signal to open. The vehicle enters through the open gate and crosses a second loop detector that signals the gate to close.

Upon leaving, the parker pays a parking fee based on time parked to a cashier. The cashier inserts the ticket received from the exiting parker into a ticket-printing time clock, then calculates the fee owed and processes the transaction using a standard cash register. If exit cashiering is used, the cashier activates the exit gate after completion of the parking fee transaction to allow the vehicle to leave. If central cashiering is used, the parker is given a token to insert at the exit gate to open the gate, or an attendant stationed at the exit collects some proof-of-payment before allowing parkers to leave.

Revenue control for the basic automated gate system consists of the cash register journal tape, the serial numbered and time stamped tickets collected from the parker and unused numbered tickets left in the locked dispenser. Auditing requires substantial time, and cashier errors can easily be made in computing the parking fee and/or entering the transaction on the cash register. The system is relatively easy for employees to cheat and labor intensive to monitor.

The basic system can be upgraded in various configurations to provide a better audit trail, reduce labor and speed traffic operations. An automatic vehicle counter added to the system can provide additional audit comparison information and indicate parking space available at any given time. For prepaid contract parkers, gate opening can be activated by a card reader device. Some magnetically coded card system incorporate anti-passback controls to assure that more than one vehicle cannot be parked at the same time using the same card. Provisions are available to record times cards which are used to facilitate auditing. Some card systems also provide non-computerized means to prevent access after the card has expired or authorization has been withdrawn to use the parking facility.

Further automation upgrades use basic computer logic in some components, yet they are not considered computerized systems. Ticket dispenser arming loops (pavement imbedded loop detectors used to activate the ticket dispenser) are an example. Because it is possible to activate a simple loop with a metal object such as a trash can, employees or patrons could obtain tickets fraudulently. To reduce this possibility, two pavement loop detectors can be placed in the lane prior to the gate. The loops are coupled with a directional and sequential logic system. If a ticket is taken fraudulently or a vehicle enters and takes a ticket then backs out, the barrier gate will respond to block access and an alarm will sound. Proper action can then be taken to prevent honoring the fraudulently obtained ticket.

An entry barrier gate counter can be used to count vehicles that have entered the parking facility. This type of counter is activated by the gate closing loop to prevent counting vehicles that approach the entry gate then backout without actually entering.

At cashier stations a time clock is used to print the exit time for vehicles leaving the facility. Clock controls are locked to prevent unauthorized access. Cash registers can provide a variety of features. Minimum features include a journal tape, a printout mechanism for the customer receipt, and a cash drawer. The journal tape provides a record of transactions, giving date, sequence number, dollar amount, register number and/or cashier codes — information that should not be resetable by the cashier. The cash register printer is necessary to issue a receipt either automatically or on call. Information should include date, sequence number, register number and/or cashier code, as well as the parking facility's name.

Computerized Gate Systems. The fee computer cash register brings revenue control for the basic automated gate systems to a much higher level of control. Fee computers provide summaries of activity, report transactions by type, reconcile cash that should be in the drawer, and identify exceptional transactions, such as lost tickets. Fees are calculated by entering the "in" time and any validations. The parking fee is automatically calculated and displayed to the parker. For exit cashiering, one fee computer is needed for each exit lane cashier station.

Fee computers are available that machine read tickets, reducing cashier error and much of the manual ticket auditing. Using central cashiering, the patron can use a machine-read ticket to exit the parking facility. Automated central cashiering is available that reads the patrons parking ticket, indicates the fee owed, and issues an exit ticket when the patron deposits the proper amount of payment. Machines that accept credit card payment are in limited use, but are expected to expand in popularity as the credit card and banking industries develop a nationwide system of extending on-line credit for all popular cards.

Numerous other devices are available to automate gated access operations. Controllers/monitors are available to monitor access lane activity, report equipment malfunctions and service needs such as a ticket dispenser running out of tickets. Intercoms and CCTV monitoring of entry/exit lanes can be used to communicate with patrons experiencing access problems and to facilitate revenue control. Some parking facilities use CCTV monitoring to assist in recording license plate numbers of entering vehicles. The license plate number can be tracked automatically to determine time parked for patrons who have lost their ticket or attempt to use an illegally acquired ticket indicating a shorter parking duration. License plate reading systems can eliminate paper tickets entirely if the license plate of every vehicle is read at entry and again at exit. The fee computer can check its memory for the entry time and calculate the fee or confirm authorization as a prepaid contract parker. A major shortcoming of camera-read systems is the long processing time compared to other methods.

A single parking facility or a system of two or more facilities can be placed on-line with a central computer to provide control/monitoring from a central location. The computer can reduce the amount of personnel time required to generate various management reports. The computer can monitor access lane activity, parking space usage, equipment performance and exceptional transactions. This information can be used to identify trends, and forecast facility utilization and revenues, as well as for auditing/revenue control purposes.

In general, a good fee computer system, and/or a programmable or on-line card system may be appropriate for many parking facilities. Owners who are particularly interested in monitoring activity closely and will use the voluminous reports that can be generated, may be interested in having an activity-monitoring computer in an individual facility. This system, however, may be most cost effective to those who own or operate a number of parking facilities.

How much to spend on a fee computer and monitoring system is another consideration. In facilities with relatively low revenues, the system is usually designed to keep unauthorized users out more than to retain revenues. A basic second-generation system will usually run $30,000 to $50,000 (installed 1990), depending on the number of lanes. Upgrades to the system can easily push the cost to $100,000 or more. When a facility or group of facilities has annual revenues exceeding $1,000,000, an investment in a computerized system equal to 10 percent of the annual revenues has been found to be appropriate.[29]

Auditing Control Procedures. Auditing for a gated system involves comparing time parked (space usage) with revenues collected. It requires a means to count all entering and exiting vehicles, identifying the amount of time parked and fee collected from each parker. It also requires a means to identify each transaction with the cashier responsible for performing the transaction.

A ticket-printing time clock is indispensible to accurate audit control in garage operations. Multiple entrances and exits should be controlled by a master clock system to assure that parkers are timed on exactly the same time base when entering and leaving. The clock works should be tamper-proof. The access key should be controlled by a person that is not involved in collecting parking charges.

It is not practical to audit every ticket; however, periodic checks should be made. A commonly used checking method involves checking all transactions for an entire day that is selected randomly. The frequency of ticket audits should be a management decision.

For an audit period, each ticket should be checked for elapsed time and applied charges. Total calculated receipts can be checked against reported receipts and receipt patterns for compa-

[29]Anthony P. Chrest, Mary S. Smith and Sam Bhuyan, *Parking Structures: Planning, Design, Construction, Maintenance, and Repair* (New York, NY: Van Nostrand Reinhold, 1989).

rable days. Each ticket should be checked for the correct charge calculation shown on the ticket face as a cash register transaction.

To ensure proper audit control, randomly timed parking facility inspections should be made. The sequence of tickets in use and those stored should be checked, including time clock operation. Overcharging patrons for parking can be prevented by having an illuminated sign connected to the cash register to display the total charge in full view of the motorist.

Both primary and secondary audits of tickets, shift reports and daily reports are essential for effective cash control. The primary audit is usually performed at the parking facility either by a supervisor or a clerk. The secondary audit is usually performed in the central (or regional) office of the parking operator. A third audit may be performed by an independent accounting group checking an agency's records.

1. *Lost Parking Tickets.* When a customer loses the parking ticket, it is impossible to determine the exact charges to be made. The customary practice is to accept the customer's word on the time the parking facility was entered. In such cases, the cashier should use a blank ticket, marking it "lost ticket," and register it in the same manner as a normal ticket. Repeated lost-ticket problems by the same person should be called to the attention of the garage manager who is responsible for discussing the problem with the customer and taking proper administrative action.

2. *Voiding Parking Tickets.* All parking tickets should be subject to audit, and no parking ticket should be destroyed. The garage manager or assistant manager should be the only person having authority to void a parking ticket, and should signify that a ticket is void by signing it. The serial numbers of void tickets should be recorded on the daily record sheet.

3. *Cash Control.* Normal operating procedure is to issue each cashier a cash drawer containing a specified sum. The garage manager is responsible for determining and recording the cash amount. Cashiers are responsible for their own cash drawer when going on and off duty.

4. *Cashier Shift Changes.* At a shift change, the oncoming cashier should record the beginning ticket number at each ticket spitter. The outgoing cashier should be informed of these numbers in order to be able to record the ending ticket number for each shift ending, which is one ticket number lower than the beginning ticket number for the next shift.

PARKING FEES

Parking fees are tailored to a facility's demand potential. Rates should depend on (1) what parkers will pay, (2) operating and development costs, and (3) public policy. In all cities, central business district parking rates are highest near core areas, where land-use intensity and assessed land values are highest. Airport and hospital parking fees often are high relative to central business district parking because there is less sensitivity to price — the price elasticity is lower.

Parking fees can be set on an hourly, all-day, weekly, and/or monthly basis. Hourly rates are set to satisfy the requirements of short-term parkers, while rates based on longer periods of time satisfy regular and occasional customers with longer parking durations.

In high parking turnover situations, some operators consider a proper parking rate to be one that does not keep the facility 100 percent full. Private operators, seeking maximum income, suggest that an 85 percent occupancy is desirable. Many believe that with substantially higher use of available capacity, potential customers can become discouraged, thinking the facility has filled, a situation particularly true for lots, since parked vehicles there are usually more visible than those parked in garages. From an economic viewpoint, a facility constantly filled above 85 percent would indicate to these operators that the rates are too low — and usage less than 85 percent during peak periods would suggest that the rates are too high.

Since parking garages are usually situated in a competitive area with an established rate schedule, prevailing rates must be taken into account to establish or change a schedule of charges.

Contract Parking

Contract parkers make an agreement with a particular parking facility to pre-pay for parking on a monthly or weekly basis. By doing so, they are guaranteed a parking space, usually at a lower cost than if paid for at the normal daily rates. Contract parking is sometimes called monthly or permit parking. It is common practice to oversell contract spaces, knowing that not all of the contract parkers will be parked at any given time.

Several methods are used to process contract parkers in self-park garages serving both monthly and transient parkers. Bumper or window stickers are used with some processing methods to visually identify contract parkers. The stickers are nontransferable and, once affixed to a vehicle, cannot be removed without destroying the sticker. This also prevents substitution of vehicles.

In garages having ticket-type operations, one of two methods is generally used to process contract parkers. With the first method, the contract parker takes a ticket on entering the facility. The ticket is given to the cashier in lieu of cash, with the customer's signature and contract account number. The second method does not require the parker to take a ticket. Variations are numerous, ranging from an attendant on duty who identifies and records the entry of contract parkers to mechanized automated systems that use magnetic card readers. With the costs associated with parking, daily accountings should be made of contract parking. Monthly or contract rates commonly are set about 14 to 22 times the maximum daily charge.

Hourly and Daily Rates

Hourly rates normally are set at a high charge for the first 1 to 2 hours, and a lower charge for each succeeding hour. Many communities, however, have tried to set uniform hourly rates to encourage short-term parking. In a few cases (e.g., Madison, Wisconsin, and New Haven, Connecticut), there is an increase in hourly charges as the duration increases. Such rate structures, while consistent with transportation policy objectives, are not widespread among privately-owned facilities. It is more common practice to set a maximum daily rate at what would be charged for about 6 to 8 hours of parking.

Merchant Validation Programs

Merchant validation enables one or more businesses to pay all or a portion of the parking fees incurred by their customers at designated parking facilities. Validation agreements, sometimes called "park and shop" programs, permit a customer of a participating business to receive a validation slip or token when purchases of a specified minimum amount are made. This is redeemed for parking time at a participating parking facility.

Local merchants and professionals offering a product or a service usually group together to financially support a validation program. The "free" parking provided to this group's customers, and the associated advertising of the program, is paid for from membership dues and from profits that accrue to individual members as a result of offering parking validation to attract increased patronage.

The participating merchant purchases validation stamps or tokens from the merchant's association or group. Each stamp is worth a specified amount of parking time at a participating facility. In some cases, merchants give a customer one or more stamps, based on the dollar amount of the customer's purchases. In other cases, merchants provide only one validation for a specific amount of time, regardless of the dollar amount involved in the purchase above a minimum.

At the end of each month, the parking operator sends the validated tickets that have been collected to the sponsoring group for payment of validated parking. In most instances the merchants' group is able to negotiate with a parking facility for a lower parking fee than would otherwise be charged.

The concept of "park and shop" dates back to Oakland, California's Downtown Merchants Parking Association that was formed in 1929. Allentown, Pennsylvania's "park and shop" plan was a successful early arrangement that was copied in other communities. Of 106 garages surveyed by the Eno Foundation in 1975, 66 participated in a validation program.

Validation programs have declined in popularity in recent years. Contributing factors are the complexity and costs associated with maintaining the program, the need for ongoing promotion, and the provision of parking (sometimes free) by many merchants.

1. The success of a validation program closely depends on the amount of promotion given the "free" parking aspects to attract larger volumes of retail customers and clients of professional services, and thus, parkers.

Program promotion mainly has been the responsibility of the merchant's organization and its individual members. Participating parking operators usually are not required to be members of the organization and, therefore, do not normally contribute financially to the program's support except for reduced rates — which can be a substantial expense to the garage or lot operator, particularly if the program does not increase parking volumes. Some parking operators have found that after granting lower rates for a validated parking program, it is difficult to adjust parking rates at a future date.

2. Control of validation stamps has presented other problems, such as customers removing extra validation stamps from their parking ticket to use at another time. Some garages have found that employees remove extra validation stamps as parking tickets are received. These stamps are saved until a cash customer pays for parking. The employee is then in a position to pocket the cash and affix the saved validation stamp to the ticket, thereby satisfying the accounting controls.

Customer and employee abuses of validation stamps can be eliminated to a large degree by changing stamp colors regularly and by using special pressure-sensitive stamps that are nearly impossible to remove after being affixed. Franking machines that mark tickets are also used in lieu of stamps. This system generally is considered more costly for the merchant, but has been used successfully in high-volume situations. A validation program is also possible with metered parking where parking meters accept tokens as well as coins.

OPERATING COSTS

Parking garage and lot operating costs vary by method of operation, facility size and type, management, and in some cases, by geographic area. Other factors influencing operating costs include parking characteristics, utility costs, and security requirements. The age and condition of a facility influence maintenance requirements and costs. Major garage repairs increasingly are treated as a capital cost item.

Cost Elements

Parking garage and lot operating costs, include personnel payroll (including labor, benefits, and sometimes administration) utilities, housekeeping maintenance, insurance, and miscellaneous items. Each is influenced by characteristics of the facility, policies of the operators, and the environment where the facility is located.

Accounting and bookkeeping procedures followed by owners and operators can produce a wide variation in apparent costs. This is partially true for items charged as miscellaneous and administrative expenses.

Personnel Requirements and Costs. Manpower requirements must be geared to the magnitude and peaking characteristics of each facility's parking demand. High turnover/short duration parking generates more activity and, consequently, more intensive labor input than facilities that mainly serve all-day or contract parkers.

Personnel required to operate a garage or lot may include a manager, assistant manager, attendants, cashiers, maintenance, security, secretarial, and bookkeeping personnel. Duties of individual employees generally vary and may include responsibility for covering more than one position, depending on demand and operational characteristics of the parking facility. This is frequently the case in smaller garages where labor costs are often reduced by judicious scheduling of work assignments and reliance on the ability of personnel to perform several different job functions.

1. *Manager*. The manager supervises the entire garage or lot operation and is responsible for promoting the facility. He also is responsible for personnel training and job performance, and must anticipate periods of heavy or unusual demand to have sufficient personnel available. The manager is usually the person who must deal with the public concerning accidents, complaints, or other circumstances involving customer convenience, safety, and satisfaction. Managers must often perform the functions of other employees to assist in peak periods.

2. *Assistant Manager*. The assistant manager generally has the same responsibilities as the manager for a particular work shift.

3. *Attendants*. Duties of parking attendants

depend on garage or lot design and operating method. In self-park facilities they may be required to issue or collect tickets or parking charges, direct traffic and, in some instances, provide assistance in parking-unparking. In attendant-park operations, they handle vehicles.

4. *Other Personnel.* Cashiers are responsible for calculating and collecting parking charges. As a revenue control safeguard, they rarely double as the bookkeeper. The secretarial and bookkeeping functions, however, are often the combined responsibility of one individual not involved in parking fee collection.

Security and maintenance duties are routinely handled by attendants. Municipal police personnel, paid by the city, commonly provide regular security patrols in municipally operated facilities — an expense not typically shown as an operating cost. Some cities have agreed to extend police patrols on a regular basis to privately-operated parking facilities, and at no additional expense to the operator.

5. *Employee Uniforms.* Uniforms provide a means of identification and easy recognition of personnel for security and customer convenience, while assuring a higher level of employee appearance. They also advertise the parking facility, and they may contribute to better employee moral and relations.

Garage operators usually provide employee uniforms and are responsible for cleaning uniforms. Many garages have found it more satisfactory to rent uniforms, with laundry service provided. As an incentive for employees to take care of uniforms, they are sometimes required to pay a portion of uniform expenses.

Utility Costs. Utility costs include electricity, heat, and water. The principal utility cost is the electricity used for lighting and powering equipment. Parking structures usually require lighting throughout the day in addition to evening hours. Underground garages typically have higher electrical needs than above-ground structures, since they usually require more lighting fixtures and a ventilation system. Water usage, heating of the manager's office, cashier booths, restrooms, and enclosed pedestrian walkways, generally are not a significant portion of operating costs.

Maintenance Costs. Maintenance costs, especially costs for major structural repairs, traditionally have been underestimated. This has led to deterioration and even structural failure of many facilities. Therefore, it is essential that ample funds be budgeted for "major" repairs — either through an annual operating budget, a special depreciation fund, or as a special capital cost item.

Insurance Costs. Insurance costs vary widely. Some cities self-insure their parking facilities while others carry either basic comprehensive liability or a complete program of insurance coverage. Some insure on full replacement value, others only on the cost of the outstanding debt service. A comprehensive insurance program may include, comprehensive liability, garagekeeper's legal liability, workmen's compensation insurance, coverage against loss of money or securities, special equipment coverage, and fire and extended coverage. Comprehensive insurance programs also may include insurance coverage against rent and business interruption.

1. *Comprehensive Liability.* This type of policy usually is written on an annual basis. It provides coverage for accidents involving injuries to persons other than employees, and damage to property of others arising out of the facility's use. Liability always is limited to a specific dollar amount per person, per accident for bodily injury, and per accident for property damage.

Special endorsements can be written to extend coverage or liability limits. Pedestrian elevators, for instance, are usually covered by a special endorsement.

2. *Garagekeeper's Legal Liability.* This is the garagekeeper's basic coverage for damage to customer's automobiles in the garage's custody when caused by fire, theft, riot, malicious mischief, or vandalism. It supplements the comprehensive liability and is written on an annual basis.

3. *Workmen's Compensation Insurance.* The annual policy under state workmen's compensation laws provides specific benefits for injuries to employees during the course of their employment.

4. *Equipment Coverage.* This type of policy provides coverage for stated machinery, such as elevators. Liability is always limited to specific amounts. and inspection services are often included as part of the coverage. Policies are typi-

cally written for 3 years.

5. *Money and Security.* This type of policy covers loss of money by holdup, robbery, theft, and mysterious disappearance from the premises, and losses occurring off the premises when money is in the custody of an authorized agent. It is commonly written on a 3-year basis.

6. *Blanket Honesty Insurance.* This coverage provides replacement of losses resulting from employee dishonesty, up to a specified amount. It is written on a 1- to 3-year basis.

7. *Fire and Extended Coverage.* This covers the garage or lot structures against risks of fire. Special endorsements are commonly used to extend the coverage to practically an all-risk basis. Policies are typically written for 3 to 5 years.

8. *Rents and Business Interruption.* This insurance policy provides the equivalent of up to one year's net income during business interruption. Such coverage is written for 3 to 5 years.

Miscellaneous Operating Costs. These costs include a variety of operating expenses, depending on the method of accounting. Cost items include uninsured damages, depreciation of equipment, office supplies, parking ticket printing, telephone, employee uniforms, auditing fees, legal counsel and taxes.

Operating Cost Experience

Operating cost information assembled from various parking agencies is summarized in Table 10-1. These representative cost distributions indicate that personnel costs typically account for about 50 to 60 percent of total operating costs. The remaining operating expenses include utilities, routine preventive maintenance, insurance, supplies and administrative/contractual costs, and miscellaneous cost items such as telephone and equipment maintenance contracts.

Cost Ranges. Operating costs for a parking garage open to the general public 168 hours per week with cashiers for collecting fees averaged about $600 per space per year (at 1989 levels). Table 10-2 gives an illustrative operating cost breakdown, assuming an overall cost of $600 per space per year. Some $360, about 60 percent of the total, is for payroll, while about $240 per space per year are for other cost items.

Actual personnel costs are the most variable of all operating expenses, while other cost items remain relatively constant. Personnel costs depend on facility size, design, number of access points, type of cashiering used (if any), and operating hours. They also depend on whether garage personnel are unionized, and the general cost of living in the area; larger cities generally experience the highest wage rates. The high personnel costs is why garages and lots usually are designed for self-parking. Automation can reduce, but not eliminate labor costs.

Operating costs are highly variable. The best information source is a similar existing operation in the same market area. Generally, annual non-personnel operating costs for a parking garage range between $1.32 and $1.54 per space times weekly hours of operation (1989 dollars). The most significant influence on this cost range is electrical usage and housekeeping/routine maintenance requirements. This cost range excludes major maintenance and replacement expenses, as well as administrative costs.

Table 10-3 gives illustrative examples of the building block approach to cost estimation. It also highlights the need to avoid very small parking garages because of the high labor costs involved. This is an important consideration when planning new facilities.

Self-Park vs. Attendant-Park Costs. The substantially small number of persons required to operate a self-park facility represents a significant savings in labor costs when compared to attendant-parking operations. Studies of 50 garages by the Eno Foundation in 1978 found that personnel costs in attendant-park garages were 40 percent more than self-park garages with cashiers. Conversely, self-parking in metered spaces (without cashiers) resulted in personnel costs about 23 percent less.

Comparative labor costs for garages owned by the same city show even more striking differences in labor costs (see Table 10-4). The attendant-park garage had 2.5 times the labor cost of the two self-parking facilities.

MAINTENANCE

Proper maintenance of garages and lots is essential. A good maintenance program protects

Table 10-1. Illustrative Distribution of Annual Operating Costs
(Garages Open to Public)

	Percent Distribution		
Item	*37 Garages 1974*	*Mid-Atlantic City 2300 spaces (mainly garage) 1981-2*	*New England City 4100 spaces Mainly Garage 1981-2*
Payroll	NA	43	44
Fringe benefits	NA	10	6
Subtotal	51	53	50
Security	NA	—	7
Utilities	21	13	15
Maintenance, material, supplies	19	9	4
Insurance	5	4	8
Contractural	-	8	3
Administrative & other	4	13	13
Total	100	100	100

Source: Wilbur Smith and Associates in association with Herbert S. Levinson, D. Baugh Associates, Gruen Associates and Shearson/American Express, *Parking Policy and Program Downtown New Haven Traffic and Parking Study*; Robert A. Weant, *Parking Garage Planning and Operation* (Westport, CT: Eno Foundation, 1978).

NA = Not available

the investment, makes the facility pleasant and safe to use, and can produce savings over the long run. This program should be clearly defined, carefully scheduled, incorporated into the annual budget, and carefully monitored.

The amount of maintenance that is needed depends on the age of the facility and equipment, usage, and climatic conditions. Heavy snowfalls and frequent freezing weather increases maintenance requirements. Maintenance costs usually are lower during the early years of an operation because both the structure and equipment are new. As the facility ages, higher maintenance costs can be expected and should be included in operating budgets.

Preventive maintenance is generally more cost-effective than repair maintenance. Where parking facilities are owned by one party and operated by a second party, the maintenance responsibilities of owner and manager should be clearly defined.

Maintenance normally includes "housekeeping" activities such as sweeping, cleaning windows, removing snow, repainting stall markings, and replacing light fixtures. It also includes the servicing of equipment. Equally important, and often overlooked, is maintaining the basic concrete and steel structural system in multi-level garages. Too many garages have deferred needed maintenance — a situation that leads to premature deterioration and the infusion of large sums of money to keep them functioning.[30]

Maintenance activities can be grouped into three categories: housekeeping (including snow removal) or "routine" maintenance, equipment maintenance, and structural system maintenance. Routine maintenance is normally carried out by garage personnel as part of other duties.

[30] See, Parking Consultants Council, *Recommended Parking Garage Maintenance Provisions* (Washington, DC: National Parking Association, 1990) for specific guidance on maintenance needs and frequencies.

Table 10-2. Illustrative Annual Garage Operating Costs per Space[a] (1989)

Item	*Percent of Operating Costs*	*Cost/Space*
Payroll (includes fringe benefits, security patrols, and training program)	60%	$ 360
Utilities	15%	90
Maintenance (day-to-day housekeeping, routine preventive maintenance, and equipment service contracts)	10%	60
Insurance	5%	30
Supplies	3%	18
Miscellaneous	2%	12
Administrative	5%	30
Total	100%	$ 600

a. Assumes 168-hour per week operation and cashier collection of parking

However, in large garages, or where several facilities are operated by the same management, there may be enough work for a full-time maintenance crew. Maintenance of equipment and major structural repairs usually require outside expertise. Service contracts commonly cover elevators, cash registers, computers, revenue controls, and office equipment.

Routine Maintenance

Cleaning and "housekeeping" is desirable to maintain the appearance and safety of a garage. The accumulation of dirt and debris are inescapable in garage operation; unless they are removed they can clog floor drains and produce water ponding.

Typical Housekeeping Tasks. Examples of housekeeping tasks include the following:

- sweeping and washing floors in the pedestrian and vehicular areas
- washing windows
- cleaning stairs, including handrails
- cleaning elevator cabs
- emptying trash cans
- picking up trash in landscaped areas
- maintaining landscaped areas
- cleaning signs
- removing grease drippings, or snow and ice
- replacing burned out light bulbs
- removing graffiti
- repainting parking stall stripes and other pavement markings

How often these tasks are performed depends on specific circumstances. Heavily used parking areas normally require more frequent attention than those receiving little use. Weekly or even daily sweeping is necessary to prevent trash buildups. If water connections are available, hosing down of floor and wall surfaces can be an effective cleaning means.

Floor drains must be kept free of sediment and debris. Picking up trash without sweeping has some benefit. Floors should be washed at least once a year. Where salt is used to melt snow and ice, or is present in the air, the washdown of floors should occur in the early spring.

While painting of interior wall surfaces can improve appearances, the paint requires periodic maintenance. Lighting fixtures and signs also require maintenance and should be designed and located for maximum replacement economy and servicing convenience.

Preventive Maintenance Actions. Broken surface areas and floor cracks should be patched promptly to prevent further deterioration and water dripping onto parked cars on lower parking levels.

Support columns frequently are located near parking stalls where they are occasionally contacted by vehicle bumpers. Columns and other structure appurtenances should be protected to a height of 2 feet 6 inches (0.76 meter) up from the floor by use of concrete encasement, guardrails, or steel plating.

Snow Removal. Snow removal may be accomplished by pushing it to the sides of the top level with a jeep or light truck equipped with a front-end plow. This method is not completely satisfactory for several reasons: (1) piles of snow may become large and eventually turn to ice, making them difficult to remove; (2) parking structures are usually not designed to sustain heavy concentrated loads likely to result with large snow piles;

Table 10-3. Example of Building Block Approach to Estimating Garage Operating Costs

	Example			
	I	*II*	*III*	*IV*
Facility Availability	*General Public*	*General Public*	*General Public*	*Restricted to Employees of Specific Office Building*
Number of spaces	300	600	900	600
hours of operation	84	84	84	84
Personnel required				
Manager	1	1	1	1
Cashiers (full-time)	1	2	2	0
Cashier (relief)	0[a]	1	1	0
Cashier (part-time)[b]	3	2	3	0
Maintenance personnel	1	1	1	1
Total personnel	6	7	8	2
Annual personnel costs $20,000/cashier $30,000/manager $17,500/maintenance 25% benefits	$122,125	$165,875	$173,875	$ 59,375
Personnel cost/space	$ 407	$ 277	$ 194	$ 99
Administrative cost/space[c]	$ 28	$ 21	$ 17	$ 11
Non-labor costs/space	$ 114	$ 118	$ 122	$ 111
Total cost/space	$ 549	$ 416	$ 333	$ 221
Total annual cost	$164,700	$249,600	$299,700	$132,600

a. Manager also serves as relief cashier.
b. These personnel receive no benefits package.
c. Administrative cost at 5% of total cost per space.

(3) periods of rapid thawing may overburden the drainage system, causing flooding; and (4) piling snow on parking levels may reduce parking capacity.

Snow accumulations may be dumped over the side of the structure when proper safety measures are observed. In addition to a snowplow, a front-end loader also is needed. If possible, the snow is piled and stored on the ground; otherwise, it must be carried away. Care should be taken that snow piling and heavier equipment operation (such as a front-end loader) are performed near a structure corner or as close as possible to column supports, to minimize chances of structural damage.

Snow melting pits may be justified in northern climates but are relatively expensive, particu-

Table 10-4. Comparative Labor Costs of Self-Park and Attendant-Parking Garages

Facility	*Type*	*Spaces*	*Relative Cost/Space Indices*
A	Integrated structure with department store (self-park)	800	1.0
B	Multi-level ramp, free-standing (self-park)	600	1.0
C	One-level underground (attendant park)	125	2.5
D	Multi-level mechanical (attendant park)	220	1.2

Source: Adapted from Table XV in Robert A. Weant, *Parking Garage Planning and Operation* (Westport, CT: Eno Foundation, 1978).

larly if they were not constructed with the original structure. A melting pit consists of a large pit, normally covered with a steel grate when snow is not being dumped into it. Melting pits usually have gas-fired burners to melt snow and drain it into the storm sewer system. They can be an effective means of removing snow from the top level of a garage; however, they require year-round maintenance.

Equipment Maintenance. The maintenance program should include preventive maintenance on all equipment to assure proper functioning. Equipment with moving parts usually should be inspected and lubricated at regular intervals. It is desirable to maintain a file containing the manufacturer's manual for operation and maintenance of each piece of equipment. The manufacturer's recommendation for operation and preventive maintenance should be followed. When an inspection indicates a piece of equipment is not functioning properly, it should be repaired or replaced immediately.

Equipment in a parking facility that requires regular inspections, lubrication, or other preventive maintenance includes, but is not limited to, the following:

- parking and revenue control equipment
- elevators, escalators, and manlifts
- electrical equipment including typical lights and emergency lights
- doors including hinges, closers, and latch sets
- mechanically operated doors
- security systems
- heating, ventilating, and air conditioning equipment
- carbon monoxide monitors
- sanitary facilities
- sump pumps
- fire protection system
- floor and roof drainage system

Some of these elements, such as a carbon monoxide monitor, should be checked for proper operation each day. Other equipment may need less frequent inspection or attention.

Most equipment is subject to corrosion, which can impair the function or life of the element. Accordingly, all inspections should include observations for corrosion. Where it is observed, the element should be cleaned and properly painted or protected.

Structural System Maintenance

The most common causes of deterioration in a parking structure are from freezing and thawing; corrosion of steel and other materials; and movement of the structure due to changes in temperature and other causes. These causes can interact and compound the rate of deterioration. Water is the causative agent in both freeze-thaw and corrosion damage. Cracks caused by movement of the structure often leak water that damages the structure and the finish on automobiles. Thus, maintenance of the structural system must not be neglected.

The structural maintenance management program should provide periodic inspection of the entire facility. This inspection should note areas of deterioration, water leakage, or corrosion of exposed metals. It should observe:

- top surface of all floors
- bottom of parking floors
- columns
- beams
- guardrails and handrails (to verify that they are rigid and safe)
- stairways
- walls
- connections and bearing pads in a precast concrete system
- wheelstops

When leaks, deteriorated concrete, corrosion of exposed metals, or other problems in the structural elements are noted, corrective measures should be taken immediately. Specific correctives will vary with the situation. A qualified engineer is necessary to identify problems and to recommend courses of action.

Parking Lot Maintenance

Cleaning is the principal element of parking lot maintenance. Markings and signs should be repainted as required for good visibility. Light fixtures should be cleaned at least annually or when lamps are replaced. Lamps should be replaced prior to burnout.

Snow removal in northern climates is an additional concern. Snow cannot simply be pushed into the streets; it must be removed by truck to a suitable dump site, stored in nearby areas or melted. Storing snow on the lot is doubly expensive in "pay" facilities, because the loss of revenue from spaces devoted to snow storage must be added to the cost of moving the snow. Melting has been successfully employed in some lots. Oil and gas-fired snow-melting equipment, both stationary and portable, is available.

Salt or other chemicals have been used extensively in some areas to lower the melting point of snow and ice and to facilitate subsequent runoff as water. These materials can harm unprotected concrete surfaces and may not be environmentally acceptable.

LEASE AGREEMENTS AND MANAGEMENT CONTRACTS

Many parking facilities are operated by people other than the owner. This is normally done through *lease agreements* or *management contracts*. The goals are to take advantage of the services of experienced parking operators and to relieve public agencies or private-businesses from the responsibilities of running parking facilities.

Lease Agreements

A lease is the conveyance of property by the owner to a second party, for the second party's use over a specified amount of time. In such arrangements, the owner is the lessor and the second party is the lessee. The lessor is compensated for the use of leased property by periodic payments from the lessee of rent and other value considerations.

When leasing a parking garage, the operator assumes all of the operating costs and pays the lessor a specified annual amount and/or percentage of the receipts. Historically, gross receipts have been the basis for a percentage payment; however, some parking garage lessors have agreed to various levels of net receipts. Normally, the operator (lessee) assumes all monetary risk in the successful operation of the parking lot or garage.

Long-term leases usually are avoided. A lease term of 3 years is a desirable maximum.

Management Contracts

A management contract is an agreement between a property owner and a second party for the second party to operate or manage the owner's property for a management fee. Typical management contracts provide that all gross income, less operating costs and management fee, be paid on a periodic basis (usually monthly) to the owner.

The owner, of course, has the decision on whether to lease or have a management contract. From the owner's viewpoint, a management contract is much more flexible than a lease, since in the management contract the operator's principal concern is providing the service that the owner wants. And if the owner is not satisfied with the service provided by the operator, it generally is possible to terminate the agreement without penalties associated with breaking leases.

Under contract management, the owner's responsibility for some or all operating costs can be a possible disadvantage. The owner may be responsible for paying associated operating costs but has little direct control over these expenses other than terminating the agreement.

Contract Management Provisions. Contract management provides for a private operator (usually a parking company) to act as an agent for a parking facility owner. Contract management can hold certain advantages for operators — primarily less economic risk. The operator can be guaranteed the management fee, regardless of possible unfavorable developments affecting the parking facility's success. The security offered by contract management may require the operator to settle for smaller profits, as well as possible termination at the owner's discretion. Management contracts should have a term of 1 to 3 years.

Decisions on such items as pay rates, equipment purchases, operating hours, and parking fee schedules are the right and responsibility of the owner. Parking fee monies and documents related to revenue are the property of the owner, and usually deposited in the owner's account at the end of each day.

The operator provides a qualified resident manager, and provides all other employees necessary in the actual operation of the facility. Under contract management, parking companies generally are the operators because they are in a position to support the resident manager with experts in pertinent areas of concern such as legal, insurance, and personnel. Housekeeping and simple maintenance are the responsibility of the contract operator, as well as accounting reports and audits to the owner. The contract operator is obligated to maintain liaison with the owner and to carry out the owner's instructions.

Management Fees. Management fees are negotiated between the owner and operator. They may include: (1) a percentage of the gross revenue derived from the parking operation; (2) a fixed monthly management fee; and (3) a fixed fee plus a percentage of the gross receipts that sometimes is limited to a maximum amount.

The incentive portion of the fee usually is a small portion of the total management fee. There are numerous options in determining the incentive portion, such as varying the percentage of the gross as the amount of the gross varies.

PERIODIC OPERATING ASSESSMENT

Changing conditions can affect parking facility performance. Gradual change or the sudden occurrence of various events can deteriorate or accelerate parking's operational performance. Typical occurrences include changes in access (introduction of a one-way street system, construction detours, and increased traffic congestion, as examples); changes in prime traffic generators or the introduction or elimination of competitive parking within the same area of influence; changes in regulation, public policy or taxation; changes in parking demand or user characteristics; the availability of new equipment, products, services and techniques that could affect operating costs and revenues; and changes in local parking rates. These are generally externally influenced occurrences over which the parking operator has little or no control yet must make an appropriate and timely response.

There also are many internal occurrences or changes that can affect parking, and the causes are sometimes difficult to identify and correct without special expertise. Internal changes include suspected breakdown in revenue control; parker abuses of available parking space; access and capacity problems within the parking facility; adverse parker perceptions of operations, security and safety; and increasing operating costs compared to revenues and historical trends.

Change creates opportunities as well as problems and, either way, the parking operator is placed under pressure to react. The appropriate reaction depends on how well the effects of changing conditions are anticipated and identified, and how well the parking operator is prepared to initiate action and what action is taken. Where change is affecting parking operation and performance, outside objectivity and knowledge of how others have addressed similar problems can be a most beneficial resource for the decision-maker.

Anticipating and Identifying Performance Changes

The person in charge of parking should know (or have available) accurate and current information on the number of existing spaces available, their location and operating characteristics and current operating costs and revenue trends. The purpose of gathering and monitoring this information is to have an accurate picture of the parking operation's vital signs: percent of utilization, characteristics of utilization, cash flow, income and expenses.

Monitoring Operating Characteristics. Change in operating characteristics is a good indicator of an approaching problem or opportunity. Percent utilization (the extent a facility is used) is a key operating characteristic to monitor. The practical capacity of a parking facility is usually less than 100 percent of the number of spaces provided, and will vary according to operating method and parking characteristics. For on-street spaces, practical capacity is seldom higher than 85 percent for spaces restricted to short-term parking (2 hours or less). For off-street parking facilities, practical capacity expectations for short-term parking of 85 to 90 percent may be reasonable, with a slightly higher percentage for long-term employee parking. Employee parking utilization is affected by vacations, sick leave, ridesharing and other factors. The more frequent the parking turnover, the lower the practical capacity because of increasing opportunity for traffic conflicts.

In a system of multiple parking facilities, individual parking facilities may not approach their practical capacity at the same time. The more convenient and first-to-fill facilities may exhibit use in excess of 100 percent, possibly indicating illegal parking. Other facilities in the system may be far below their practical capacity. It is essential that reasons for the imbalance be identified. This information can be an indicator of real or potential problems and helps to determine an appropriate response.

Change in the characteristics of parking utilization is another vital indicator. Two of the most common parking characteristics to monitor on a continuing basis are parking duration (average time a vehicle remains parked) and turnover (frequency that a space is turned over to another parker during a given operating period). This information enables the mix of short- and long-term parking to be monitored. How this mix of parking is accommodated is strategic to effective parking management and performance.

Monitoring Cash Flow. Whether or not a direct user charge is made for parking, there is cash flow involved in most parking operations. Beyond prudent accounting and record keeping requirements, monitoring cash flow for fluctuations can provide an early indication of parking facility or personnel performance problems, as well as providing a basis on which to measure the effect of actions taken to improve performance.

Cash flow monitoring begins by understanding the flow pattern of parking-related costs and revenues. This means knowing who and what the sources of financial support are, how costs are shared and revenues divided. For example, even though a parking authority is normally considered an autonomous agency, it is not unusual for a parking authority and its host city to share costs and revenues associated with its parking system. Cost and revenue sharing agreements also are common in privately developed and operated parking, as well as public-private parking ventures. The structure of these agreements and changing circumstances can affect financial performance.

The most visible function of cash flow monitoring is revenue control. Revenue control involves the physical configuration of the parking facility; procedures for handling cash and parking fee equivalents (tokens, validation, permit authorizations, etc.); supervisory and audit procedures; and revenue control equipment. Changing circumstances, including unlawful attempts to breech the revenue control system, can affect both financial and physical operating-performance.

Monitoring Revenues and Expenses. Continued monitoring of revenues and expenses on both a facility and system basis is essential. These financial performance audits will indicate where changes in rates and/or operating procedures are appropriate, and how costs can be contained. Parking revenues and expenses are highly variable between different facilities -- even between otherwise similar facilities within the same system. No two parking facilities have the same revenues or operating expenses, and the differences can be extreme. The revenue and expense characteristics for any given parking facility fluxuate on a pattern that should be very similar to prior operating cycles, adjusted for known changes in revenue parameters (changes in fee, operations, and/or host generator attraction) and unusual or extraordinary expenditures (major repair, equipment replacement, regulatory action, etc.).

Sudden and significant deviation of either revenues or costs may be a problem indication, and the cause is usually identified easily, if not anticipated. Causes for gradual change from the established pattern, in dollar amount and/or shape of pattern curves can be expected to some degree. Gradual change may result from many causes including: aging of facility (more maintenance); inflation in the economy, affecting wages, cost of services and purchases; and longevity pay/benefit increases to employees.

Actions to Correct or Improve Performance

Monitoring operating characteristics provides information necessary to identify problem causes and corrective actions. Depending on the problem, an appropriate response might involve an adjustment in operating hours and procedures, or modification of equipment and physical facility. It may involve increasing parking fee rates and/or subsidy payments received from benefited interests; or modifying agreements for sharing costs and expenses. It might require actions to optimize the parking operation's revenue producing potential and/or reduce its operating costs.

An appropriate solution may require outside action. This can involve increased enforcement and parking fines, new or redirected marketing efforts to improve revenue production, or management strategies to correct parking demand imbalances.

Causes of operating problems sometimes reflect a real or perceived need for more parking, and this typically creates pressure for developing new parking. There are many possible reasons why additional parking might be necessary. The decisionmaker will hear from those who believe additional parking is necessary to maintain or improve the competitive stance of the host attraction. Proponents will claim that new parking will be self-supporting from parking fees and/or additional revenues generated to the host land use. In many cases, there is so very little land available and priced at a premium that a parking garage appears to be the only alternative.

Certainly, these and other reasons and expectations may be valid. It is important, however, to anticipate the need for additional parking. The decisionmaker cannot wait until the additional parking is absolutely needed to start planning for new parking development. From the time study and definitive planning really begin, it typically requires at least 2 years or more to open a parking garage for business. Assessing the financial consequences of such actions is essential.

Guidelines for Maximizing Parking Performance

The value and necessity of maintaining historical and current performance data cannot be overstated. The data, however, is of little use beyond fiduciary accounting and budget forecasting requirements if it is not monitored periodically for performance change indications. Automated, computer directed equipment has eased the task of collecting and monitoring various parking data, but data analyses still require knowledgeable and experienced human input.

Properly Evaluate Equipment Needs, Performance and Replacement Options. Modern traffic and parking revenue control systems now depend to some degree on sophisticated mechanical and computerized equipment. Technical advances also have appeared in lighting, security and other specialized equipment and products used in parking operations. For any given application, this presents a problem of selecting new or replacement equipment or products to maintain or improve operating performance.

Compounding the problem is a proliferation of equipment/product suppliers and performance claims. Newer lines of equipment and products are becoming available with such frequency that an architect, engineer or owner may be unable to specify previously used lines because they have been replaced in production by newer lines, or changed to compete more successfully in the marketplace.

Proper evaluation of equipment/product needs and alternatives can be extremely important to operating performance. Parking equipment and products usually represent a significant expense, but they help produce parking revenues and other operating benefits that normally dwarf their investments. The nonspecialist often cannot afford the time to study all alternatives and perform evaluations, which is a commonly offered service of the parking consultant. While equipment and product suppliers can be helpful to the evaluation process, it usually behooves the decisionmaker to seek independent guidance to establish the need, as well as to evaluate and specify equipment and products. Equipment and products should be evaluated on their ability to meet service and procedural objectives, cost effectiveness and reliability, and maintainability, including future service and replacement parts/service availability.

Maintain Competitive and Productive Rates. Parking space is never free, even though its cost to the parker is sometimes subsidized. Where parkers are charged a fee for parking, the amount charged the patron and/or collected from subsidy sources reflects many considerations. Periodically, rates must be adjusted in response to changing circumstances and costs. And, while rates usually should not be changed more frequently than once every 1 to 3 years, change often disturbs patrons and may be fraught with political objection.

The parking decisionmaker/operator is faced with two problems: (1) anticipating costs in order to establish and maintain productive and competitive charges for space; and (2) justifying the need for rate increases. To address these problems, there is no substitute for proper records, data monitoring, and experienced judgement.

Respond to Patron Needs and Comments. Good public relations is as necessary to parking operations as it is for all service industries. The public's perception of parking facility location, physical appearance, traffic operation and employees has a strong influence on patronage and revenues.

Consider Alternatives to Additional Parking. Before launching into a program to develop additional parking space, it is essential to achieve the most efficient use of existing parking space. Under some circumstances, shared parking agreements, improved space usage control, staggered work hours, rideshare or public transit incentives, and other measures can eliminate or delay need for additional parking.

Before all appropriate alternatives are exhausted, the decisionmaker should begin planning for expansion. Growth should be monitored with the information provided by existing parking operations. Space for interim parking may be necessary if new parking construction will displace existing spaces. Expansion may increase operating and maintenance expenses brought on by construction and operation of additional parking. An appropriate development team should be established and involved as early as possible.

CONCLUSIONS

Efficient management and operation of parking facilities is essential. Sound business practices are needed to keep operating costs as low as possible and to maximize both patron service and revenue security, and to assure that facilities are well maintained. For publicly owned facilities, rates should be set at levels that reflect public policy, cover costs, and reflect what the public is willing to pay.

Specific methods of fee collection, revenue control, maintenance, and management practices will reflect local circumstances. However, whether the facilities are operated by owners, by management contracts or under lease agreements, a knowledgeable and competent management and staff are essential. Without such persons, the best located and best designed parking facility can fail to succeed.

CHAPTER **11**

Curb Parking

There are many competing demands for the use of curb space. It is used by moving traffic, by taxis and buses picking up and discharging passengers, by commercial vehicles making deliveries or on service calls, by people running errands to nearby stores and businesses, and by short- and long-term parkers. Balancing these competing demands requires tradeoffs between the traffic movement functions provided by streets, and the access and storage afforded by allowing curb parking. Both safety and traffic capacity must be considered.

Where to provide and where to prohibit (or restrict) on-street parking are major issues in small and large cities alike. Resolving these concerns depends on the type of street, character of abutting land use, traffic flow characteristics and the availability of nearby off-street parking and loading space. Once a curb-use policy is implemented, effective enforcement is essential.

This chapter describes how communities can deal with their curb parking problems. It identifies basic issues and concerns; defines parking prohibitions; discusses the role and application of parking meters; sets forth basic design guidelines; and suggests enforcement and adjudication procedures.

ISSUES AND CONCERNS

The curb parking problem permeates the entire urban area. It is most acute in high-density parts of the city where activities are clustered and adequate space is unavailable to park off-street. It is a major concern within the central business district (CBD), in outlying business districts and along streets lined with shops and offices. Curb parking also is a problem in residential areas where there is little or no off-street parking.

On-street parking provides convenient access to adjacent properties. It makes it possible to stop for a newspaper, a quick purchase or a visit to a dry cleaners. It also serves as an interim parking supply until needed off-street space is built. On-street parking, however, can impede traffic flow and contribute to accidents.

The legal basis for curb parking controls are public safety and public convenience considerations. The safe and efficient movement of people and goods is the primary function of the street system. Thus, vehicle movement should take precedence over vehicle storage.

Although traffic movement is the main function of roads and streets, some sections of the system must provide parking to serve adjacent land use. It is not desirable to prohibit parking where it would result in serious economic hardship or preclude access to adjacent properties. Where the essential purpose of a street is to provide access to adjacent property, a good case can be made for retaining on-street parking, particularly in smaller cities and during off-peak street traffic hours. Thus, the capacity and safety gains that result from restricting curb parking must be balanced against the curb access needs of adjacent properties.

Street Congestion and Capacity

Parking along a street or roadway reduces traffic flow capacity and contributes to congestion. A single car parked within a curb lane can effectively close the lane to moving traffic. Curb parking limits street capacity in two ways. First, it preempts lanes that otherwise would be used by moving traffic. Second, parking and unparking maneuvers frequently reduce the capacity of the adjacent lanes.

The prohibition of parking on a four-lane street doubles street capacity. Similarly, prohibiting parking on a six-lane street achieves a 67 percent capacity gain. Capacity gains might be greater in specific cases, since the added lanes would not be subject to blockage by left-turning vehicles.

Table 11-1 shows how curb parking reduces the capacity of adjacent travel lanes. Reductions are greatest where there is a high parking turnover, especially on narrow streets. For example, 10 parking maneuvers per hour on a signalized intersection approach would result in a 15 percent reduction in the capacity of the adjacent lane. Forty maneuvers (or more) per hour, would result in a 30 percent capacity loss to the adjacent lane.

Safety

Curb parking adversely affects the safety of the street system. Approximately 15 percent of all accidents involve parked cars. About 5 percent of all pedestrian fatalities involve people who entered the roadway from between parked cars.

Table 11-1. Effect of Parking on Capacity of Adjacent Traffic Lanes

No. of Lanes in Lane Group	*No Pkg*	*Number of Parking Manuevers per Hour*				
		<10	*10*	*20*	*30*	*40*
1	1.00	0.90	0.85	0.80	0.75	0.70
2	1.00	0.95	0.92	0.89	0.87	0.85
3	1.00	0.97	0.95	0.93	0.91	0.89

Source: *Highway Capacity Manual—Special Report 209* (Washington, D.C.: Transportation Research Board, 1985).

These proportions vary from city to city. In Chicago, moving vehicles striking parked vehicles accounted for 2 percent of all fatal accidents, 6 percent of all injury accidents and 26 percent of all property damage accidents.[31] In small communities, 43 percent of all local and collector street accidents involve curb parking.[32]

Contributing Factors. Parking accidents result from the following. (Table 11-2 gives the relative frequency of each type of accident for one-way and two-way streets.)

1. *Vehicles Parked or Stopped on the Roadway.* These vehicles narrow the usable width of the roadway, and are obstacles for moving traffic, both straight and turning. They account for nearly half of all parking-related accidents.

2. *Vehicles Leaving the Parking Position.* These vehicles disrupt the traffic flow and, by increasing congestion, may cause rear-end and sideswipe collisions. They account for about one-third of all parking-related accidents.

3. *Vehicles Entering the Parked Position.* Parking maneuvers often take place without adequate warning to other traffic. The vehicles parking usually must slow to a stop, and then back into the parking space. This parking maneu-

Table 11-2. Mid-block Accidents by Type and Parking Involvement on Major Streets

	% of Total Parking Accidents	
Parking Involvement	*One-way Street*	*Two-way Street*
Stationary	47.9	48.5
Unparking	315.3	31.2
Parking	13.0	11.0
Open door	3.5	7.9
Sight Restricted	0.3	1.4
	100.0	100.0
Parking accidents as % of total accidents	59.9	42.1
Total accidents	947	1811

Source: J.B. Humphreys, P.C. Box, T.D. Sullivan, and D.J. Wheeler, "Safety Aspects of Curb Parking," Report No. FHWA-RD-79-76 (Federal Highway Administration, 1978).

[31] *Statistical Summary*, 1973, Chicago Police Department, Chicago, 1974.
[32] Paul C. Box, "The Curb Parking Effect," *Public Safety Systems* (January/February 1968): p. 101.

ver accounts for about 12 percent of all parking-related accidents.

4. *People Getting out of Parked Vehicles on the Street Side.* The opened car door presents an added obstacle. Passing traffic may be required to swerve or stop suddenly.

5. *Reduced Sight Distance.* Parked vehicles reduce sight distance for pedestrians and other traffic.

Emergency Vehicle Access. Curb parking constitutes a serious emergency hazard wherever cars block fire hydrants or obstruct fire apparatus. Parking restrictions in the vicinity of fire stations and fire hydrants are essential public safety requirements. Street space must be sufficient for maneuvering emergency vehicles and for laying fire hose.

Land Use and Accident Frequency. The relationship between land use and parking accidents is summarized in Table 11-3. The data suggest an increase in parking accidents as the intensity of land use increases. Businesses and retail uses have the highest parking turnover as well as the highest accident rates.

Parking utilization (occupancy) also appears to increase the accident rate. Figure 11.1 shows how the accident rate rises as the annual parking space occupancy (space-hours parked per mile of street) increases.

Parking Angle. The arrangement of parking spaces, either parallel to the curb or at an angle, affects safety. Angle parking provides more parking per unit of curb length than parallel parking; but it requires more space for maneuvering thereby increasing exposure and hazard. Visibility can be inadequate for drivers backing out into traffic; oncoming drivers must suddenly stop as cars unpark; and drivers must proceed slowly to find empty spaces. Consequently, angle parking results in substantially higher accident rates than parallel parking.

Many studies have found that elimination of angle parking reduces accidents. Results of before and after studies summarized in Table 11-4 show a 19 to 63 percent accident reduction where angle parking was changed to parallel parking.

An analysis of angle versus parallel parking for 1,523 urban parking spaces in Maine found that parallel parking had an accident rate 12 percent lower than angle parking (see Table 11-5).

Table 11-3. Land-Use and Curb Parking Accidents

Land-Use/Development/ Location	*Accident Rates* *Accidents/Mile/ Year*	*Accidents/ MVM*[a]
Residential:		
Single family	1.0	
Apartments	3.1	
Business	3.5	
Industrial	1.2	
Residential		1.5
Apartment		5.4
Office		8.4
Retail		11.8
Downtown		1.6
Intermediate		0.9
Outlying		0.9

a. Acc/MVM = accidents per million vehicle miles

Source: P.C. Box, "Accident Characteristics of Non-Arterial Streets," *Traffic Digest and Review* (March 1964); T.J. Seburn, "Relationship Between Curb Uses and Traffic Accidents," *Traffic Engineering* 37, no. 8 (May 1967); and J.B. Humphreys, P.C. Box, T.D. Sullivan and D.J. Wheeler, "Safety Aspects of Curb Parking," Report FHWA-RD-79-76 (Federal Highway Administration, 1978).

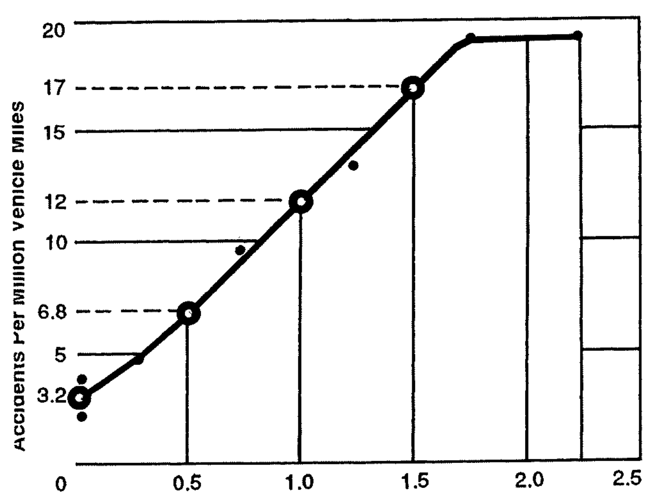


Figure 11.1. Accident rates versus parking utilization, major streets, all lands uses

Source: Paul C. Box, "The Curb Parking Effect," *Public Safety Systems* (January/February 1968).

Table 11-4. Summaries of Before-After Studies Involving a Change from Angle to Parallel Parking

Study Location	*Report Year*	*Accident Reduction*	*Comment on Results*
Minnesota City	1947	41%	27 accidents before 16 accidents after
Wichita, KS	1950	63%	8 accidents before 3 accidents after
Utah	1966	28%	Average for 8 studies (range 0 to 73%)
		57%	Reduction for parking related accidents
Grand Rapids, MI	1967	19%	
Kansas City, MO	1967	50%	Accidents/block 5 before, 1 after

Wilbur S. Smith, "Influence of Parking on Accidents," *Traffic Quarterly* 1, no. 2 (April 1947); G.L. Fisher, "Angle vs. Parallel Parking," *Traffic Engineering* 21, no. 1 (October 1950). "Community Guide to Parallel Parking (Utah State Department of Highways, June 1966); and D.J. Hanson, "Parking Restrictions and the Curb Lane," Special Report No. 93 (Highway Research Board, 1967).

PARKING PROHIBITIONS

Prohibition of curb parking, especially during peak-traffic hours, results in fewer accidents. Table 11-6, which summarizes the results of 12 before and after studies of parking prohibitions, shows accident reductions ranging from 12 to 90 percent. The wide range of reductions reflects specific local conditions.

Parking restrictions have three basic objectives:

1. To prevent loading, unloading, waiting or parking where such activity would impede traffic movement or safety.
2. To provide adequate curb-side space for loading and unloading, particularly where off-street space is not available.
3. To encourage short-term parking to service nearby land uses.

Attainment of these objectives depends on how well they are enforced.

The decision to permit or prohibit parking reflects the relative importance of traffic flow versus local access requirements. It depends on street type (arterial, collector, local land service street), location (CBD, central city, suburb), type of activity (commercial, industrial, recreational, residential), traffic flow characteristics (volumes, speeds, accident experience, levels-of-service), public transport requirements (bus stops, exclusive lanes), and availability of off-street parking space.

Effectively enforced curb parking restrictions, especially during peak periods, are the single

Table 11-5. Angle vs. Parallel Parking in Maine Cities

Parking Configuration	*No. of Sections*	*Average ADT*	*Average Acc. Rate (Acc/MVM)*	*Index*
Parallel - both sides	1,472	7,000	3.8	.12
Parallel - one side mixed parallel and angle - one side	10	5,600	11.6	.37
Parallel - one side angle - one side	36	10,300	15.0	.48
Angle - both sides	5	5,100	31.5	1.00

Source: Murray D. Segal, "Highway Safety Research Study," Maine State Highway Commission, April 1972.

Table 11-6 - Summary of Before-After Studies Involving Parking Prohibition on Major Streets

Location	*Report Year*	*Accident Reduction*	*Comments*
Dallas, TX	1946	22%	
New Orleans, LA	1947	90%	
Chicago, IL	1949	24% 34%	Two streets, 4-hour peak
Adelaide, Australia	1963	29%	4-week trial period, reduction in peak-hour accidents
Garden City, MI	1965	44%	Property damage accidents decreased 38%, injury accidents decreased 65%
Dearborn, MI	1966	3.5% 19.1%	First year reduction, Total 2-year reduction
Beverly Hills, CA	1967	-	195 fewer property damage accidents in 1965 compared with 1961
Detroit (Suburb), MI	1968	24%	32% increase in traffic flow
Gateshead, United Kingdom	1968	20%	
Yuma, AZ	1969	41%	
Knightsbridge, United Kingdom	1973	34%	Traffic increased 15%-20% in peak periods
Sheffield, United Kingdom	1973	12%	

Source: W.C. Brandes, "Parking Prohibition Reduced Dallas Accidents and Congestion," *Traffic Engineering* 17, no. 1 (October 1946); W.S. Smith, "Influence of Parking on Accidents," *Traffic Quarterly* 1, no. 2 (April 1947). "Effect of Rush-Hour Parking Control on Street Traffic and Transit Operation (unpublished study) (Chicago Transit Authority (1949); P.G. Pak-Poy, "The Effect of Banning Kerbside Parking During Peak Hours on the Anzac Highway," *Australian Road Research* 1, no. 7 (ARRB: September 1963). Michigan State Highway Department, "Parking Removal on Business Section Road Can Reduce Traffic Accidents," *American* Highways (July 1965). F. De Rose, Jr., "Reversible Center Lane Traffic System — Directional and Left-Turn Usage," *Highway Research Record No. 1151* (Highway Research Board, 1966). E.E. Tufte, "Curb Parking is Culprit," *Public Works* 98, no. 3 (March 1967). M.R. Hoffman, A.A. Lampela and N. Al-Ashari, "Evaluation of Removal of Curb Parking and Conversion to Five Lane Street Operations; M-153 (Ford Road) Through Garden City," (Michigan Department of State Highways, November 1968). K.B. Madelin and J.A. Ford, "Gateshead Traffic Management Scheme: Before and After Studies and Results," *Traffic Engineering and Control* 10, no. 4 (August 1968); S.G. Crosette and G.L. Allen, "Traffic Control Measures Improve Safety, *Traffic Engineering* (January 1969). "A Review of Town Planning in Relation to Road Safety," Expert Group on Road Safety (Australia: 1973).

most important means of expediting traffic flow. Prohibiting parking along one side of a street during peak hours can double capacity at virtually no additional cost. Curb parking may be restricted on approaches to intersections, at bus stops or along an entire route. Restrictions may apply at all times, during daytime hours, or only during peak periods.

Implementing curb parking restrictions calls for carefully balancing the needs of moving traffic with the access requirements of adjacent properties. Thus, wherever parking is restricted, it is essential that alternate parking (on-street or off-street) be available. This need is especially acute along streets with commercial frontage found in older, densely built-up cities.

While usually difficult to achieve, curb parking restrictions should establish an equilibrium between the values afforded by on-street parking and loading and their effects on moving traffic during both peak and off-peak hours. An effective approach is to appraise streets by their primary functions. Are they an essential part of the circulation system or are they mainly land-service streets? Does the prohibition of on-street parking actually provide an additional traffic lane or does it merely provide incremental gains in the use or efficiency of existing lanes? Does elimination of parking make available lanes for exclusive use by buses?

Traffic engineering and curb parking studies should be made before any changes in parking restrictions are put in effect.

Street System Considerations

Each street in the urban setting has its own traffic movement and curb parking requirements. Parking restrictions vary dramatically from center city to suburb, and along arterial, collector and local streets.

Arterial Roads and Streets. Only emergency parking should be permitted along freeways, expressways, and other controlled-access facilities. Curb parking generally should be prohibited along high-speed arterial roads — especially those lined with strip development and off-street parking lots. The primary function of these roads is to move traffic quickly and safely. Thus, vehicle movement must take precedence over vehicle storage.

It is generally desirable to prohibit parking on urban arterial streets. However, curb parking is acceptable when the moving traffic lanes can accommodate the traffic volumes. Moreover, where parking is needed and off-street facilities are not available or feasible, on-street parking may be necessary. Peak-hour parking restrictions may represent a reasonable solution in such cases.

Curb parking policies for arterial streets passing through built-up commercial areas are not clear cut. Decisions must be made on a case-by-case basis. Detailed studies are essential to determine if the benefits of curb parking exceed the benefits of removing parking all or parttime.

Business and Residential Streets. It may be more important to keep parking along a business street when nearby off-street space is not available. Similarly, parking may be necessary along many residential streets in built-up areas where off-street space is not adequate.

Downtown Streets. Allocating curb space among downtown streets is more complex and should be done within the context of an overall downtown parking policy. Curb space is a scarce and valuable resource that provides many essential often competing functions. Priorities for its use vary with specific circumstances.

Curb parking restrictions are desirable where: parking interferes with the safe and efficient movement of traffic, where it forces double parking by trucks, or where it results in backups at downtown intersections. It also should be prohibited where curb lanes are needed for bus service, goods delivery, or passenger pickup.

Where curb parking is allowed, it should favor short-term parkers; long-term parking along curbs should be discouraged. A possible sequence of curb-use priorities in larger city centers is (1) public transport (bus lane), (2) moving traffic, (3) goods/taxi access, (4) short-term parking, and (5) long-term parking.

Downtown curb parking should be permitted only where:

- the curb lane does not impair the movement of emergency vehicles,
- the curb lane is not required for buses, moving traffic, or service to adjacent property,
- streets are wide enough to allow passing of parked vehicles, and
- travel delays resulting from curbside activity do not create gridlock.

Types of Prohibitions

Parking prohibitions vary by type, time period, time limit, location, and type of user. They may prohibit stopping, standing, or parking; or they merely may specify allowable lengths of stay. They may apply at all times, part-time, or only during special events or snow emergency conditions. They may exempt taxis, trucks, buses, diplomatic vehicles, and/or residents.

Parking prohibitions benefit moving traffic, improve safety or make curb space available for goods loading. Parking prohibitions by time give more people an opportunity to use curb space.

State motor vehicle codes normally provide the legal basis for prohibiting parking on sidewalks, in driveway approaches, within and on approaches to intersections, near fire hydrants and other critical places. Municipal governments may be granted the authority for more specific restrictions, such as at schools and for overnight parking. Local ordinances normally specify the maximum distance for wheels of parked cars to be positioned away from the curb, and require parallel parking unless otherwise indicated.

State and municipal ordinances are patterned after the *Uniform Vehicle Code and Model Traffic Ordinance*.[33] Representative guidelines set forth in this code are summarized in Table 11-7. It is common practice to post signs for these regu-

[33] *Uniform Motor Vehicle Code*, National Committee on Uniform Traffic Laws and Ordinances, Washington, D.C.

Table 11-7. Locations Where Parking is Prohibited by Model Traffic Code

1. On a sidewalk;
2. In front of a public or private driveway;
3. Within an intersection;
4. Within 15 ft of a fire hydrant;
5. On a crosswalk;
6. Within 20 ft of a crosswalk at an intersection;
7. Within 30 ft on the approach to any flashing beacon, stop sign, or traffic-control signal located at the side of a roadway;
8. Between a safety zone and the adjacent curb or within 30 ft of points on the curb immediately opposite the ends of a safety zone, unless the traffic authority indicates a different length by signs or markings;
9. Within 50 ft of the nearest rail of a railroad crossing;
10. Within 20 ft of the driveway entrance to any fire station and on the side of a street opposite the entrance to any fire station within 75 ft of said entrance (when properly posted);
11. Alongside or opposite any street excavation or obstruction when stopping, standing, or parking would obstruct traffic;
12. On the roadway side of any vehicle stopped or parked at the edge or curb of a street; and
13. On any bridge or other elevated structure on a highway or within a highway tunnel;
14. Within a bus stop.

Source: Adapted from *Uniform Vehicle Code, 1968.*

lations, especially for street corner regulations, taxi zones, and bus stops.

Restriction Types. Curb parking restriction types include no parking, no standing, no stopping or standing, and no parking-loading zone.

A *no parking* regulation is used where occasional stopped vehicles will not cause a hindrance to the safe and efficient flow of vehicles. This regulation may be used throughout the full 24-hour period on major roads, or only during peak commuter hours, or times of special events.

Various short-term no parking regulations are necessary in urban areas to ensure that adequate space is provided for specific activities or vehicles, taxis, loading and unloading, bus stops, passenger zones, and like situations.

A *no standing* regulation allows a driver to stop for passenger pickup or dropoff, but ordinarily does not allow prolonged truck loading. It is used where curb space must be kept clear practically all the time during the effective limit of the regulation — often in CBDs or along streets lined with shops. In many situations, a no parking regulation, when properly enforced, is almost equally effective.

The *no stopping or standing* regulation is used where the presence of vehicles stopped at the curb, even momentarily, would seriously impede safe and efficient traffic flow. Locations include near fire stations, in tunnels, on bridges, at railroad tracks, or along approaches to signalized intersections where capacity problems are extremely critical. No stopping also is applied in key locations within the CBD (i.e., along exclusive bus lanes).

This regulation restricts the stopping of any vehicle (passenger car, truck, or bus) at the curb for any purpose during the times of the restriction, except in obedience to an officer or traffic control device.

A high enforcement level is essential. A tow-away regulation usually is required to permit vehicles to be removed when considered to be an obstruction by a police or parking enforcement officer.

Time Period Restrictions. Restrictions on curb parking can be for fulltime or parttime periods.

Full-time restrictions should be used where parking poses serious safety or capacity problems. It is essential that parking be prohibited where streets are too narrow to accommodate standing and moving traffic, or where it would impede pedestrian or emergency vehicle access.

Accordingly, full-time parking prohibitions are desirable on major traffic routes and on narrow local streets. In addition, parking should be prohibited where specified by ordinance (i.e., at fire hydrants, in bus stops, etc.).

Restrictions on major traffic routes may involve no stopping and/or standing at all times, or a prohibition on parking at all times, with no stopping and standing during peak periods. The no parking regulation should be used where curb space must be kept free for loading and unloading. The no stopping regulation should be used selectively because of its stringent enforcement requirements.

Full-time parking bans also are appropriate to provide intersection capacity, emergency vehicle access, 24-hour loading, and transit stops. These bans may prohibit stopping or standing, or just parking, depending on the particular situation.

Suggested ranges in minimum street widths for one- and two-sided parallel parking are shown in Table 11-8. These guidelines assure one moving traffic lane in each direction when the curb spaces are legally occupied. Minimum desirable

Table 11-8. Suggested Minimum Street Widths for Parallel Parking

	Parking on One Side	*Parking on Both Sides*
Two-way traffic	26-32 ft	36-40 ft[a]
One-way traffic	18-22 ft	26-30 ft

a. May be 26 feet for residential streets in suburban areas with intermittent curb parking. Widths of 34 feet may be acceptable in some cases.

Note. Lower values are for streets with average daily traffic of less than 2,500 vehicles

Source: Adapted from Louis J. Pignataro, *Traffic Engineering Theory and Practice* (Englewood Cliffs, NJ: Prentice Hall, 1973), Table 27-3.

widths for two-way traffic and parking on both sides are: arterial streets, 40 feet; collector streets, 36 feet; and local streets, 26 feet.

The 26-foot local street width results in only one moving traffic lane. Although this may inconvenience motorists, parking is usually intermittent on both sides of streets in suburban areas, and two-way traffic normally can be accommodated.

Parking should be prohibited along roads that front stores in community and regional shopping centers. It also should be prohibited from perimeter roads and access roads at shopping centers, office parks, and mixed-use developments.

Part-time restrictions are the most common form of parking regulations. They range from none at all in small towns to a full daytime ban of parking in the heart of the city center. They include peak-period restrictions on heavily traveled roads or transit routes; daytime bans in business areas and at schools, overnight restrictions, and prohibition of parking for special events, street cleaning, and snow removal emergencies.

Peak-period parking restrictions have important application on CBD and arterial streets. They maximize street capacity during periods of heaviest traffic flow, while permitting parking and essential curb access at other times. They may eliminate the need for costly and difficult street widening. In economic terms, they permit sharing the marginal costs of added lanes between peak-hour traffic (cars, trucks, buses) and off-peak parkers. They speed up bus flow, and they make it possible to implement peak-hour bus lanes.

Peak-period parking restrictions enable curb lanes to serve a dual function. The lanes serve moving traffic during rush hours, and they provide local access at all other times. They also discourage all-day employee parking.

On streets where peak-period traffic is heavy in one direction only, parking should be removed along that side. Parking along the other curb will serve businesses and residences on both sides of the street.

Where peak-period traffic is heavy in both directions, it may be necessary to restrict parking on both sides of the street. This will not pose problems where nearby parking is available or where abutting land uses do not require peak-hour curb access. However, where some curb access is needed, the benefit of better traffic flow must be weighed against the impact of reducing curb parking space.

The specific hours of parking restrictions depends on land-use, traffic flow and type of area. The hours need not be the same for all routes, and they might vary along part of the same route. They should be posted to the nearest half hour for maximum legibility. Time limits should extend slightly before and after the periods that they are actually required to compensate for possible violations at the beginning or end of the restricted period.

Typical time limits are 7-10 AM and 4-7 PM (or 3:30-6:30 PM) in large cities, and 7-9 AM and 4-6 PM in smaller cities. Where peak-period curb bus lanes are provided, the time limits should be the same as for the parking bans.

Peak-hour parking restrictions are generally appropriate when the following conditions apply.

1. Traffic volumes exceed 500 vehicles per lane per hour.
2. The roadway operates at Service Level E.
3. Operating speeds fall below a specified level (i.e., 20 miles per hour).
4. Curb bus lanes are needed during peak hours (i.e., over 40 buses per hour).

The time limits when curb parking should be prohibited can be determined by comparing hourly variations of traffic volumes and speeds at key points along a route with the capacity available with and without curb parking. Locations where volumes exceed capacity (i.e., operate at Service Level E) and/or where average speeds fall below a given level (such as 20 miles per hour) could be superimposed on a line diagram for the route under study. The two criteria — speed and volume — then could determine the extent of rush-hour parking prohibitions required. The composite restrictions, of course, should be adjusted to reflect route continuity (see Figure 11.2).

Business day parking restrictions between 7 AM and 6 PM are common in many central and outlying business areas. These bans make curb space available for transit, passenger dropoff and pickup, service vehicle access and goods deliveries.

School day parking restrictions are desirable on streets adjacent to a school and should cover the hours that the school is in session. Commonly, parking is restricted from 8 AM to 6 PM on school days.

Overnight curb parking restrictions facilitate street cleaning or snow removal. The parking prohibition usually extends from 2 AM to 6 AM. This prohibition should not be applied in densely developed residential areas with inadequate off-street parking space.

Special event or holiday parttime restrictions are desirable for events such as parades and festivals. Seasonal restrictions (as in beach areas) also may be appropriate.

Street cleaning activities occur periodically, usually on a scheduled basis. Parking is prohibited on one or both sides of a street during these periods. New York City, for example, has alternate-side parking restrictions each day on many streets to facilitate street cleaning and curb-side trash pickup. The prohibition covers 1- to 3-hour time periods.

Special restrictions — generally unpredictable — may be needed during the fall leaf collection season and for snow removal. Traffic detours, construction sites, and other emergency conditions requiring parking restrictions should be implemented on a site-specific basis. Many northern cities designate a system of priority snow removal routes along heavily traveled arteries. All parking is prohibited along these routes during the snowfall season. A temporary parking

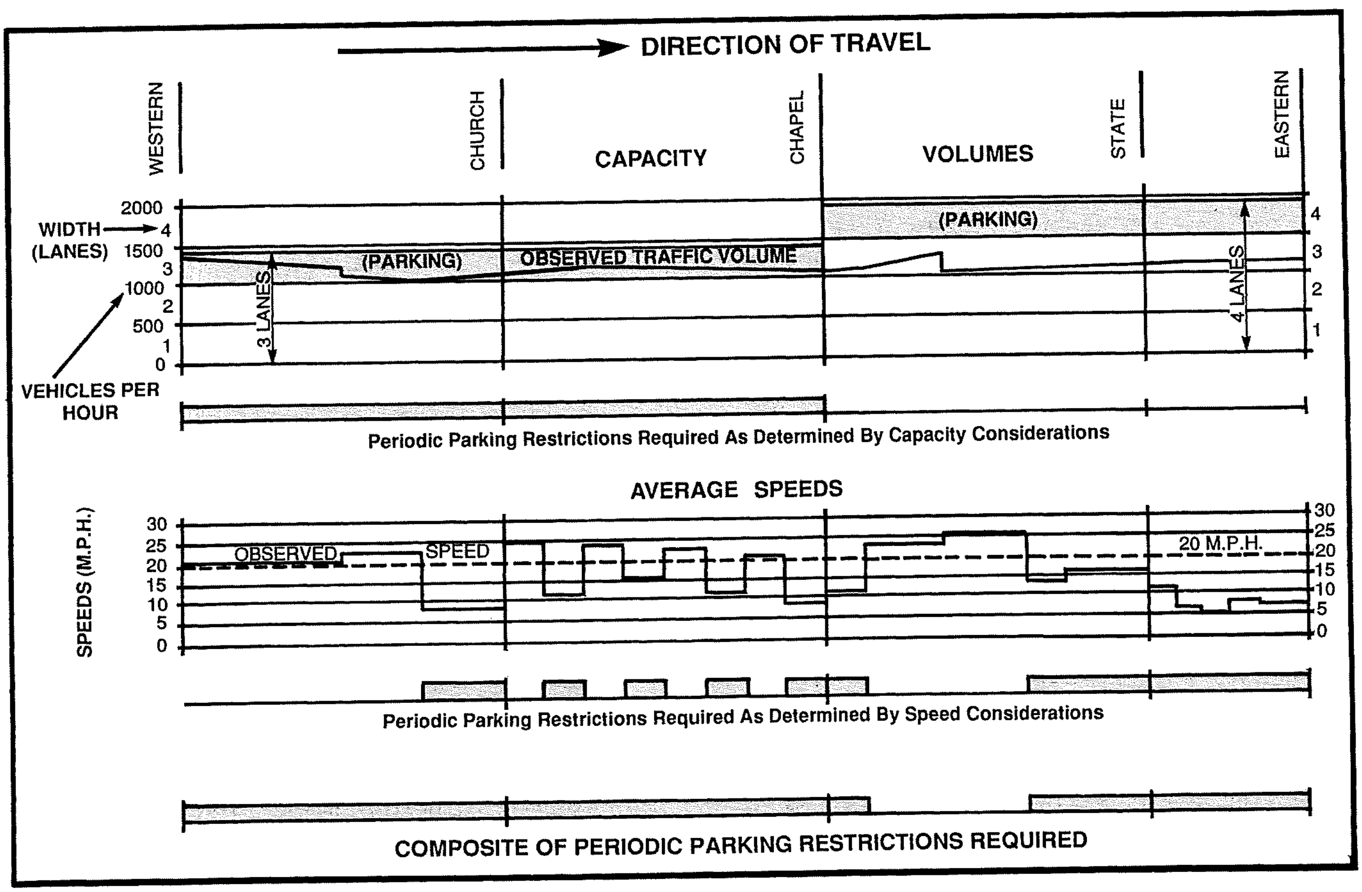


Figure 11.2. Typical rush-hour parking restriction analysis

prohibition may be declared on other routes during or after major snowfalls.

Time Limit Restrictions. The amount of curb space in any city is limited. Therefore, use of this space for parking should benefit the greatest number of people. Benefits can be maximized by setting time limits that are consistent with the needs of nearby establishments.

Time limit restrictions encourage turnover and maximum use of each space. They are effective only where demand for short-term parking and where proper enforcement exists. They are useful in discouraging employee, commuter, and other long-term parkers from preempting space in shopping and business areas.

Signs are used to convey restrictions to parkers. Signs commonly read "Two-Hour Parking," "One-Hour Parking — 8 AM to 6 PM" or "15 Minute Parking." Time limits depend on location and land use.

Very short time limits (5 to 15 minutes) are used at places of high turnover such as banks, public buildings, post offices and other busy places.

A 15- to 30-minute time limit is desirable near rapid transit and commuter rail stations to provide space for passenger pickup and discharge.

A 30- to 60-minute limit is desirable for repair shops, bakeries, drug stores, and other quick service establishments. Supermarkets, clothing and department stores require longer time limits.

Time limits of 2 to 3 hours are useful in CBD fringe areas to discourage all-day employee parking. They also are applicable in the environs of rapid transit stations to prevent commuters from usurping parking space in residential and commercial areas. Sometimes it is desirable to designate two or three parking spaces at the beginning or end of a business block for very short-term (i.e., 15 minutes) parking. These zones improve curb access to nearby activities.

Special Purpose Zones. Curb space may be designated for specific uses. These uses generally include passenger loading, taxi zones, bus (or light rail transit) loading zones, and commercial vehicle (freight) loading zones.

Passenger loading zones for picking up and discharging passengers by private vehicles and taxis may be warranted at many places within the urban area. Typical locations include theater and hotel entrances, schools, transit terminals, park-and-ride areas and airport terminals. These zones allow vehicles to stop momentarily; they do not permit long-term standing or general parking.

The length of these zones should be compatible with the amount of curb frontage available and demand characteristics. Often, a single stall properly designed, will suffice. This requires a minimum of 50 feet, assuming parking at both ends of the zone. Another 25 feet should be provided for each added stall.

Most communities allow taxis to comply with general stopping and standing regulations. Special *taxi loading zones* are provided at hotel entrances, airports, transit terminals and other places where heavy passenger loading traffic is generated.

Zones usually are limited as to the number of cabs. A two- to three-cab zone is common at a small CBD hotel or in a suburban area. Larger zones should be provided at railroad stations, transit terminals, and airports. The length needed for each stall is about 20 feet plus 5 feet for additional maneuvering space at each end of the taxi zone. At larger "hub" airports, taxi-only roadways may be appropriate; where storage space is limited, special taxi holding or marshalling areas may be required.

Sufficient space should be provided at bus and streetcar stops for passengers boarding and alighting. Where light rail transit vehicles operate in mixed traffic, special safety zones should be provided for passengers. Moving traffic lanes should be transitioned around *transit loading zones* to maintain lane continuity. This may require eliminating curb parking on the approach to and alongside the stop. A minimum 1-in-20 taper should be used for transitioning the traffic lanes.

Buses should be able to stop along the curb without protruding into the adjacent traffic lane. Sufficient curb space should be provided for both the bus stop and the distance needed for a bus to enter and leave the traffic stream.

The required length of parking prohibition depends on the size and number of buses, the type of stop (near-side, far-side, or mid-block), desired placement of the bus wheels from the curb, and the width of street. Suggested minimum lengths for curbside bus stops based on these factors are shown in Table 11-9. A single 40-foot bus stop should range from 105 to 125 feet for near-side stops; 80 to 110 feet for far-side stops; and 140 to 190 feet for mid-block stops.

The choice of near-side, far-side or mid-block locations depends on availability of curb space, locations of existing stops, passenger convenience, proximity to passenger destinations, bus routing patterns, traffic volumes and turning movements, turning radii, and type of traffic controls.

Far-side bus stops are preferable where sight distance or traffic capacity problems exist; where buses have use of curb lanes during peak-travel periods, and where there are heavy right or left turns. Near-side stops are preferable where transit flows are heavy, but traffic conditions are not critical, and where curb parking is permitted in peak periods. Mid-block stops generally are applicable in downtown areas where multiple bus routes require long loading areas.

It is common practice to let cars load and unload passengers in bus zones. However, truck standing or parking in bus zones should be prohibited.

Most downtown districts and many other business areas do not have adequate off-street space or alleys for goods loading and service vehicles. The need for on-street *truck loading zones* in these areas depends on availability of off-street or alley loading space; frequency of delivery or pickup, size of load, type of vehicle, and number and nature of establishments serviced. Truck loading zones are desirable when (1) no alley or off-street space is available for loading, and (2) there are at least 6 to 8 truck stops per day for pickup and for delivery. The precise frequency of truck use should be set by local policy.

Loading zones limit the use of curb space to vehicles that are engaged in deliveries, service calls or loading. They are marked by signs, specifying hours and days that the zones are in effect. They should not be restricted to adjoining places of business since they are a public loading zone. It is usually not necessary to have the zone at the exact point of loading access. Loading zones generally should be used by several businesses.

Loading zones should have sufficient length to allow parallel truck access. This depends on expected truck size and location within the block face. Zones usually range from 30 to 60 feet in length. Minimum lengths should be at least 30 to 40 feet. Extensions of existing no-parking areas (such as driveways, fire hydrants, bus stops or intersections) are desirable because these areas can be used to provide additional maneuvering length. Figure 11.3 shows how commercial loading zones can be integrated with bus stops and corner parking restrictions.

Proper enforcement is necessary to prevent loading zones from becoming "private" parking for store owners, managers, or employees. Violations can be handled better by parking tickets than by removing the zone.

Many cities post special parking regulations for police, judges, diplomats, and other VIPs. Such *agency zones* should be kept to a minimum. It is more desirable to provide these reserved spaces in parking lots or along alleys behind buildings where they are less obvious to the general public.

Table 11-9. Minimum Desirable Lengths for Curb Bus Loading Zones

	Wheel Position from Curb			
Type of Stop	*6 inches*	*1 foot*	*Each Additional Bus*	*Single-40 ft Bus*
Near side	L + 85	L + 65	L + 5	105-125
Far side				
Street 40 ft or more wide	L + 55	L + 40	L	80-95
Street 32-39 feet wide	L + 70	L + 55	L	95-110
Midblock				
Street 40 ft or more wide	L + 135	L + 100	L	140-175
Street 32-39 ft wide	L + 150	L + 115	L	155-190

Note: L = Length of Bus

Source: Adapted from Wolfgang S. Homburger and Henry D. Quinby, "Urban Transit" in *Transportation and Traffic Engineering Handbook*, 2nd ed. (Institute of Transportation Engineers, 1982).

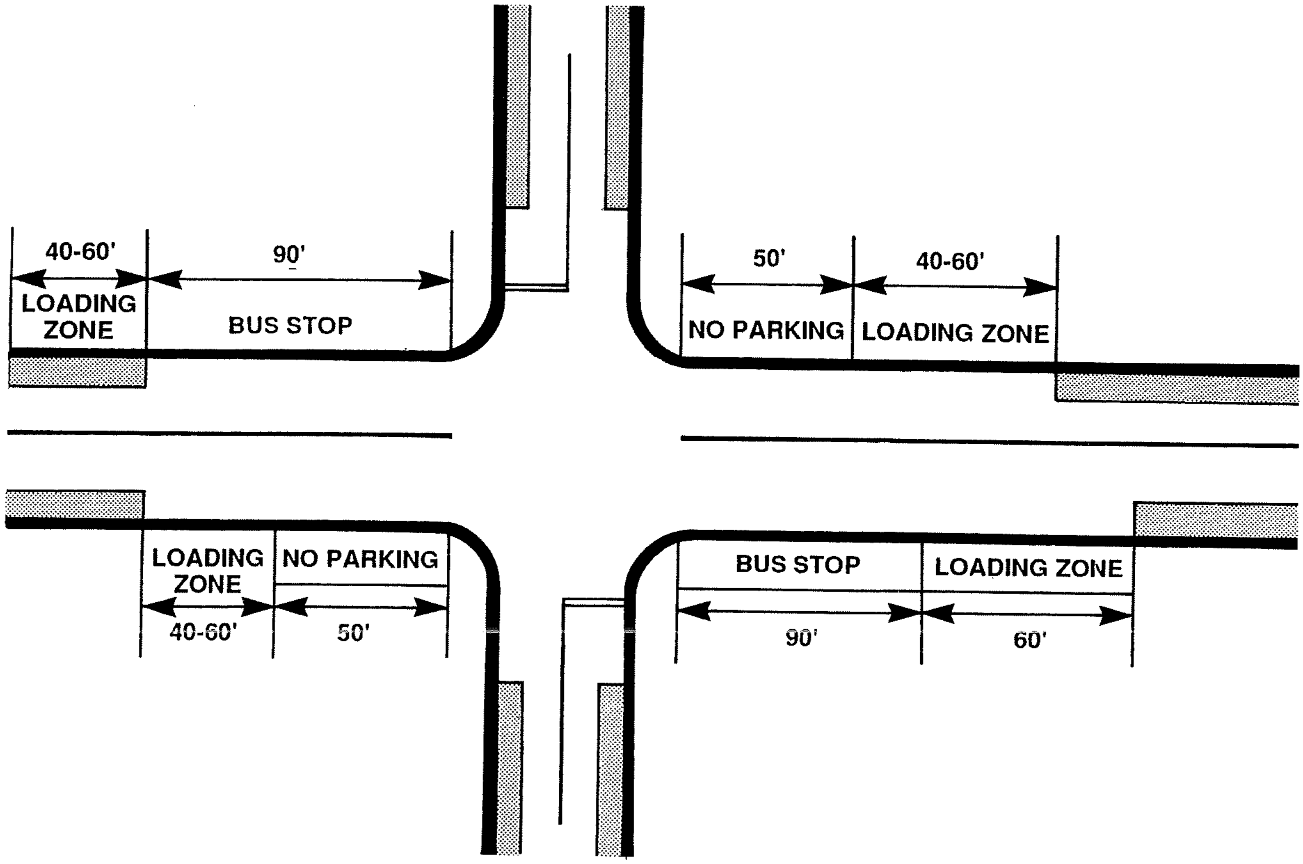


Figure 11.3. Loading zones integrated with bus stops and corner parking restrictions

Many cities have established *tow zones* along principal arterial roadways in conjunction with peak-hour parking restrictions. The zones are set by ordinances and the police (or parking agent) are authorized to tow away illegally parked vehicles within these zones. The ordinances require public notice through signs along the roadway. A small plate reading "tow zone" is often annexed to the standard no parking or no stopping sign. Effective enforcement is essential.

PARKING METERS

Parking meters are used to aid in the enforcement of time limit restrictions and to promote desired parking turnover at curb spaces. Correctly applied, meters simplify and reduce the cost of enforcement. Without them, it is necessary to check parking durations by recording vehicle license numbers or by chalk-marking tires of parked vehicles.

Meters encourage better compliance with regulations. This is because the red flag that appears after the time has expired makes the parker more conscious of the consequences than is the case with un-metered space.

Parking meters also produce revenue. This revenue is used to offset the costs of installation, operation, and maintenance. The remaining net revenues are often applied to the overall off-street parking program.

The effectiveness of parking meters depends on how well they are enforced. It is necessary to limit the installation of meters to areas where enforcement can be provided.

Tire chalking by police may be necessary in areas where there is a tendency to "feed" meters, periodically returning to parked cars to deposit additional coins to extend beyond the legal time limit. This checking is especially important in 15- and 30-minute metered zones.

Four significant factors assess the effectiveness of meters. These are: proportion of overtime parkers, proportions of available time used by them, the average parking duration of these violators, and curb-space turnover. An improvement in all four factors is evidence of the effectiveness of meters and enforcement practices. Meters reduce overtime parking and increase turnover.

A study of over 900 municipalities found that meters reduced overtime parking by more than 75 percent in nearly half of the communities. Ninety percent of the communities reported improved parking turnover.[34]

This study found that the percentage of vehicles parking overtime in 58 reduced from 24 to 13 percent after meters were installed. Turnover increased 35 percent overall.[35]

A study of parking meters conducted in Ann Arbor, Michigan, during 1985 and 1986 found a high level of meter violations and a low level of enforcement. About one in three parked vehicles violated meter regulations by parking free or exceeding the time limit, while only one in twenty was issued a citation. The study found that 37 percent of the parking meter violations exceeded the time limit, but received only 3.3 percent of the tickets. Eliminating this hidden violation could increase parking capacity about 25 percent. The study concluded that short-term parking meters do work, even at low to medium enforcement levels. Though many users either parked for free, exceeded the time limit, or both, most parkers observed parking restrictions. Almost half of the users (47.2 percent) parked for 20 minutes or less, and four in five (81.1 percent) for 1 hour or less. The relative short parking duration versus the feasible enforcement interval might explain the high rate of "free" parking since citations exceed losses from meters. Thus, as a means of allocating a limited supply of premium parking space for the public, the meters performed efficiently since it is hard to catch people who park free for a short time.[36]

Several cities have removed parking meters and, in some cases, have reported excellent results. St. Petersburg, Florida, removed more than 4,000 meters from its downtown streets in 1963, and established a uniform 2-hour parking time limit. Before and after studies found no change in parking turnover.[37] Questionnaires sent to 35 communities (most under 50,000 population) that had removed meters found violations of parking time limits decreased in 16 cities, remained the same in 12, and increased in 7 cities.[38]

Types of Meters

The parking meter is a timing mechanism activated by insertion of a coin. Meters can be manual or automatic.

Manual Parking Meters. Manual meters require the parker to insert a coin and turn a handle that winds the clock and activates the meter for a time period determined by the amount of money inserted.

Automatic Parking Meters. In automatic parking meters, a coin is inserted and the time automatically registers for that coin. The clock mechanism of the automatic meter must be wound periodically by maintenance personnel.

Many cities in the United States color code meters as an additional means of advising parkers of the time limit at a particular location. Some cities paint meter poles red to indicate that parking is prohibited during peak hours.

Placement

Parking meters may be installed at either curb or off-street locations. For curb locations, meters are mounted on a pipe generally placed about 18 inches back from the curb and about 2 feet from the front edge of the parking stall. The use of "T" pipe connections provides for the mounting of two meters on the top of each post. This practice is more economical than the single-post installation, and it reduces the "clutter" along the road-

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[34] D.R. Levin, "Parking Meters — A Study of their Number, Revenue, and Use," *Highway Research Board Bulletin* (1956), p. 81.
[35] Ibid.
[36] Aaron Adiv and Wang Wanzhi, "On-Street Parking Meter Behavior," Transportation Research Board Annual Meeting, January 1987.
[37] "St. Petersbury Test — Free vs. Metered Parking," *Rural and Urban Roads* (October 1964).
[38] *Experience of Municipalities in Parking Meter Removal* (American Automobile Association, Traffic and Safety Department, 1966).

way. Motorists, however, may have difficulty identifying the appropriate meter. The double-post installation is best used on both sides of an island in "paired" parking where one post (with two meter heads) serves the parking stalls immediately ahead and behind the meters, or in off-street facilities where two parking spaces face each other across an island. Figure 11.4 shows such an arrangement.

Meter Revenue Collection and Security

Effective external security requires a parking meter with a good lock and key. As no key is immune from duplication, no large municipal meter system should have all meters operated with the same lock-and-key combination. The lock should be designed so that it can be quickly and easily changed in the field to a different key combination whenever desired. This must be done when a parking meter is stolen or a key disappears.

The coin collection system should be designed so that coins go directly from the parking meter into a collection device without the collector having access to them. Several meter systems provide a high degree of security. One system uses a meter coin box that can be inserted into a locked collection cart. The collection cart and the meter container have matching connections that release the money directly from the meter coin box into the cart. A second system consists of a closed collection cart that is connected by a flexible hose to a similar fitting in the meter collection system. This system releases the coins from the collection box directly into the cart. A third system has a long vacuum hose on a collection truck that connects directly to the parking meter collection bus. A fourth system involves the use of two coin containers. The full container is replaced with a duplicate empty container. The locked containers are removed with the coins and then carried to the collection point for emptying and counting.

Meter revenue is collected by city personnel or by contract. It is desirable to keep accurate time and material records so that the costs of collecting and accounting can be determined.

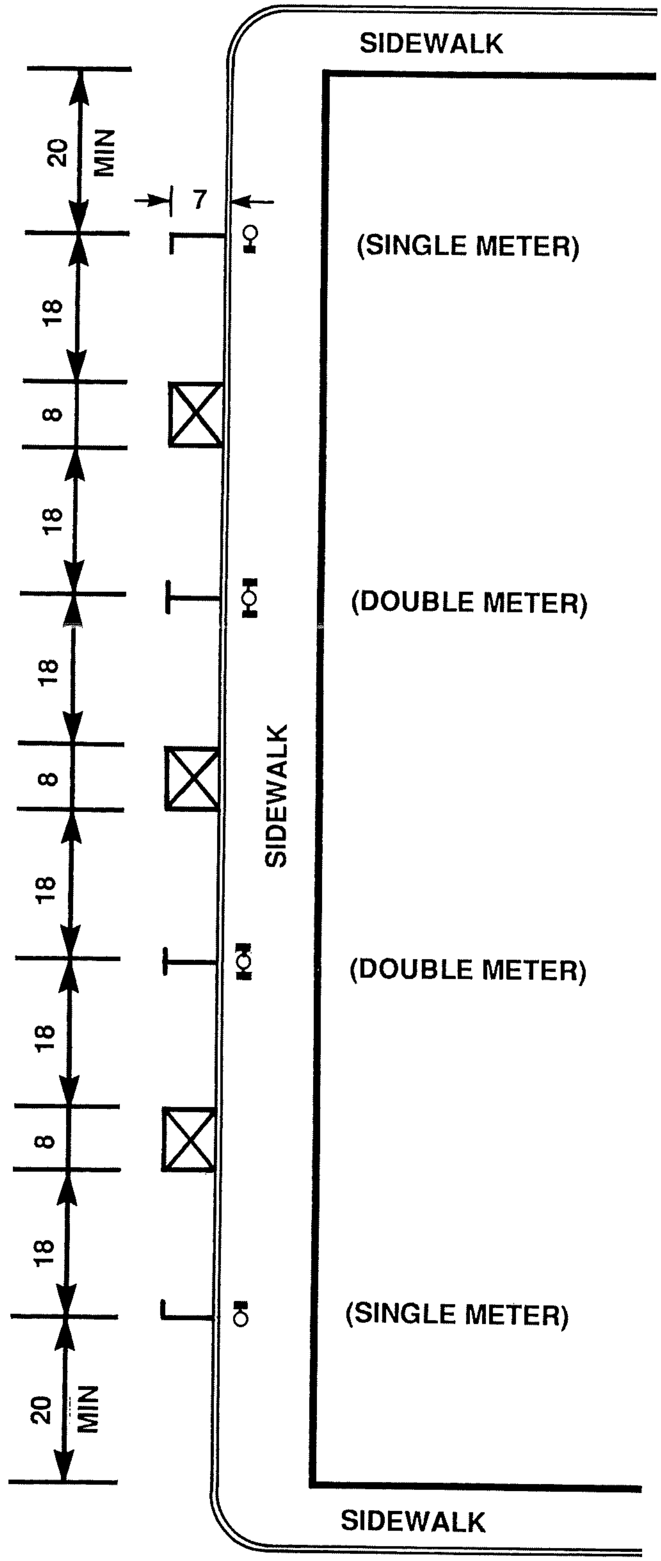

Figure 11.4. Example of paired parking meter layout

Time Limits and Fees

Time limits should reflect the needs of motorists and abutting developments. They should consider the time spent walking to and from major traffic generators. In areas of very high turnover, 15- and 30-minute meters are desirable; in retail areas, 1-hour and 2-hour time limits are typical.

Fees charged vary by location and city. They should reflect overall parking policy and be compatible with rates charges in nearby off-street space. On-street parking should be priced higher than off-street parking to encourage high turnover of curb space.

Premium curb space in many cities is metered at rates of $0.25 to $0.50 for 15- to 20-minute periods. Metered space in peripheral areas commonly costs $0.50 per hour (1989).

Meter Revenues

The average amount of net meter revenue depends on: (1) parking demand for metered space and the rate charged; (2) cost of maintenance and collection; (3) amortization of the original meter and installation costs; and (4) effectiveness of the parking enforcement program. Some meters will produce substantial returns while others may result in losses.

Disposition of parking meter revenues is an important policy consideration. Use of meter revenues to help finance an overall parking system should be encouraged. (See Chapters 2 and 5.)

Maintenance

A comprehensive maintenance program is essential to ensure that the meters function properly. A good, coordinated reporting system among enforcement, collection, traffic, and parking staff is necessary. Reports on meter malfunction or vehicular damage should be promptly investigated. Broken meters that cannot be repaired immediately should be covered or "hooded."

Special tools are available to straighten meter posts. Signs and insert plates must be inspected and replaced when defaced or when wording is obliterated.

Advantages and Disadvantages of Parking Meters

Advantages

Parking meters, when accompanied by adequate length of stalls, appropriate time restrictions, and proper provision for loading zones thoroughly supervised and actively enforced, produces the following benefits:

1. Provide an accurate time check on parking, simplifying detection of overtime parking and discouraging all-day parkers.
2. Reduce overtime parking, increase turnover, and make parking available for more motorists.
3. Aid merchants in metered areas by increasing space turnover.
4. Reduce personnel required for parking enforcement.
5. Reduce double parking.
6. Aid traffic flow by reducing congestion.
7. Aid in the financing of traffic control and off-street parking facilities.

Disadvantages

1. If used where not warranted, they arouse resentment.
2. Unless properly enforced, motorists learn that they can park overtime without receiving a summons.
3. Unless frequently checked, some motorists will park overtime for long periods by feeding coins into the meter.
4. After meters have been installed, the desire to continue the revenue may discourage elimination of curb parking when traffic demands indicate a need for it.
5. On streets where parking is prohibited during rush hours, the presence of meters may make enforcement more difficult.

Source: Louis J. Pignataro, *Traffic Engineering Theory and Practice* (Englewood Cliffs, NJ: Prentice Hall, 1972).

A preventive maintenance program for the mechanical parts of the meter is essential, and a shop overhaul is needed periodically. Maintenance frequency depends on meter usage, age and type.

OTHER CURB PARKING CONTROL METHODS

Several other curb parking control methods are used in Europe and Asia.

Parking Disks

In a parking disk system, the motorist sets the initial pointers to the arrival time (i.e., 5:15 as illustrated in Figure 11.5). As the space between the pointers is fixed for each disk, the allowable duration is shown and the second pointer shows the time when the maximum allowable duration has been reached (6:45 in the illustration). The disk is displayed inside the vehicle and enforcement officers can check readily for violations.

Disks are distributed without charge by police and also by recognized commercial firms who supply them free as an advertisement. Offenses are committed by failure to show a disk, by exceeding the permitted times, or by falsifying the setting. Enforcement involves ticketing and towing offending vehicles.

Disks eliminate the need for parking meters, and they do not preempt sidewalk space. However, they require a larger enforcement staff — up to three times that for meters.

The disk system has been adopted by towns in Austria, France, Great Britain, Greece, Italy, and Switzerland. The Swiss experience suggests that meters should be placed within the disk zone where there is a demand for very short-period parking — as at the main post office and railway station.

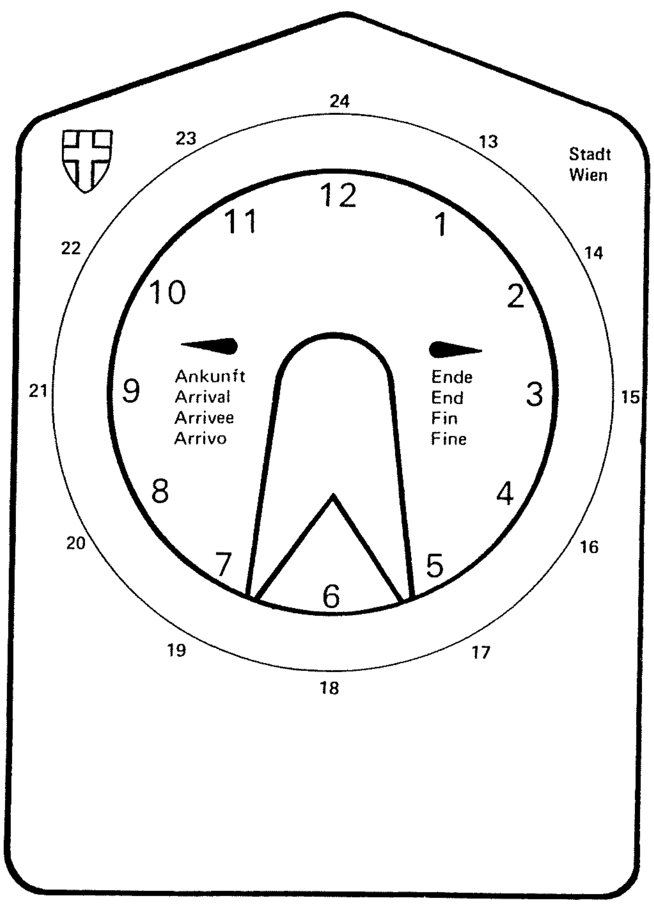

Figure 11.5. Sample parking disk

Parking Cards

The PARCARD system consists of color-coded parking tickets in a packet graduated by price and/or time limit (see Figure 11.6). The motorist, on parking, selects from the packet a ticket of the appropriate price or duration, punches the month, date, hour, and minute of arrival, and displays the ticket in the vehicle's window. Cards are purchased by motorists at retail and government outlets. This system is used in Cork (Ireland), Nyhoking (Sweden), Singapore and Tel Aviv. It has been proposed for the central area of Charlotte Amalie in St. Thomas (U.S. Virgin Islands).

Advantages of parking cards include minimum capital and operating and vandalism costs as compared with parking meters. Cards do not consume sidewalk space and are easier to alter in price than meters.

Disadvantages of the cards include inconvenience to visitors, need for a distribution system, possible abuse, and added enforcement. Violation levels vary from city to city depending on parker attitudes and enforcement levels. In Cork, Ire-

Figure 11.6. Sample PARCARD parking ticket.

land, for example, only 7 percent of the total parking offenses were of such permits.[39]

Charlotte Amalie Proposal

The suggested PARCARD plan in Charlotte Amalie would encompass the entire commercial area. The PARCARD would be a 3 x 8 inch ticket containing three major items of information: month of year, day of month, and a series of space time indicators showing successive expiration times. The front bottom of the card also would have a serial number, boxes to fill in user's license plate number, and a 1-hour parking designation. The back of the card would provide necessary instructions for proper use and the user's address. The unused space on the back of the card would be used for advertisement.

Writing in the license plate number would discourage stealing of PARCARDS. Only the vehicle bearing the plate number written on the PARCARD would be able to use it legally. In addition, the serial and license plate numbers would be used for enforcement purposes. Upon issuing a parking summons, enforcement agents would record the time, date, license plate number, and the serial number of the PARCARD used. This procedure would minimize the possibility of violations being dismissed in court. The serial number would identify the PARCARD involved in the violation and date of violation, and would have to be produced as proof by a parker claiming he was not guilty.

Source: *Comprehensive Transit Plan for the Virgin Islands*, Technical Report, January 1989. U.S. Department of Transportation, and Urbitran Associates Inc.

DESIGN GUIDELINES

Key considerations in design of curb parking space include the angle of parking, width of parking lanes, stall layouts and dimensions, and sign design and installation.

Angle of Parking

The choice of parking angle has important bearing on the design of on-street space. Most on-

[39] Tom Higgins, "Innovations in Parking Control, Time for Assessment," *Urban Innovation Abroad* 4, no. 2 (Washington, D.C.: Council for International Liason).

street parking is parallel to the curb. Some communities, especially smaller towns, provide angle parking — often on the main shopping street.

Space Requirements. Figure 11.7 shows street widths and curb lengths needed for various parking angles.

Arranging parking at an angle to the curb results in more parking spaces per unit of curb length than parallel parking. The increase becomes greater as the parking angle gets greater. At 90 degrees, almost 2.5 times as many spaces can be provided than with parallel parking.

Operating Problems. As the parking angle increases, there is a corresponding need for more road space for vehicle maneuvering. Special problems result from projected vehicle length and the sight distance obstructed by larger vehicles (vans and recreational vehicles) as the parking angle increases. Many before-and-after studies have shown that changing angle parking to parallel parking reduces accidents (see Table 11-5).

Angle parking maneuvers can pre-empt the entire roadway, even on wide streets. For example, 45-degree parking along both sides of a 100-foot wide street will affect the entire width. Each angle parked vehicle would extend into the street nearly 18 feet, and the backout operation would require another 12 to 15 feet. This leaves less than 35 feet for moving traffic and would result in frequent lane changes (see Figure 11.8).

Applications. Where parking is an element of street design, parallel parking is usually more acceptable. Parallel parking should be used wherever parking is permitted on arterial and collector streets.

Angle parking should be limited to streets that function primarily as parking lots. Wherever angle parking is used, suitable "neckdowns" should be provided at each end of the block to channelize entering and exiting vehicular traffic (see Figure 11.9).

General guidelines for closing streets to through traffic and converting them to parking lots are: (1) the street is not needed for the through traffic network, (2) through traffic can be effectively prohibited, and (3) the parking space is more important than traffic circulation.

Flat Angle Parking. Flat angle parking represents a compromise between parallel and angle parking. It provides parking convenience and parking efficiency, but still poses the capacity and safety problems associated with angle parking.[40] Illustrative layouts are shown in Figure 11.10.

Flat angle parking improves the ease of entering the parking space without delaying following traffic. It gives the driver a reasonably clear view of the intended parking space, and there is no encroachment on the travel lane by opening the car's doors.

There are, however, several disadvantages. Drivers tend to disobey the painted lines and may

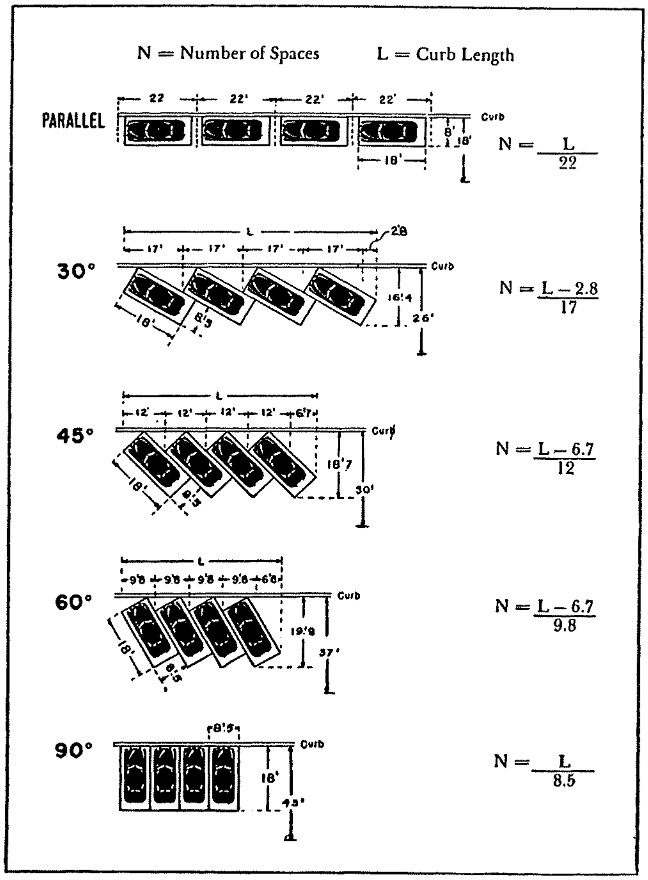

Figure 11.7. Street space used for various parking positions, using 8'6" x 18'0" stalls

Source: Robert H. Burrage and Edward G. Mogren *Parking* Eno Foundation for Highway Traffic Control, Westport, CT, 1957

[40] Ed K. Ischna, "Operating Efficiency in On-Street Parking in Wichita Falls, Texas," *Institute of Transportation Engineers Technical Notes*, October 1978.

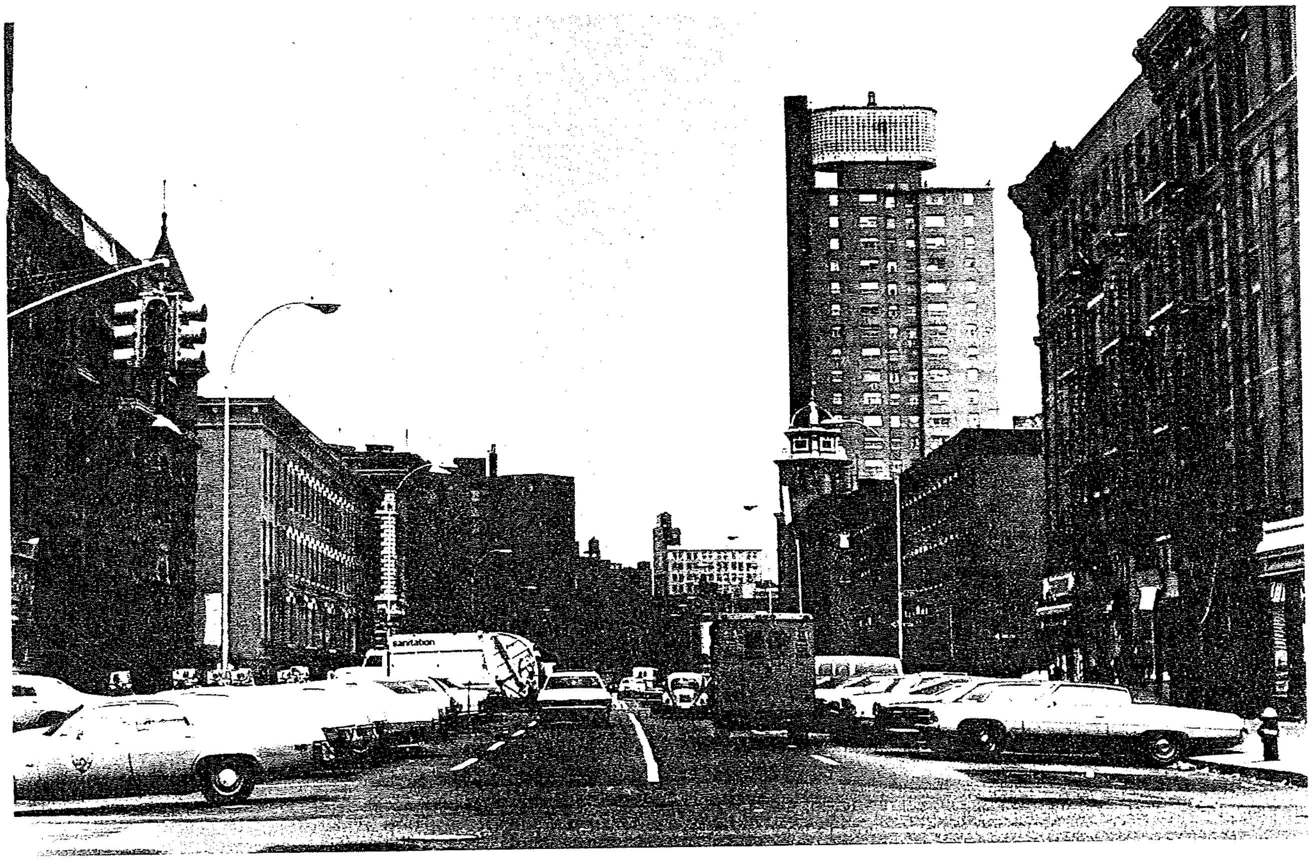

Figure 11.8. Angle parking reduces the amount of road space available to moving traffic

Source: New York City Department of City Planning.

fail to align their vehicles properly in the marked space. Large trucks and campers may block sight distance. Enforcement is essential to ensure that vehicles are aligned properly in the parking stall. Thus, its use should be limited to wide, lightly traveled, low-speed streets.

Width of Parking Lanes

The width of parking lanes should be viewed within the context of the total roadway. It is necessary to consider the width of adjacent lanes, and to determine whether or not the parking lanes might be used for moving traffic during peak periods now or in the future.

Most vehicles park parallel within 6 to 12 inches of the curb face. They occupy approximately 7 feet of actual street space. The desirable minimum width of a parking lane is 8 feet including gutter pan width where curb and gutter sections are used. To provide better clearance and to enable the parking lane to be used as a through lane during peak periods, a 10- to 12-foot wide parking lane is desirable.[41]

Where parking is allowed at all times (e.g., residential streets), the parking lanes should be 8 feet wide. Twelve-foot lanes are desirable where there is a large number of parking-related accidents, a significant amount of on-street truck or bus loading or high parking turnover. Where the curb lanes may be used for moving traffic during

[41] *A Policy on Geometric Design of Highways and Streets* (Washington, D.C.: American Association of State Highway and Transportation Officials, 1984).

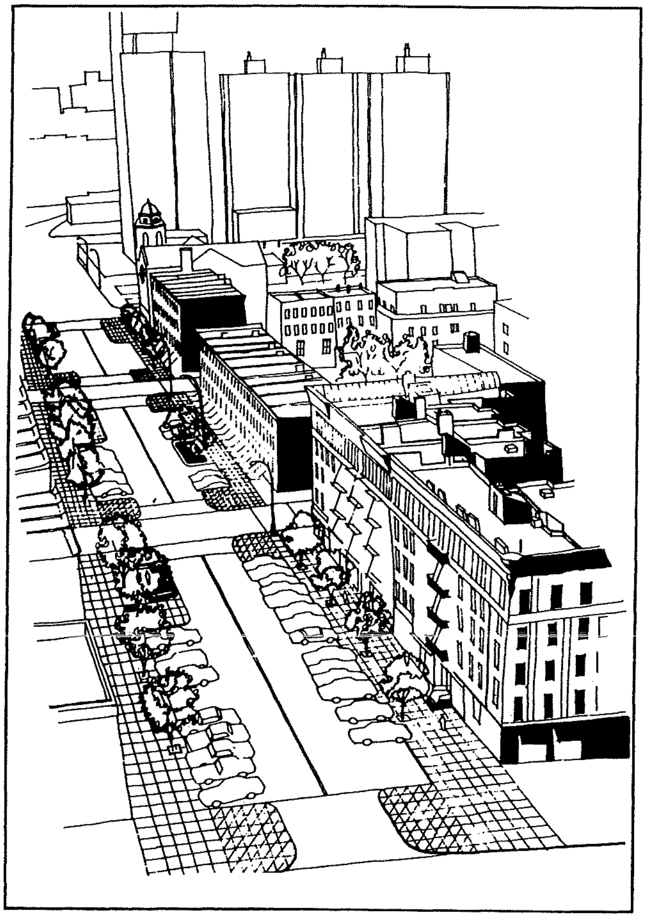

Figure 11.9. Illustrative conversion of a street to a parking lot. Neckdowns protect 90 degree angle parking and provide space for plantings and amenities.

Source: *City of New York*, Department of Planning.

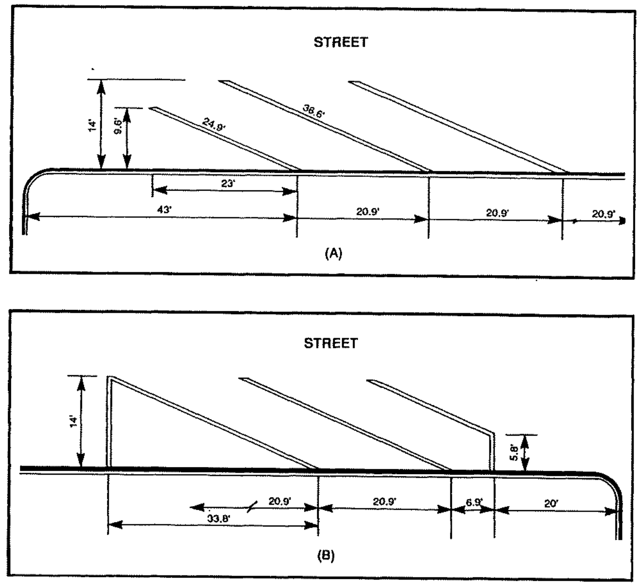

Figure 11.10. Typical flat angle parking layouts

peak hours (or at all times in the future), they should be at least 10 feet wide. This also is a minimum width where the curb lane is used for bus stops.

Stall Layouts and Dimensions

Parking stalls should be marked on arterial and business district streets when parking is permitted, and on other streets when additional parking control is necessary. The markings define the parking place, discourage erratic parking maneuvers and reduce the average time required to park. Specific details vary for end, interior, and paired parking stalls.

Parking stalls should be marked by white lines that extend out about 7 feet from the curb. The end of a stall row is marked with an L, while interior stalls have a T-shaped mark.

End and Interior Stalls. The end stall is used where a vehicle can be driven directly into or out of the space. End stalls occur at the ends of parking rows, adjacent to an intersection, alley, driveway, or restricted area such as a bus stop. A 20-foot length accommodates a typical passenger car and is normally used.

Interior stalls typically are striped in 20- to 22-foot lengths. With an average vehicle length of 18 feet or less, the extra length is needed for maneuvering space. The length of a series of parallel stalls should fit the available curb frontage. Some stretches of curb space will not divide exactly into 20- or 22-foot spaces. The surplus length should be distributed among the stalls involved to speed parking maneuvers. For example, if the distance available for parallel interior stalls totals 225 feet, each of the 10 stalls should be marked at 22.5 feet.

Paired Parking. Paired parking arranges stalls so that two cars are parked bumper to bumper in 18-foot stalls that are separated by maneuvering areas at each end of the paired stall arrangement. Stall lengths of 18 to 20 feet are provided. Maneuvering areas should be 8 to 10 feet long, and clearly marked as open spaces where parking is prohibited (see Figure 11.11). Crosshatching of the clear space is desirable.

A variation of the paired parking layout is Travers Tandem Parallel Parking. The system expands the maneuvering area to 16 feet, allowing the driver to pull alongside the curb in one forward motion. Thus, traffic in the lane adjacent to the curb parking can proceed virtually uninterrupted. This system reduces the number of spaces that can be provided but improves traffic flow. It allows a vehicle to leave the traffic lane in about 4 to 6 seconds as compared to approximately 38 seconds for the standard parallel parking maneuver. The conventional paired method -- depending on the individual driver — can be accomplished in approximately 30 to 32 seconds with 6 individual movements. Travers Tandem Parking allows the vehicle to enter a final parking position in one or two maneuvers depending on whether the vehicle is entering the upstream or downstream stall.

Stall Setbacks. Parking stalls should not be placed too close to driveways, fire hydrants, and intersections. Fire hydrants should be cleared by 15 feet on each side. Driveways should be cleared by a distance at least equal to the proper turning radius. This should be 15 feet from the point the driveway crosses the back edge of the sidewalk for most cases, and no closer than 5 feet to the curb radius ending, if more than a 10-foot radius exists.

No stall should be placed closer than 20 feet from the nearest sidewalk edge of any cross street. Additional distance usually is required on the approach to an intersection to assure adequate sight distance. A minimum 50-foot setback is commonly required on uncontrolled intersection approaches.

The required stall setback distance depends on width of the intersecting street, angle of intersection, type of traffic controls and operating speeds on both highways. It is essential that stalls be setback sufficiently to assure adequate sight distance.

Corner Neckdowns. The narrowing of roadways (neckdown) and the widening of sidewalks at intersections are design features sometimes used on shopping streets and in commercial areas. They are desirable at intersections where there are a large number of pedestrians, a high-parking density and a high probability of parked cars blocking the crosswalk. They are also useful where pedestrian crossing times need to be reduced and corner radii enlarged.

Corner neckdowns have several desirable features. They reduce crosswalk distances, increase sidewalk space, increase sight distances and enlarge turning radii.

Neckdowns require careful monitoring to assure that cars do not illegally park in narrowed sections of the road. They should be used selectively because of maintenance and snow removal problems. Neckdowns should be discouraged where the curb lane might be needed as a through or turning lane, or where turning traffic or bus stops block through travel lanes. Figure 11.12 shows how a neckdown relates to curb parking at an intersection. The minimum neckdown distance should be 20 feet, although longer distances are desirable in areas with heavy pedes-

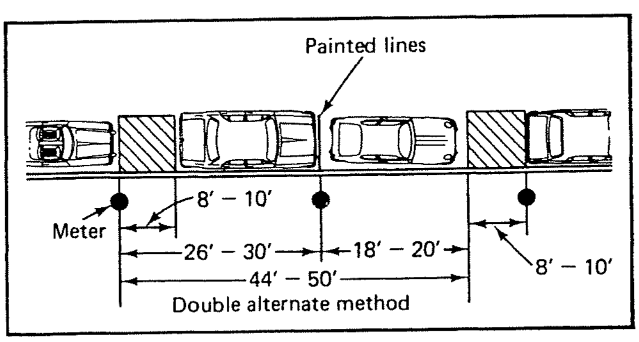

Figure 11.11. Paired parking layout

Source: James Madison Hunnicutt & Associates.

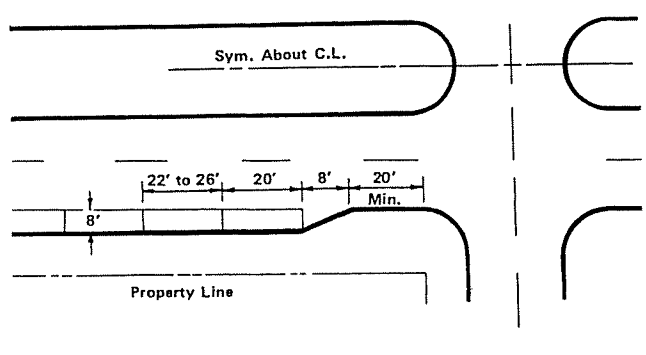

Figure 11.12. Parking lane transition and neckdown at intersection.

Source: A Policy on Geometric Design of Highways and Streets (Washington, D.C.: AASHTO, 1984).

trian traffic. A sharp 1-in-1 taper should be provided between the neckdown and the parking lane.

Signing

It is essential to advise motorists of where and when to park. This is normally accomplished by signage. Some communities supplement "No Parking" signs with painted curbs and pavement stripes. Even in these cases, signs are desirable.

Signs should be visible to motorists, properly located, simply worded, and clear in meaning. Their effectiveness is improved by using standard sizes, shapes, lettering, colors and messages. They should be well maintained, actively enforced and supported by legally enacted ordinances.

International road signs and the U.S. *Manual on Uniform Traffic Control Devices* contain standards for sizes, shapes, colors and placement of signs. The *Manual on Uniform Traffic Control Devices'* standards have been approved by the Federal Highway Administration. They have been adopted (or adapted) by most state Departments of Transportation.

Colors and Messages. The 1978 edition of the manual specifies:

> *...The legend on parking signs shall state whatever regulations apply, but the signs shall conform to the standards of shape, color, location, and use. ...Where parking is prohibited at all times or at specified times, parking signs shall have red letters and borders on a white background; where only limited-time parking is permitted, or where parking is permitted only in a particular manner, the signs shall have green letters and borders...Where parking is prohibited during certain hours and permitted under a time limit at other periods of the day, two parking signs should ordinarily be used, the red above the green. As an alternative, both messages in different colors may be used on a single plate, with the sign lengthened vertically if necessary.*[42]

Both symbols and messages may be used. When a symbol is used for no parking, a black P is circumscribed in a red circle with a red slash on a white background and a black border.

Generally, parking signs should display the following information as is appropriate, from top to bottom of the sign, in the order listed:

1. Restriction or prohibition.
2. Time of day it is applicable, if not at all hours.
3. Days of week applicable, if not every day.

Where the parking regulation applies at night and street lighting is poor, a reflectorized message may be desirable.

Drivers are guided to off-street parking facilities by a sign that says "parking" together with a directional arrow. The legend is green on a white background.

Shapes and Sizes. Most parking signs in urban areas are 18 x 12 inches. The 18 x 24 inch sign is also used to emphasize no stopping regulations along arterial streets or to provide increased readability along higher-speed roads. (International parking signs are circular.)

Location and Placement. Parking signs can be placed perpendicular (90 degrees) to the roadway or parallel at angles of 30 to 45 degrees with the line of traffic flow. Perpendicular signs provide maximum target value to approaching motorists, but they may detract driver's attention from warning signs and signals. Parallel or angle signs allow the use of arrow indications. Where parallel signs are used, a single-headed arrow should point in the direction where the regulation applies. Double-headed arrows should be used at intermediate points within zones that are more than 200 feet long. Depending on the sign legend, a 600-foot block may require up to four signs of 12 x 18 inch size to convey adequately the same message as three 18 x 24 inch sizes.

The parking directional sign is usually installed on major streets at the nearest point of access to the parking facility or roads that lead to it. The *Manual on Uniform Traffic Control Devices* recommends that parking signs "be mounted not less than 7 feet nor more than 10 feet above the top of the curb, and with no part of the sign less than 2 feet back from the face of the curb."[43] With these dimensions, a sign would not likely be blocked by parked vehicles, would not pose a hazard to pedestrians, and would be less

[42] *Manual on Uniform Traffic Control Devices for Streets and Highways* (Federal Highway Administration, 1988), p. 2D-33.
[43] *Manual on Uniform Traffic Control Devices.*

likely to be damaged by errant vehicles.

Parking signs can be placed on utility poles, street light poles or traffic signal devices whenever possible to minimize the number of obstacles and clutter along the sidewalk and roadway. However, correct location should not be sacrificed. Utility poles should be used only with the permission of the controlling company. Where existing poles cannot be used, parking signs should be mounted on posts of sufficient strength so that they will resist wind and vandalism.

Signs supports should be well maintained and replaced if damaged or lost. Good maintenance includes regular scheduled patrolling, adequate stockpiling and rapid replacement of defaced or damaged signs. A periodic replacement program is normally a budget item.

Lighting

Lighting is not normally provided for the specific purpose of curb parking along public streets. When lighting is warranted along streets for other activity reasons, the spillover illumination is usually more than sufficient for curb parking concerns.

Light standards (poles) are normally set at least 1.5 to 2.5 feet behind the face of the curb. This offset, in addition to the 6 to 12 inches people normally park away from the face of curb, provides adequate door-opening space for parallel parking at curbs. The curb setback for light poles and the marked parking stall location in respect to light poles can be a critical concern for parking at curbs.

ENFORCEMENT AND ADJUDICATION PROCEDURES

Parking restrictions are meaningful only if they are properly enforced. Good regulations can be nullified by lax enforcement (see box story). Thus, enforcement of illegal and overtime parking is essential. Equally important are adjudication programs that support enforcement actions.

Nearly all cities provide some form of enforcement. However, many contemporary parking and traffic management policies require more effective actions.

Accordingly, a number of cities have instituted strict enforcement programs to reduce congestion and improve traffic flow, to achieve greater utilization of existing parking supply, and to increase municipal revenue. These programs typically involve one or more of the following actions: rigorous enforcement of on-street parking regulations, towing, and booting. Boston, Denver, Washington, D.C., and Billings, Montana are among cities that use all three of these enforcement actions.

By far, the most commonly-employed action is rigorous enforcement of on-street parking supply. Towing and booting programs are implemented less frequently.

There are two major concerns associated with implementing strict enforcement programs. The first is the issue of police priorities and use of police personnel. Parking enforcement is not perceived to be as important as other police duties, such as apprehension of criminals or prevention of serious crime. In most communities, the police traffic division responsible for parking enforcement is usually the first to be cut both in money and manpower when budget reductions are made. As a consequence, there is increasing use of non-police personnel to enforce parking regulations.

The second concern is the fear that implementing a strict enforcement program will deter customers from entering the CBD to shop and/or conduct personal business. No doubt, overly zealous enforcement of parking regulations, in some cases, has diverted shoppers to suburban malls. The purpose of strict parking enforcement, however, is to free parking spaces in the CBD for those very shoppers by reducing abuse of short-term spaces and creating greater turnover. Thus, success of a strict enforcement program is measured, in part, by assessing the benefits derived from greater utilization of existing spaces and improved traffic flow against the costs of increased merchant displeasure and public concern engendered by stepped-up enforcement measures.

Other benefits are financial in nature, unrelated to parking enforcement's effect on traffic flow or parking availability. If enforcement can create better use of existing parking space, the need to develop additional parking is reduced — representing a savings in development, fi-

Parking in Midtown Manhattan

In a lane-by-lane study of traffic movement in the Lexington corridor, standard traffic counts were used to record the number of cars passing over a counter cord stretched across a roadway. While this approach is useful for obtaining gross figures, it does not tell anything about internal characteristics of the flow. To get this, the daily traffic was filmed with a series of time-lapse cameras aimed at two cordon lines. Then, frame by frame, the passage of each vehicle was charted: what type of vehicle it was — car, taxi, bus, or truck; which lane it was traveling in; the precise second it passed by. In addition, spot observations were made to check vehicle occupancy, right-turn behavior, and the like. The result was one of the most thorough analyses of vehicular traffic made up to that time.

The chart of the traffic on each line showed just how badly distributed the traffic was. Lanes two and three carried 75 percent of the traffic; lane one, the bus lane, had a very small flow; so did lane four, the double-parking lane; lane five had particularly no flow at all.

The key factor was lane blockage by parkers. Close-up studies were performed. How long did the parkers stay? What was the turnover? Time-lapse films were taken and from them charts, like player-piano rolls, were made to chronicle a day's parking in several blocks. The charts showed that a smaller number of long-term parkers accounted for two-thirds of the available parking time. They came early, they stayed late. In the few spaces they did not hog, there was some turnover. But not much, and little of the kind that merchants like to think takes place.

Merchants like on-street parking because they believe it services a high turnover of customers. But it does not. This study showed that in-and-out parking accounted for only a small proportion of the double parking time available. The bulk was by cars parked for hours or more — and they were much more likely to belong to storeowners or employees than customers.

Double parkers? Lots were expected. While it appeared like Lexington was always jammed with double-parked vehicles, when counted, only one or two were found per block at any given time. It seemed odd that so few could do so much. But the number found was not the critical factor. It was the amount of time a lane was out of action because of double parking. Just one vehicle per block is enough.

The double parker, however, is not the villain. Most often he has a truck with a delivery or he is on a service call. He double parks because he has to and he does not tarry long. The real villain is the nonessential parker. He blocks access to the curb for those who really need it; he also slows down traffic in the lane out-board of him. Drivers do not like to skirt too close to a lane of parked cars: since they can expect abrupt pullouts they give it a wide berth, resulting in as much as one-half reduced out-board lane capacity.

A study of the entire midtown business district was also performed. A sweep count of every block, plotting location of each parked vehicle, its license plate, and any identifying cards on the windshield (for example, "Member Police Chiefs Association") was made. The pattern was the same as Lexington's, a relatively small number of vehicles were doing the congesting. On the 36 miles of street in midtown, 4,031 parked vehicles were logged — 2,000 were parked illegally; only 22 were ticketed. In every single block of midtown at least one lane interdicted to traffic — whether by cars parked legally or illegally, double parked, or standing.

There is an extraordinary dis-efficiency in all this. Once one lane is blocked, it takes only a few more elements to bring about a complete stoppage. Add a utility crew digging a hole in the street, a parked mail truck straddling two lanes as is their custom, a trailer truck caught halfway across an intersection — add just one more double-parked car — and the whole thing comes to a honking, cursing halt.

Source: William H. Whyte, *City: Rediscovering the Center* (New York: Doubleday, 1989), pp. 71-72.

nance and tax-roll costs to the community. Better enforcement and adjudication also result in increased revenues. Booting is particulary effective in this respect, because the owner of the booted vehicle must pay all outstanding parking fines before the vehicle is released.[44]

Strict enforcement programs are the result of conscious policy decisions, backed by adequate resources. These programs are ordinarily found only in CBDs, where there is an urgent need to prevent congestion and the hazards created by illegal parking, as well as to regulate use of

[44] Public Technology, Inc., *Innovations in Parking Management*, prepared for the Office of Budget and Policy, Urban Mass Transportation Administration in cooperation with Technology Sharing Program (Washington, D.C.: U.S. Department of Transportation, 1982) p. 16.

available parking space. Outside the city center, enforcement usually is done on a selective basis in response to specific complaints. Strict enforcement in outlying areas is commonly related to arterial streets and business areas where there has been a high incidence of complaints or accidents due to illegal parking.

A comprehensive parking enforcement program consists of ticket writing, towing and impoundment, vehicle immobilization, and an adjudication process with penalties and means of pursuing scofflaws.

Ticket Writing

Ticket writing is the heart of an enforcement program. All cities attempt to ensure compliance with their parking regulations by placing tickets on illegally parked vehicles. Methods of ticket writing, however, vary greatly from city to city. In a study of more than 20 cities, ticket-writing productivity varied from a low of 37 tickets per ticket writer per day to a high of 110. The average productivity was 75 tickets issued per ticket writer daily.[45]

Police Enforcement. Police departments in most cities are involved in the ticket-writing effort. The paramount responsibility of the police department is crime prevention. Police officers do not like to enforce parking regulations. Some police officers feel that parking enforcement is a degrading activity for a trained and experienced officer who is interested in the protection of the public. This feeling is reinforced in some departments by the practice of giving parking enforcement assignments either to light-duty officers or as a form of punishment.

Dislike of parking enforcement activities sometimes reflects the fact that the officer is likely to get more verbal (and sometimes, physical) abuse and political pressure than appears warranted by the results obtained. In residential areas, parking complaints are frequently the result of neighborhood squabbles; while downtown the officer has to deal with merchants, shoppers, delivery vehicle drivers, VIPs, and others who easily become irate over the receipt of a parking citation.

Civilian Parking Enforcement Agents. Use of civilian enforcement agents is increasingly common throughout the United States. Civilian agents are used to enforce parking restrictions in metered areas, areas where residential parking permit programs are in effect, along arterial streets and at loading zones, driveways, fire hydrants, and street intersections.

Civilian enforcement agents may be under police department supervision or they may be employees of another department — usually a department of transportation or a parking agency. Some cities also use civilian agents to control traffic and investigate accidents. Fire officials sometimes can cite and tow hydrant and emergency vehicle easement violations. In San Francisco, transit police enforce bus stop parking restrictions.

In some cities, civilian agents may tow or boot illegally-parked vehicles. In others, a sworn officer must be called if a vehicle is to be towed or immobilized. In all instances, sworn officers have enforcement jurisdiction concurrent with that of civilian agents. There is a tendency for sworn officers not to exercise this authority in areas served by civilian agents, but they have primary jurisdiction and responsibility in those areas.

Advantages of using civilian enforcement agents are:

- Their positions carry lower pay classification grades than police officers.
- They require less training time and expense.
- They devote full time to parking enforcement and cannot be diverted to other activities.
- They release sworn officers for other assignments.

Operating Guidelines. The appearance and actions of ticket-writing personnel are especially important. Personnel should wear a uniform, similar to that of police, signifying the authority of their enforcement role. They should pass rigorous training on what constitutes a parking violation, vehicle identification, patrol ticket writing and record keeping, professional conduct and dress, radio communications, and emergency procedures. Ticket writing personnel should have the sole decision on what constitutes a ticketable offense, as well as what vehicles are to be towed.

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[45] John M. Brophy and Harry W. Voccola, "Parking Enforcement and Follow-Up," *IMPC 25 Proceedings* (Fredericksburg, VA: Institutional and Municipal Parking Congress, 1979) p. 204.

Personnel should have the high-visibility backing of the police department and the city administration. The extent and nature of ticket-writer productivity incentives depends on local circumstances.

The number of ticket writers and supervisors needed depends on individual community circumstances, including the magnitude of its parking violation problem and the physical characteristics of the enforcement area. It also depends on the productivity of personnel — whether the individual can write 30 tickets a day or 100. This latter factor is partly influenced by how ticket writers search for violators — a walking beat or with motorized vehicles.

Washington, D.C.'s ticket-writing program incorporates some of the best strategies used in other cities. Measures include personnel deployment to ensure that both AM and PM peak periods are adequately covered, "sweep" techniques, and radio communications. A computerized management information system makes current planning information available to formulate management decisions in a quantitative, objective fashion.

Advance study before implementing the D.C. program provided much information on how ticket-writing operations could be most effective. From a productivity standpoint, a supervisor/ticket-writer ratio not to exceed seven to one for walking beats was found necessary for adequate coverage and control. With motorized ticket writers, the ratio could go as high as ten to one and still be effective.

Another planning conclusion reached by the D.C. study was that 30 of the 50 ticket writers employed would be more productive if they were assigned walking beats downtown. Large passenger vans were purchased for the supervisors to transport ticket writers to and from their walking beats. The remaining 20 ticket writers were assigned to cover areas outside the CBD and along major arterials during the AM and PM peaks.

During the first year of operation for the civilian enforcement program in Washington, D.C., meter revenues increased nearly 33 percent.[46] This unexpected benefit was enough to fund the entire ticket-writer program and was projected to yield better than a seven to one benefit-cost ratio.

The level of enforcement of parking regulations depends on local policy and the resources available to maintain the level of effort required by that policy. Parking enforcement must be carefully planned to be effective. Random enforcement by police officers on beat assignments is rarely satisfactory.

Towing and Impoundment

The primary purpose of towing is to remove any vehicle from the street that creates a hazard, impedes traffic flow, or is abandoned. A secondary purpose is to enforce the collection of fines when a number of tickets issued for a particular vehicle remain unpaid. Cities place emphasis on towing because motorists simply are not deterred by threat of a parking ticket. In fact, the majority of parking tickets issued across the country are never paid.

An effective towing program addresses several problems:

- Costs are high, although they usually can be recovered from the violator.
- Existing law may require that a sworn officer be present to authorize the tow and vehicle impoundment. In some cities, however, civilian agents can authorize towing.
- Contract towers may provide unsatisfactory service, particularly if a towing request conflicts with a higher-paying, non-contract job. Thus, the ability to terminate a contract for unsatisfactory service is critical.
- Damage claims may be filed.

The issue of whether to buy tow trucks and hire drivers or to enter into a contract with a private operator may generate considerable political heat. In many areas, towing contracts traditionally have been a source of graft and patronage. Finally, some courts have held that unless a hazardous situation exists, a vehicle owner is entitle to due process, including notice and hearing, before the vehicle is towed.[47]

Traditionally, towing and impoundment operations have taken one of two forms: an operation

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[46] Ibid, p. 206.
[47] Public Technology, Inc., *Parking and Traffic Enforcement*, p. 4.

The Washington, D.C. Tow Program

The Washington D.C. program is unique. It is neither private nor municipal; rather it is a blend of both. The towing staff is in the employ of a private firm under contact to the District. The company provides drivers and tow trucks only. The District provides management and overall direction. This gives them minute-by-minute control over street activities and greatly reduces the potential for mishandling towed vehicles and misappropriation of valuables inside vehicles. Drivers have an incentive program that is designed to produce a high number of tows per day, which is targeted at 1.5 vehicles towed per hour.

As part of its overall program direction, the D.C. Department of Transportation runs the dispatch office and impoundment lots with government employees. The dispatch office has been modeled after taxicab operations. The tow truck driver is given absolutely no discretion in making a tow. Vehicles are identified for tow by civilian parking enforcement agents, who make the sole determination to remove a vehicle. The District's tow program is designed to peak at 450 tows per day. Projected annual revenue to cost ratio is 3.7 to one.

Towing and Impoundment Guidelines

1. Tow drivers should only tow vehicles on the dispatcher's orders, and only those vehicles clearly marked for towing by the ticket writer.
2. Tow drivers should relinquish a marked vehicle to its owner if the owner returns before the car is removed.
3. Before towing, tow drivers should complete a written description of any pre-existing vehicle damage. The report should be verified by the impoundment lot supervisor when the tow is completed.
4. Towing equipment should be capable of removing a vehicle without inflicting damage.
5. Towed vehicles should be sealed as soon as they are brought to the impoundment lot. Access to vehicles should be limited to the lot supervisor only.
6. Impoundment lots should be conveniently located to minimize towing distance and time.
7. Impoundment lots should be secure at all times.
8. Impoundment vehicles should be listed with the police department and the parking enforcement agency, and checked for any outstanding warrants, their appearance on stolen vehicle lists, and any reported involvement in criminal activity. Information provided should include vehicle description, vehicle identification number, and registration number.
9. Provisions should be made for disposing of unclaimed vehicles in accordance with local, state, and federal laws.
10. Provisions should be made for releasing impounded vehicles to owners. These procedures must ensure that all fines and impoundment charges have been paid, and the claimant is the legal owner or the owner's designated representative. Also, an expedient means of recourse should be established for financial hardship cases.

Identifying Vehicles For Towing

A ticket is written against the vehicle, and a bright orange sticker is placed on the rear window. The ticket writer then calls the DOT dispatcher via walkie-talkie and asks for a tow truck, and gives the plate number and location of the vehicle to be towed. The dispatcher calls for the nearest tow to remove the vehicle. Some cities merely ticket vehicles as they choose. The District's program originators felt that this type of operation was susceptible to wrongful tows, theft by tow drivers, and encouraged confrontation between tow drivers and vehicle operators.

The District's program can monitor towing operations closely. For example, to avoid street scenes and bad publicity, they have instructed the tow operator to return the car to the owner whenever a vehicle owner returns before the car is removed from the curb. This policy has kept street confrontations to a minimum and has contributed to strong public support for the tow program.

Tow Truck Equipment

Another unique feature of the District's tow program is the tow truck itself. The District requires the contractor to use a "cradle snatcher" instead of the conventional hook and sling vehicle. The cradle crane uses a rubber belt that fits under the car's chassis. With this device, the car can be gently lifted from a parking space and carried safely to the impoundment lot with little risk of damage. This feature has been extremely successful in reducing damage claims to less than 1 percent of all tows performed. In addition, tow drivers are required to fill out a report on each towed vehicle, describing pre-existing damage. When the driver arrives at the impoundment lot, this report is verified by the District's lot supervisor.

Securing Towed Vehicle Contents Against Theft

The District's answer to missing property from the vehicle is to seal every vehicle as soon as it comes to the tow lot. Doors, trunks and hoods are secured with tape and numbered seals so that entry to the vehicle can be strictly controlled. Only supervisors are permitted to break these seals, and only for specific reasons such as returning personal property to car owners before the vehicle itself is redeemed.

Impoundment Lots

The District's towing program uses several impoundment lots. Each is strategically located to provide quick access for tow trucks from virtually any section of the city. This is in contrast to many cities where impoundment lots are located in remote areas, forcing tow drivers to travel long distances between tows and greatly reducing the efficiency of operations.

Considerable attention has been paid to security in the District's impoundment lots (where the potential for theft and vandalism is greatest). The lots are well-lighted and fenced. Guards are on the lots 24 hours a day, 7 days a week.

run exclusively by municipal employees or one that is handled by a private contractor. Normally, the contract operation is characterized by good productivity and poor controls. The towing firm generally hires a team of experienced tow drivers — offers them a dollar incentive — and turns them loose on the street.

The problems are different for a municipal operation. Productivity is usually low. The pay is low and the job offers little incentive. However, the controls are better because the municipal employee is under no pressure to tow a large number of vehicles each day. Washington, D.C.'s program was planned to capture the best feature of both types of operation.

Vehicle Immobilization

Another way to collect overdue fines from scofflaws is to use the "boot" (often referred to as the Denver boot) or other devices that immobilize a vehicle and prevent its use until outstanding tickets are settled. This is an effective means of parking enforcement. It involves the identification of scofflaws that have outstanding unpaid tickets. After the vehicle is found on public property, a steel device (boot) is lock-clamped on one of the wheels to prevent the vehicle's movements. When convenient, the vehicle can be towed to an impoundment lot, or left at its parking spot.

Booting is used successfully in many cities. Boston uses it on over 90 percent of the scofflaw vehicles that it identifies. Potential advantages of booting include:

- Fewer damage claims.
- Less impoundment lot storage space required.
- No loss of time waiting for a tow truck.
- No traffic control problems such as occur when towing.
- The boot can be used when a car is parked too close to other vehicles to permit towing.
- Training in the boot's use requires only 30 minutes.
- The vehicle remains on the street as a visible deterrent.
- Release process is simpler and less time-consuming for all involved.

Obviously, booting cannot be used where failure to remove the vehicle will create a hazard or impede traffic, nor would it be used in areas where car-stripping is common. Towing is preferable along arterial streets with peak-hour parking bans.

The vehicle immobilization program can be operated by the police department, special civilian personnel, or both. Ticket writers usually are not prepared or expected to spot scofflaws. Specifically assigned search teams should be charged with this task. Additional staff support is needed to provide the search team with information on scofflaws, including areas frequented, type of violations outstanding, and the hours violations are committed. This backup data is critical to the success of a vehicle immobilization program.

Adjudication of Parking Offenses

Adjudication is the follow-up process that assures the effectiveness of a parking enforcement program. Adjudication consists of the judgement process and the penalty and pursuit process. Penalty and pursuit processes are government actions taken once it is determined that a parking ticket has not been acknowledged voluntarily. The adjudication process is initiated by the ticket recipient. A percentage of ticket recipients will pay their fine or appear for adjudication without the threat of pursuit and further penalty. Depending on the credibility of the pursuit process and eventually penalty, the percentage of violators that promptly pay or appear varies roughly between 10 and 33 percent.[48]

Many cities have improved traffic and parking conditions by integrating and coordinating their enforcement activities. They also have collected significant additional revenues from parking meters and parking fines that were previously unpaid.

The implementation of an effective parking enforcement program requires that both enforcement and adjudicatory personnel have ready access to a reliable source of current data about violations and unpaid tickets. When the volume of these data in a large city increases materially

[48] Brophy and Voccola, "Parking Enforcement and Follow-Up," p. 212.

because of a strict enforcement program, the capacity of available computer facilities and staff may be strained, causing error to occur in such activities as towing, booting and the denial of registration renewals. The adequacy of the data system and the actions necessary to bring it up to a satisfactory level should be considered as a part of enforcement program planning and costs.

Judgement Process. In the past, many local jurisdictions treated parking tickets as criminal violations. This meant that the 2 to 3 percent of these tickets that were contested had to be heard in the criminal court system. Increased enforcement of parking violations during recent years has added to already staggering criminal court system loads, where parking ticket appearances are given the lowest priority.

Efforts to improve this situation have led many jurisdictions to decriminalize parking violations, removing them from the criminal court to an administrative adjudication process. This civil law process provides for administrative determination (usually by a para-judicial hearing examiner), imposition of a monetary penalty, possible civil judgement, and authority for the ultimate execution of the judgement. Generally, administrative adjudication allows the parking ticket to serve as the *prima facie* evidence, meaning that the ticket serves as evidence at the hearing, without the need for the ticket writer's appearance at a hearing.

Some cities, like Washington D.C., that use administrative adjudication also permit other conveniences that would not be allowed in the criminal court system. These include unscheduled walk-in hearings during business hours, write-in explanations to contest tickets, and the acceptance of credit card payment for fines.

Penalty and Pursuit Process. Penalty and pursuit is the other half of the follow-up process. Today, many cities experience parking ticket collection rates of less than 35 percent. This not only affects the public's perception of the enforcement program, but also represents substantial revenue loss.

Since the cost to process a parking ticket, including adjudication and pursuit, frequently exceeds $5 per ticket, fines must be established high enough to cover processing expenses. Fines also must be substantially higher than the cost of parking legally.

The penalty and pursuit phase of the follow-up process should begin with the parking ticket itself. The ticket should be designed to encourage a response. It must be durable — able to withstand the weather — and it must present a clear and legible image. The ticket should include these elements: vehicle description, location of occurrence, time and date of violation, type of violation being charged, fine amount, legal time allowed for response, and alternative methods of responding.

For the pursuit process to be effective, interagency cooperation must be established. This normally includes department of motor vehicles, police department, and the parking enforcement agency. At least one (and perhaps, only one) notice of delinquency should be sent to the offender.

The delinquency notice should include: options for response (payment or hearing), time limit for response, acceptable payment methods, locations for response, and the consequences for nonresponse. If there has been no acknowledgement after 15 to 30 days, the pursuit process can become more aggressive. The vehicle can be impounded or renewal of its registration can be deferred.

Some communities have found telephone contact to be very effective in reaching individuals who ignore parking tickets. This can be carried out by department staff or by contracted collection agencies, whichever is more cost effective. Collection agencies also employ skiptracers to locate scofflaws who change address. Collection agencies generally collect between 15 and 25 percent of the tickets assigned to them, and their fee ranges from 18 to 50 percent of the money collected.

SUMMARY

Curb space is a scarce resource especially in the city center. Priorities for its use should be established in the public interest. Arterial streets should favor the needs of moving traffic; thus, parking should be restricted at all times or during busy traffic periods. Collector and local streets may permit parking, especially where off-street space is not available.

Parking should be prohibited at all times where safety conditions mandate — near fire hydrants, at driveways, on approaches to intersections and along narrow streets. At other locations, a balance should be made between the needs of moving traffic and curb access.

Curb parking restrictions are a cost efficient means of providing street capacity. The restrictions, however, are effective only if they are properly enforced. Thus, a strong and active enforcement and adjudication program is essential.