THE DIMENSIONS OF PARKING

FIFTH EDITION

ULI Urban Land Institute

NATIONAL PARKING ASSOCIATION

THE DIMENSIONS OF PARKING

FIFTH EDITION

Urban Land Institute

National Parking Association

Printed in the United States of America.
19 18 17 16 15 14 13 12 11 10   1 2 3 4 5

ISBN: 978-0-87420-120-8
ULI Catalog Number: D113

Library of Congress Cataloging-in-Publication Data

Dimensions of parking. – 5th ed.
p. cm.
ISBN 978-0-87420-120-8
1. Automobile parking. 2. Parking garages. 3. Land use, Urban. I. Urban Land Institute. II. National Parking Association.
HE336.P37D55 2009
388.4’74–dc22
2009024162

About the Urban Land Institute

The mission of the Urban Land Institute is to provide leadership in the responsible use of land and in creating and sustaining thriving communities worldwide. ULI is committed to

▷ Bringing together leaders from across the fields of real estate and land use policy to exchange best practices and serve community needs;

▷ Fostering collaboration within and beyond ULI's membership through mentoring, dialogue, and problem solving;

▷ Exploring issues of urbanization, conservation, regeneration, land use, capital formation, and sustainable development;

▷ Advancing land use policies and design practices that respect the uniqueness of both built and natural environments;

▷ Sharing knowledge through education, applied research, publishing, and electronic media; and

▷ Sustaining a diverse global network of local practice and advisory efforts that address current and future challenges.

Established in 1936, the Institute today has more than 32,000 members worldwide, representing the entire spectrum of the land use and development disciplines. ULI relies heavily on the experience of its members. It is through member involvement and information resources that ULI has been able to set standards of excellence in development practice. The Institute has long been recognized as one of the world's most respected and widely quoted sources of objective information on urban planning, growth, and development.

About the National Parking Association

The National Parking Association is an international network of companies representing thousands of parking industry professionals. It represents private operators, parking consultants, colleges and universities, airports, municipalities, parking authorities, hospital and medical centers, developers, and others, along with industry vendors.

It has as its mission:

▷ To serve and assist members in identifying and solving the difficulties that arise in their business activities;

▷ To promote the research and publications necessary to keep the industry abreast of all critical developments affecting parking and parking-related services;

▷ To enhance the image, public acceptance, and economic progress of the parking industry by means of programs and projects directed to the general public instrumentalities of government and the business community; and

▷ To encourage and promote ethical business practices among the operators of parking facilities, and to instill in public and nonpublic users of parking services confidence in the integrity and skills of parking operators.

Project Staff

DEAN SCHWANKE
Senior Vice President
Publications

ROBERT T. DUNPHY
ULI Project Manager

JASON SCULLY
ULI Project Manager

ADRIENNE SCHMITZ
ULI Project Manager

STEPHEN SHANNON
NPA Project Director

JAMES A. MULLIGAN
Managing Editor

SANDY CHIZINSKY
Manuscript Editor

BETSY VANBUSKIRK
Creative Director

BYRON HOLLY
Senior Designer

CRAIG CHAPMAN
Director, Publishing Operations

ACKNOWLEDGMENTS

THE PREVIOUS EDITIONS OF *THE DIMENSIONS OF PARKING* have been enthusiastically received by the planning and design community as a benchmark resource for understanding the basics of the parking industry. Needless to say, updating a popular publication such as this and incorporating new and fresh concepts has been a challenge. This is especially true given the fact that the publication is written by numerous skilled and experienced individuals, each with a different style of writing and a unique perspective on the parking industry. My sincere thanks go to the principal authors and contributors who spent hours writing and rewriting their respective chapters. Sincere thanks go to Jerry Marcus, who at the start of this project gave much time and effort to lay the foundation for this important publication, and to Scott Herman, Stephen Rebora, and Donald Monahan, who assisted with final review of the manuscript.

At the Urban Land Institute (ULI), Jason Scully took on the enormous task of reviewing every chapter, coordinating the editing and layout, and ensuring that the publication has a single, unified voice. This update would not have been possible without his attention to detail and constant prodding to keep me focused and the project on schedule. A special thank you is extended to Robert T. Dunphy, former ULI senior resident fellow, transportation, who not only oversaw this edition of *Dimensions*, but also was instrumental in the update and completion of the fourth edition. My gratitude goes to Sandy Chizinsky not just for her work as a copy editor, but also for her artistry in improving the flow and readability of the text. Rachelle L. Levitt, former executive vice president of ULI's Global Information Group, was steadfast in her support of this book in both its current and previous editions. Finally, the efforts of other ULI staff members, who behind the scenes provided much assistance with the execution and completion of this publication, are greatly appreciated. The guidance of Dean Schwanke, ULI senior vice president of publications, has been essential to completion of this edition. Byron Holly created an inspired and eye-catching design for the book. The talents and skills of James Mulligan, Betsy VanBuskirk, Adrienne Schmitz, and Craig Chapman were also essential to the book's completion.

STEPHEN J. SHANNON
Managing Principal, Carl Walker, Inc.
National Parking Association/Parking Consultants Council
Project Director

ABOUT THE AUTHORS

THIS FIFTH EDITION OF *THE DIMENSIONS OF PARKING* is the result of a collaborative effort between the Urban Land Institute (ULI) and the National Parking Association (NPA) that goes back 30 years. Since the first edition was published in 1979, many members of the NPA's Parking Consultants Council (PCC) have worked innumerable hours to contribute their knowledge and expertise to production of a resource for the average reader on the many facets of the parking industry. More information on the PCC, a full listing of the active members, and a list of other publications can be found at www.npapark.org/pcc.php.

For this fifth edition, the following individuals served as primary authors and contributors:

Robert A. Chapman, senior project manager, Kimley-Horn & Associates, Inc., Orlando, Florida

Rick Choate, principal, Choate Parking Consultants, Inc., Irvine, California

Larry Church, senior project manager, Walker Parking Consultants/Engineers, Elgin, Illinois

Gary Cudney, president and CEO, Carl Walker, Inc., Kalamazoo, Michigan

Larry Donoghue, president, Larry Donoghue Associates, Inc., Park Ridge, Illinois

John W. Dorsett, senior vice president, Walker Parking Consultants/Engineers, Indianapolis, Indiana

Matt Feagins, principal, Walter P. Moore & Associates, Inc., Houston, Texas

Scott B. Herman, owner/architect, HNA/Pacific, Kailua-Kona, Hawaii

Forrest N. Hibbard, senior parking planner, Kimley-Horn & Associates, Inc., Atlanta, Georgia

Mark Hoffman, principal, THP Ltd., Inc., Cincinnati, Ohio

Chuck M. Ignatz, principal, Graelic LLC, Cleveland, Ohio

Victor M. Iraheta, vice president/managing principal, Walker Parking Consultants, Atlanta, Georgia

David LoCoco, principal, Watry Design, Inc., Redwood City, California

Jerry S. Marcus, principal, Walter P. Moore & Associates, Inc., Houston, Texas

Sylvie Mercier, principal, Read Jones Christoffersen, Ltd., Vancouver, British Columbia

Donald R. Monahan, vice president, Walker Parking Consultants/Engineers, Englewood, Colorado

David A. Moore, principal, Walter P. Moore & Associates, Inc., Atlanta, Georgia

John Purinton, principal, Watry Design, Inc., Redwood City, California

Stephen J. Rebora, president, DESMAN Associates, Chicago, Illinois

Richard A. Rich, principal, Rich & Associates, Inc., Southfield, Michigan

Stephen J. Shannon, managing principal, Carl Walker, Inc., Cherry Hill, New Jersey

Mary S. Smith, senior vice president, Walker Parking Consultants/Engineers, Indianapolis, Indiana

David Vogel, design partner, Parking Design Group, Long Beach, California

H. Carl Walker, CW Consulting LLC, Kalamazoo, Michigan

Finally, the current membership of the PCC acknowledges the contributions and efforts of all the authors of the previous editions of this publication who laid the foundation for this newest edition. Many of these individuals represent icons in the parking consulting community who, with their decades of service, have helped establish parking industry guidelines and standards to improve parking conditions worldwide. The PCC gratefully acknowledges: Richard S. Beebe, Charles M. Bolden, Thomas J. D'Arcy, George Devlin, Bernard Dutch, T.J. Feagins, Jr., John Fujiwara, Norman L. Goldman, E. Carlton Heeseler, Norman G. Jacobson, Jean Keneipp, Robert Lathan, Howard D. Linders, Howard R. May, Merritt A. Neale, Richard C. Rich, Richard F. Roti, Richard Sawka, Charles J. Sharitz, James E. Staif, Gerald Stocks, Edward M. Whitlock, and Ben W. Young.

PREFACE

PUBLISHED IN 1979, THE FIRST EDITION of *The Dimensions of Parking* was the start of an enduring partnership between the Urban Land Institute (ULI) and the National Parking Association (NPA). Each edition is written by members of the NPA's Parking Consultants Council (PCC), which was formed in an effort to consolidate knowledge in the field of parking design and management, and to provide a mechanism for making this information available to the public. Composed of experts, the council focuses on economic analysis, functional and structural design, financial counseling, research analysis, and maintenance of parking facilities.

Four years after publication of the first *Dimensions*, a second edition was released. A third edition came out in 1993 and the fourth edition was published in 2000. With each new version, the information is revised and updated. Out-of-date information is deleted and new topics added. In the 30-year lifespan of *Dimensions*, the country and the world have changed dramatically. The ten years between the fourth edition and this current edition have been especially marked by historic milestones, national traumas, and looming decisions on a response to global challenges created by climate change.

Of special interest to parking professionals are shifts in demand for cars, availability of oil, and alternative fuel technologies. The popularity of light trucks and sports utility vehicles is rapidly diminishing, and many are debating whether parking geometrics need to change in response to the potential for decreased use of these large vehicles. (In short, changes in geometrics are not recommended; see Chapter 7 for details.) The 2009 bankruptcies of General Motors and Chrysler are a cause of concern for the American automobile industry as a whole. The steep increases in oil prices, concerns about peak oil, unrest in the Middle East, and the rise of the Chavez regime in Venezuela mean that both short- and long-term supplies of oil are in question. Further, alternative fuel technologies may create unforeseen changes in how cars are parked in the future.

Despite all these changes and the challenges, it is clear that the need for parking will continue. What form future parking facilities will take and what innovations will occur are unknowable. However, *The Dimensions of Parking* has proved itself—with its previous editions and this fifth edition—capable of keeping up with and reporting on the new directions and challenges that parking and real estate professionals face. It is with great pride that ULI and NPA present *The Dimensions of Parking,* Fifth Edition.

CONTENTS

INTRODUCTION

JERRY MARCUS

THE PURPOSE OF THIS PUBLICATION is to foster a better understanding of the planning, design, development, and operation of parking facilities. While we all hope to see a reduced dependence on the automobile as the main means of urban mobility, today, the prospect of a more pedestrian-oriented transit infrastructure is not realistic in many regions of the country.

In many types of development, the overall area of the parking component is equal to or larger than that of the businesses the parking serves. Yet despite its large share of a project's total square footage, parking has been at best a secondary consideration in many prominent developments.

The Dimensions of Parking seeks to provide those who develop parking facilities with information that can improve development of those assets. This publication has been cowritten by professionals from top consulting firms that specialize in parking and share the desire to improve parking conditions.

HISTORY

Since the time when Model T owners stored their cars next to buggies in horse barns, the parking facility has become a fundamental element in the development of urban centers throughout the world. Parking garages began as one-story brick buildings in mostly residential neighborhoods. Hotels in major cities were the first business type to build structured commercial garages, and most first-generation commercial garages were attended "valet garages." Many of the early garages were heated, enclosed buildings with traditional window glazing systems.

It was the hotels, predominantly in the downtowns of cities like Chicago and New York, that revolutionized parking and made garages a significant part of the urban landscape.[1] The Hotel LaSalle in Chicago was among the first hotels in the country to take on the parking challenge. It built a red-brick, multilevel, freestanding garage with glazed windows to keep out the rain and a ramp to ensure speedy parking. The hotel touted it as "America's finest garage."

Although automobiles were invented in the 19th century, they did not become common until 1905, when hundreds of companies churned out "horseless carriages." In cities everywhere, these early automobiles jockeyed for space with carriages, horses, and trolley cars; there simply was not enough street parking available to accommodate them all. There was only one way to go: up.

In the late 1920s, resilient automobile paint finishes set off another major change in parking facility design. Cars could be left outside in the rain or snow overnight without being damaged, an innovation that led to garages without windows. Although the construction of new garages came to a halt with the Great Depression, and later with World War II, new construction rose sharply in the late 1940s with the first self-park garages. The interfloor ramping systems in early self-park garages were straight express ramps, with all vehicles parked on flat floors. In the late 1940s, parking garage designs were reinvented once again with the proliferation of park-on ramp designs.

With the building boom of the 1950s, the self-park, open-air facility became the standard of parking design for many years. Just as service stations evolved into self-serve gas stations, parking garage owners, in an effort to reduce operating costs, moved away from the 100 percent valet model. The self-park garage design was used at commercial for-pay facilities, as well as private parking garages. With the move away from attended facilities dramatically reducing labor costs, many businesses that previously could not afford structured parking developed new parking garages.

EVOLUTION OF PARKING FACILITY DESIGN

The design of parking and particularly parking structures has evolved since those first horseless-carriage barns. Early parking garages were short-span structures. Designs that allowed clear-span structures were extremely expensive and not economically viable because paying for parking was not yet a universally accepted concept. Many early parking facilities earned revenue from the sale of gasoline or on-site repair services. But as parking became a viable business in many of the country's larger cities, garage designs improved.

In addition to valet and self-park garages, several other parking schemes were attempted. Elevator garage operations began in the United States in the 1930s—simple elevator systems that moved cars vertically to pigeon-holed spaces or single-bay parking floors. Mechanical systems designed in the late 1940s used elevator cars that operated on a gantry and allowed the car to move vertically and horizontally. Although there were many elevator garages in America's most dense urban centers, automated parking never became popular in the United States: economics favored conventional self-park designs with lower labor and maintenance costs. Mechanical parking systems fared much better in Europe and Japan, where large real estate parcels are scarce—a scarcity that continues to drive advancement of mechanical designs in those countries today.

The overriding goal imposed on most parking designers has always been "efficient parking." Much attention has been paid to minimizing stall geometry and circulation area in parking facilities to yield highly efficient parking. While optimized efficiency is still important, the trend now is to provide more functional, user-friendly designs.

Today's parking facilities are sophisticated buildings created for specific user groups, with designers focusing on the vastly divergent use patterns of parking patrons. For instance, a garage appropriate for a downtown office building may be inappropriate for a medical office building. Many authors of the fifth edition of *The Dimensions of Parking* focus on the facility patron, not just the automobile. Space width, row orientation, vertical circulation, wayfinding, throughput, and new technologies in the area of parking access and revenue control—all topics that address the user's overall parking experience—are covered in this publication.

WHY *DIMENSIONS OF PARKING*?

There is no type of development that is not touched by the issue of parking. No sports facility, convention center, theater, apartment building, retail center, office building, medical complex, airport, municipal facility, or institution of higher education can be developed without considering some of the issues presented in this publication.

Just as the fundamental business strategies of other property types have evolved, so has much of the subject matter featured in this publication. The sports facility has evolved from a place offering a simple family activity to a retail and corporate entertainment colossus. Retail venues have morphed from regional malls into lifestyle centers. And commuter stations have quickly grown up to become transit-oriented developments.

The fifth edition of *The Dimensions of Parking* strives to cover many aspects of parking and provide the reader with the current best practices in the industry. The authors are more than just architects, engineers, designers, and consultants; they are specialists who are passionate about their field. They take the reader through the processes of planning and design, and then weigh in on the operational considerations of managing safe and secure facilities. And, finally, they discuss the long-term maintenance issues associated with this building type. It is the authors' hope that readers of *The Dimensions of Parking* will gain a greater appreciation for parking facilities.

NOTE

1. Mary Beth Klatt, "Car Culture: Some Cities Convert Historic Parking Garages into Lofts or Lots," *Preservation* online, Oct. 4, 2004. www.preservationnation.org/magazine/story-of-the-week/2005/car-culture.html.

THE DIMENSIONS OF PARKING

FIFTH EDITION

CHAPTER 1

Parking STUDIES

JOHN W. DORSETT AND MARY S. SMITH

ADEQUATE, CONVENIENT, AND AFFORDABLE PARKING is a concern for nearly everyone who uses an automobile—or is affected by the use of automobiles. First, automobile parking is essential to most land uses. Second, parking affects property values and influences the economic return on public and private sector investments. Finally, on a broad scale, decisions about parking influence travel behavior, including choice of travel mode, and land use and development patterns.

The development, construction, operation, and maintenance of parking facilities represent a significant expense and usually call for both public and private sector involvement. Public involvement can range from the typical permitting and regulatory actions to full responsibility for developing and operating parking facilities. Most parking, however, is developed and operated by the private sector.

Regardless of how responsibilities are allocated, the intricacies of parking warrant careful analysis and coordinated decision making. As a result, parking consultants are now typically involved in all aspects of the development and operation of parking facilities. The parking consultant's role is to provide technical assistance to those who are in decision-making positions: public and private sector managers; elected officials and their staff; investors; and real estate developers. Parking consultants are familiar with the parking characteristics associated with most land uses, and understand that proper data collection, careful analysis of site-specific circumstances, and experienced judgment are crucial to the successful development of parking facilities.

Some parking consultants offer highly specialized services; others provide comprehensive services, including the following:

- planning and site studies;
- traffic studies and engineering reports;
- design;
- construction management;

The rules of designing and developing parking garages are changing. For example, the John P. McGovern Texas Medical Center features six levels of parking (four above ground and two below) in addition to a food court, a conference center, and office and meeting spaces.

- ▷ financial analysis;
- ▷ operations consulting; and
- ▷ recommendations for maintenance and repair.

Whether the problem is how to meet current or future needs, how to improve operations, or how to evaluate the need for maintenance and repair, the first step is often a parking study. There are as many types of parking studies as there are parking problems to be solved. In general, however, the consultant undertaking the study evaluates a parking problem and its causes, analyzes alternative solutions, and develops recommendations on the basis of site-specific evidence. The consultant may also identify opportunities for coordinated actions, detail the probable ramifications of implementing those actions, and provide an estimate of financial and other costs. No parking study should be more voluminous than

Parking can be an essential tool in urban revitalization. The 905-space, seven-level South Spring Street Garage in Greenville, South Carolina, was developed as part of a larger strategy to bring new life to the city's downtown.

necessary, and it should communicate in a way that is easily understood by nonspecialists; ideally, the client should be able to use the data to arrive at the same conclusions as the professionals who performed the study.

Typically, a parking study includes three components: a parking supply/demand analysis; a site alternatives analysis; and a financial analysis. Some studies include only one of these three components; others include additional components, such as an analysis of traffic impacts or of parking management and operations. The following list describes some of the elements that may be included in parking studies.

▷ *Parking supply/demand analysis.* An evaluation of the current and future amount of parking space in relation to demand; identifies shortages or surpluses.

▷ *Market study.* A projection of the number of users who may be captured by a facility on a particular site, given demand, competition, and prevailing parking rates.

▷ *Shared-parking analysis.* A projection of parking demand in mixed-use areas that takes into account (1) variations in demand by season, day of the week, and time of day, and (2) the relationship between parking needs and planned land uses.

▷ *Alternatives analysis.* An evaluation of the alternatives that can be used to increase parking capacity and perhaps reduce parking demand; typically undertaken where there are documented parking shortages.

▷ *Schematic design.* A functional design for a proposed parking facility, developed to a sufficient level of detail to obtain consensus among interested parties. (Normally, design documents are not prepared until the first phase of a design contract, but they may be necessary during the study phase to provide the background information needed to obtain consensus and proceed with design and funding.)

▷ *Traffic impact analysis (TIA).* The application of standard methods of traffic engineering analysis, with the goal of identifying current and/or future traffic conditions and recommending improvements. Although the TIA generally focuses on determining the effect of a proposed parking facility on traffic conditions, it sometimes addresses existing traffic problems that should be considered simultaneously with parking needs.

▷ *Financial analysis.* A projection of the operating expenses, revenues, and sometimes the debt service associated with a proposed new facility or with the expansion of an existing facility; includes an assessment of the owner's ability to fund the improvements through parking income.[1] The financial analysis may include some or all of the following elements:

- estimates of development costs;
- estimates of use and rates;
- projections of revenue and operating expenses;
- financing costs, including interest rate and terms;
- analysis of the ability of a parking facility to service debt on its own; and
- analysis of the viability of adding a new facility to an existing system.

▷ *Financing method analysis.* A study of available financing methods and their legal ramifications: evaluates the interest rate and terms; insurance; debt reserves; and other requirements. Financing options may include public/private partnerships; federal, state, or local financing programs; private ownership and financing; and nontraditional funding sources.[2]

▷ *Parking management study.* An identification and analysis of parking problems that can be corrected through changes in policy, management, or operating strategies.

▷ *Organizational and administrative review.* A detailed study of the administration and operation of the parking system as a whole; considers issues such as use and allocation of resources, staffing needs, assignment of responsibility, and general organization. The review is often needed to establish an authority or agency that will run an entire parking system.

▷ *Parking revenue controls and operations study.* A review of current revenue collection systems and other policies and procedures to ensure that revenue is maximized and that theft, fraud, and evasion are minimized.

▷ *Equipment acquisition analysis.* A review of current operations for the purpose of determining the appropriate type and number of access and egress lanes and recommending control equipment. The study phase usually includes cost estimates and an outline of specifications; detailed construction documents are developed later.

▷ *Parking facility evaluation.* An evaluation of the extent of deterioration in a parking structure floor and frame; includes repair and cost estimates, and may include recommendations designed to maximize revenues and mitigate theft, fraud, and evasion. Construction documents for repairs are not part of a parking study.

NOTES

1. In most cases, a client who engages a parking consultant already knows how the parking project will be financed. For example, a city that plans to use general-obligation bonds will have financial experts in house or on retainer who will provide information on the interest rates and terms of the financing instruments under consideration.
2. For a detailed discussion of financing, see Chapter 6, "Financial Feasibility and Financing."

CHAPTER 2

Parking DEMAND

MARY S. SMITH, JOHN W. DORSETT, AND BOB CHAPMAN

FOR MANY LAND USES, THE AMOUNT OF PAVED PARKING area is as great as, or even greater than, the occupied area of the buildings being served. For example, an office building may have a 1:1 ratio of parking area to leasable space; a shopping center may have approximately 1.5 square feet (0.14 square meters) of paved parking area for each square foot (0.09 square meters) of gross leasable area. The number of parking spaces provided for a site, complex, or district is thus a key determinant of its character. In the words of former Disney CEO Michael Eisner, "Form follows parking."[1]

Because parking is so crucial to the success of the development it serves—whether that development is commercial or institutional—developers and property owners want to be sure that parking is adequate. Local governments, for their part, want property owners to provide enough off-street parking to prevent tenant or visitor parking from overflowing to public streets or adjacent private property. Nevertheless, it is not in the interest of either the private sector or the public sector to require an excessive amount of parking. Because parking is a necessary component of development, the land area and/or resources devoted to parking may constrain the amount of development that a given site can support. Moreover, excessive parking requirements often lower the density of development; reduce land values; reduce the economic viability of public transportation; undermine the walkability of the site, complex, or neighborhood; and damage the natural environment.

Parking is a key component of transportation demand management—a set of strategies that are designed to make more efficient use of transportation resources.[2] When parking is oversupplied, it is likely to be undervalued. As Donald Shoup notes in *The High Cost of Free Parking,* drivers park free for 99 percent of all automobile trips, which means that the cost of parking is almost never a factor in transportation decisions.[3] Shoup also notes that "planning education provides no instruction on how practicing planners should set parking requirements and textbooks offer no help."[4]

In recent years, three separate but related planning approaches have focused attention on the negative impacts of the “more is better” philosophy of parking: smart growth, transit-oriented development (TOD), and new urbanism. All three approaches strive to use land more efficiently, contribute to the availability of affordable housing, reduce dependence on automobile travel, and create more livable communities. All three also rely heavily on the same things: “mixed use, higher density, buildings at the sidewalk, less private and more public open space, smaller blocks, narrow streets with wider sidewalks, street trees and lighting, lower parking ratios, shared parking, parking behind buildings, and on-street parallel parking.”[5] Carefully crafted parking requirements support the values that underlie smart growth, TOD, and new urbanism.

This chapter describes the basics of analyzing parking demand: the first major section describes the principal estimation methods; the second discusses issues in demand estimation; the third examines the use of recommended ratios; and the fourth describes how to refine demand estimates. Estimations of parking demand are used for multiple purposes: by developers, tenants, and lenders who wish to ensure that adequate parking will be provided; by local officials, to determine parking requirements for zoning ordinances; by developers who wish to obtain reductions in the amount of parking required by local ordinances; and by financial planners, who must project usage levels for facilities where paid parking is contemplated. Chapter 3, “Shared Parking,” discusses demand estimation for shared-parking situations, and Chapter 4, “Zoning Requirements,” addresses the development of parking requirements for zoning ordinances.

TECHNIQUES FOR ESTIMATING PARKING DEMAND

Parking demand is defined as the number of spaces that should be provided to serve a particular land use, given factors such as the price of parking and the availability of alternative travel modes. There are two basic approaches to estimating parking demand. The first approach begins with recommended parking ratios, which are then adjusted to reflect local characteristics. The recommended ratios are based on industry standards—which, in turn, are typically based on free parking in locations where virtually 100 percent of the arrivals are by private automobile.[6]

CARL WALKER, INC.

In Grand Rapids, Michigan, a seven-level parking structure located next to the 12,000-seat Van Andel Arena provides 794 spaces for arena patrons and monthly parkers.

The second technique, which bases the estimate of parking needs on a forecast of person-trips or vehicle-trips, or on the number of people expected to be present at peak hours, is often used for event facilities, such as performing-arts centers, arenas, or stadiums. (It is important to note, however, that when parking demand is estimated on the basis of person-trips or vehicle-trips, it is generally converted to a ratio of spaces per unit of land use, so that the resulting ratio can be compared to industry standards and to zoning requirements.) Parking demand for a particular event can be estimated on the basis of three pieces of information: the number of seats, the modal split (the percentage of attendees who arrive by private auto), and the number of persons per car. Employee parking needs can be estimated similarly, on the basis of the number of employees on duty, the modal split, and persons per car.

Both approaches—those based on parking ratios and those based on estimated person-trips, vehicle-trips, or seating capacity—yield fairly accurate forecasts of parking demand, as long as the proper amount of research is conducted and strong consideration is given to local conditions. Industry standards—whether for parking ratios, person-trips, or vehicle-trips—cannot be applied without attention to local characteristics.

The key is to gather as much information about the site as the client can provide, to compare that information to standards established by industry organizations, and to adjust for differences in various factors, including density, availability of public transportation, local policies, the price of parking, and economic vitality. It is important to note, however, that budgetary limitations may prohibit extensive field surveys and analytical work, restricting analysts' ability to collect detailed data.

ISSUES IN THE ANALYSIS OF PARKING DEMAND

The next five sections consider a number of issues and practices with which parking analysts and their clients must be familiar: (1) the units used to express parking ratios; (2) the impact of the size of the land use on parking ratios; (3) the delineation of the study area for parking-demand analysis; (4) the determination of design day and design hour; and (5) the impact of effective supply.

Units

Parking requirements are generally stated as a ratio of spaces per unit; the particular unit varies by land use, but is usually square footage. Other units that may be used are per dwelling unit, bed, hotel room, seat, or person. Ideally, the unit will be something that can be calculated during project planning. Thus, demand ratios based on the number of employees, which often varies over time, should be avoided. However, parking requirements for certain land uses, especially institutions such as hospitals and schools, are so variable that per employee, per student, or per patient may be the only reasonable units. In some cases, particularly for spaces such as auditoriums, the maximum legal capacity can serve as the basis for parking requirements.

In the past, parking ratios tended to be stated as one space for X number of square feet. But most industry groups now prefer to state the ratio as X number of spaces per 1,000 square feet (or Y spaces per 100 square meters), because it is easier for the average person to multiply than to divide. When the number associated with the unit is consistent, the magnitude of the requirements—and the differences between them—are easier to grasp. For example, 1 space per 200 square feet (19 square meters) and 1 space per 250 square feet (23 square meters) are equivalent to 5 spaces and 4 spaces per 1,000 square feet (5.4 and 4.3 spaces per 100 square meters), respectively.

When ratios are based on square footage, how the square footage is calculated is an important consideration. Because there is wide variation among both industry standards and zoning ordinances on this issue, the following modifiers are often added for clarity: gross floor area (GFA), gross leasable area (GLA), net floor area (NFA), and net rentable area (NRA).

While older ordinances and references tended to use NFA, most industry standards today, including those of the Urban Land Institute (ULI) and the Institute of Transportation Engineers (ITE) use GFA—or, for multitenant buildings, GLA.[7] The adjustment of square footage to reflect leasable or rentable area has become particularly important because of the trend toward large developments with multiple tenants: merely enclosing the space connecting the tenant spaces does not add to parking demand. Because the difference between GLA and GFA is negligible in smaller buildings, many standards use GFA for single-tenant buildings but GLA for multitenant buildings.

Size

Higher parking ratios are often appropriate for small concentrations of a specific land use than for larger buildings in the same land use category. The reasoning is simply a matter of probability: among 50 small office buildings, a number will have demand that is high enough to justify a 3.8/1,000 parking ratio. But if the tenants of those 50 buildings moved into

Definitions of Square Footage

	Abbreviation	Definition	Exclusions[2]
Gross floor area	GFA[1]	Total floor area, including the exterior building walls, on all floors of a building or structure	▷ Parking areas ▷ Floor area occupied by heating, ventilating, and air-conditioning (HVAC) equipment ▷ Floor area occupied by mechanical, electrical, communications, and security equipment
Gross leasable area	GLA	Gross floor area available for leasing (that is, GFA minus the exclusions that pertain to GFA and GLA)	▷ Floor area of elevator shafts and stair towers ▷ Public restrooms ▷ Permanently designated corridors ▷ Public lobbies ▷ Common areas
Net floor area	NFA	Total floor area	▷ Exterior building walls ▷ Parking areas ▷ Floor area occupied by HVAC equipment ▷ Floor area occupied by mechanical, electrical, communications, and security equipment
Net rentable area	NRA	Net floor area available for leasing	

Notes

1. Thus, in relation to exterior walls, GFA is calculated "out-to-out," and NFA is calculated "in-to-in."
2. These elements are excluded because they do not contribute to parking demand.

one large building, some of the tenants will regularly have an unusually high concentration of employees and/or visitors, while others will have few visitors, or will have employees who are often "on the road"; a 2.8/1,000 supply will therefore be sufficient. Different ratios for the same use are therefore entirely appropriate.

It is important to note that parking demand does not always decline as the quantity of a land use increases. For example, it is well established that parking ratios for shopping centers increase as the size of the center increases.[8] This pattern is caused by the fact that the larger the center, the more likely patrons are to visit multiple tenants—which lengthens their stays and increases demand.

Study Area

The study area should be defined to include all sources of demand and supply that affect the land uses for which demand is to be estimated. For example, a freestanding development in a suburban location may not interact with other uses, and the study area would therefore be limited to the tract of land to be developed. In other cases, however, land uses and parking supplies may interact. For example, on-street parking near a hospital or university may meet some of the institution's parking needs. In a study of overall parking demand in a central business district (CBD), the study area should encompass all parking generators and parking supplies within the generally accepted boundaries of the CBD. In a more focused analysis known as a market study (see Chapter 1, "Parking Studies"), the study area should include (1) the land uses that will generate demand for the facility and (2) the competing sources of supply. To determine the potential for use of existing spaces, the analyst should obtain data on occupancy patterns for all land use types in the study area.[9]

Design Day and Design Hour

In any discussion of parking demand, it is critical to identify the level of parking activity that recurs frequently enough to justify providing parking spaces. In the industry, this level is often referred to as the design day or design hour. For many land uses, parking demand is defined as the demand associated with the peak hour on a design day. For example, a facility designed for the peak hour on the median day would have an insufficient supply for the peak hour on 50 percent of the days of the year. Although this is obviously not a desirable outcome, it is equally inappropriate to design for the highest conceivable demand, particularly for a single hour.

Many references, including *Shared Parking*, recommend setting parking requirements using the 85th percentile of the peak-hour parking accumulations in a statistically reliable data set.[10] Unfortunately, *Parking Generation*, the most widely available compilation of actual parking-accumulation data, includes very few statistically reliable data sets: the counts may not have been taken at peak hours, and may have been taken at inconsistent times (for hotels, for example, some counts were taken at midnight and others at midday).

Other references, such as Shoup, recommend using the average rather than the 85th percentile, primarily as a means of limiting parking and facilitating paid parking—which, in turn, encourages more sustainable development and alternative travel modes. But for some uses, even the 85th percentile approach would not be acceptable. For example, because the holiday shopping season accounts for 25 to 40 percent of total annual retail sales, adequate parking during this time period is essential to their viability. Therefore, the shopping center industry has adopted a design hour that is significantly higher than the 85th percentile: the 20th-highest hour in the year. Designing for adequate parking on a Saturday in October—much less an average weekday—would not be acceptable for retail tenants.

Office developers, as well as their lenders and tenants, usually want to provide at least as much parking as other competitive buildings have—a pattern that tends to perpetuate parking requirements based on "wants" rather than "needs." Over time, however, changes in parking ratios have been accepted and widely implemented when well-researched and carefully documented studies support such changes. In 1965, for example, the standard for the shopping center industry was 5.5 parking spaces per 1,000 square feet (93 square meters) of GLA.[11] According to research reported in the May 1977 issue of *Urban Land,* 5 parking spaces per 1,000 square feet of GLA was, by then, a valid national maximum for regional shopping centers with GLAs of at least 800,000 square feet (74,300 square meters). By 1982, a ULI-sponsored study had concluded that the recommended ratio was slightly less than 5, and was even lower for smaller centers. When ULI repeated the same study in 1999, it recommended yet lower ratios:

- For centers with between 25,000 and 400,000 square feet (between 2,320 and 37,160 square meters), the recommended parking ratio was 4.0 spaces per 1,000 square feet (93 square meters) of GLA.
- For centers with between 400,000 and 600,000 square feet (between 37,160 and 55,740 square meters), the recommended parking ratio was 4.0 to 4.5 spaces per 1,000 square feet.
- For centers with more than 600,000 square feet (55,740 square meters), the recommended parking ratio was 4.5 spaces per 1,000 square feet.

These ratios are appropriate for centers in which less than 10 percent of the space is occupied by dining and entertainment uses; however, for each percentage point over 10 percent occupied by these uses, the study proposed an adjustment in parking requirements. (*Shared Parking* simply recommends conducting a shared-parking analysis whenever more than 10 percent of the space is occupied by dining and entertainment.) Center developers, tenants, and lenders have accepted the recommended declines in requirements for shopping centers because experience has confirmed that fewer spaces are required.

Effective Supply

Effective supply is an important element in the evaluation of parking need. Simply put, effective supply is the number of spaces needed to avoid the perception that, because of the difficulty of finding the last few available spaces, the parking supply is inadequate. The effective-supply cushion—the difference between the actual number of spaces and the effective supply—reduces the need to search an entire system for the last few available spaces; provides room for vehicle maneuvers; takes account of operating fluctuations; and makes up for spaces that are lost for various reasons. It also provides for unusual peaks in demand—at least on some, if not all, peak days. The parking facility may not operate as efficiently as desired on such days, but it can absorb somewhat higher demand.

The level of occupancy at which optimum efficiency is achieved varies; generally, however, a parking facility operates most efficiently when occupancy is somewhere between

Using the Data in *Parking Generation*

Planners and other analysts who rely on data from *Parking Generation,* a publication of the Institute of Transportation Engineers, need to be aware that the data are simply observed parking accumulations; they are specifically not intended as recommendations.[1] Where enough data are available, *Parking Generation* lists the 85th percentile, the average, and the 33rd percentile as ratios of spaces per unit of land, but does not recommend any particular ratio. Unfortunately, when *Parking Generation* is used as the primary source of parking ratios, the tendency is to interpret the average of the reported parking ratios in a given category as a recommendation.

Moreover, although *Parking Generation* is the best available source of data on parking accumulations, many of the figures are statistically unreliable. As Donald Shoup notes, "half of the 101 parking generation rates are based on four or fewer studies, and 22 percent are based on a single study."[2] And even where the sample is reasonably large, many of the studies were not well designed, and the volume provides only a brief summary of the extent, season, and time of day of the surveys. It may not even be clear whether a study actually captured the peak accumulation of vehicles on the survey day. For example, at least some of studies of hotel parking seem to have been undertaken during the day, when demand may have been driven by meeting rooms and convention facilities, while other hotel studies were conducted late at night. But the resulting report converts the peak parking accumulation to an average number of spaces occupied per room, regardless of what time of day the survey was conducted.

Notes

1. Institute of Transportation Engineers (ITE) *Parking Generation*, 3rd ed. (Washington, D.C.: ITE, 2004).
2. Donald C. Shoup, *The High Cost of Free Parking* (Chicago: American Planning Association, 2005), 25. Shoup also criticizes the very idea of starting from the data found in *Parking Generation*, because it is based on free suburban parking that exceeds demand on most, if not all, days of the year, and includes little or no public parking.

85 and 95 percent. Key determinants of optimum efficiency include the size of the system and the types of users. Generally, recommended parking ratios in industry publications incorporate an effective-supply cushion.

USING INDUSTRY REFERENCES AS A STARTING POINT

It is important for the analyst to obtain a detailed accounting of the land uses that will generate parking demand. For example, a developer may tell an analyst that there will be "500,000 square feet (46,450 square meters) of retail," without noting that 15 percent of the space will be restaurants of various types, and that a 2,000-seat cinema will be included. Equally important, the restaurants may include a wide range of facilities—from a food court, to casual restaurants with very active bars, to a nightclub, to a gourmet restaurant open only for dinner—each of which will have a very different parking-demand profile.

After the analyst identifies the land uses to be considered, the next steps are (1) to select base parking ratios from a reliable source; (2) to try to understand all the underlying assumptions used to prepare those ratios, such as the design day, number of persons per car, and modal split; and (3) to adjust the ratios to reflect local conditions.

Shared Parking discusses available data sources, including *Parking Generation,* and recommends parking ratios for some of the most common land uses found in mixed-use developments. As is noted later in this chapter, *Shared Parking* also discusses adjusting these "base ratios" to reflect transportation characteristics, season, time of day, automobile occupancies, and the effects of transit and of captive markets. The Parking Consultants Council (PCC) recommends the same ratios as *Shared Parking,* but includes some additional ratios that the council believes to be reasonably supported by either published data or the collective experience of its members. These ratios are included in Chapter 3, "Shared Parking."

Specialized uses such as hospitals, rail stations, and airport terminals—as found at Terminal D at Dallas/Fort Worth International Airport, pictured here—use specific base ratios for estimating parking demand.

Another reference for base ratios (which is somewhat outdated as of this writing) is *Parking,* which includes a table showing suggested ratios for peak parking demand. *Parking* also includes tables on turnover and demand, sorted according to long and short terms.[12] Other tables address special generators such as hospitals, airports, railway stations, and shopping centers. The ITE's *Transportation Planning Handbook* also offers a table of recommended ratios, which are based largely on earlier PCC references.[13]

Despite the limitations of the available data, the PCC and publications such as *Shared Parking* recommend the use of such data as a starting point for the development of parking ratios, both for planning purposes and for the development of zoning ordinances. Starting with the available data and then making appropriate adjustments for local characteristics is, quite simply, the only rational and economical way to determine the parking needs of a new development. Of course, when an existing development is being expanded, the model of parking demand should be calibrated against observed parking accumulations before future demand is forecast. The ratios recommended in this volume are merely starting points, because they reflect parking at individual suburban sites with little or no transit.

In *Recommended Zoning Ordinance Provisions,* the PCC compiled a list of base parking ratios for single-use projects in areas with little or no transit service.[14] As with the ratios in *Shared Parking,* these ratios can and should be adjusted to reflect local transportation services, auto-ownership characteristics, and a site's location within the community. These ratios are reprinted in Chapter 4, Figure 4-1.

REFINING PARKING DEMAND ESTIMATES

The most challenging and important step in the estimation of parking demand is adjusting the base parking ratios to reflect local conditions. The fundamental adjustments to recommended parking ratios will depend on local transportation characteristics—in particular, the modal split and the cost of parking.

In order to properly discount the recommended ratios to reflect non-auto modes of transportation, the analyst needs to take into account the availability of mass transit, the level of walk-in traffic, and the potential for car- or vanpooling. Transit-oriented development, for example, would warrant a significant discount from the base ratios for nearly all land uses.

Because the cost of parking is integral to decisions about the mode of transportation, adjustments to recommended ratios must also reflect parking cost. Paid parking generally brings about at least some reduction in demand, even if it is relatively small. If parking is expensive, the reduction in demand will be significant.

Whereas in the past, it would have been necessary to survey users to determine the effect of transportation characteristics such as parking cost, a number of tools—including the national census and the Federal Highway Administration's National Household Travel Survey (formerly the Nationwide Personal Transportation Survey)—have made such information widely available, allowing analysts to assess local transportation characteristics without extensive local study.[15] Because the data are highly segmented, adjustments can be fine-tuned to reflect a range of circumstances. For example, it is possible to obtain information about two different parking environments within the same community: a CBD with paid parking, and a suburban setting with free parking.

In addition to evaluating the effects of transportation characteristics, the analyst should determine the impact of a number of other factors:

▷ *Socioeconomic characteristics of the people expected to visit the development.* Parking demand can be affected by the trade area. It is likely to be higher, for example, in a suburb with high levels of automobile ownership.

▷ *Accessibility.* Particularly in shared parking situations, the proposed location for a parking facility could be more or less convenient for entry or egress than competing parking facilities.

▷ *Efficiency.* If finding parking in, or exiting from, a given garage requires excessive time, that garage may lose patronage when better alternatives are available.

▷ *Parking management policies.* Parking facilities often place restrictions on who may use a facility and when. For example, parking fees may be set to discourage use by employees; or specific spaces may be held vacant until 10:00 a.m., to accommodate visitors other than employees. Similarly, a hotel operator in a mixed-use project may insist on segregated and reserved parking for hotel guests. Since such policies can affect demand, they must be taken into account.

▷ *Local codes and policies.* Because legal and other constraints can profoundly affect the number of spaces that have to be provided, such constraints should be identified as early as possible in the planning process. For example, if the local zoning ordinance prohibits reductions in required parking ratios because of shared parking, efforts to analyze the effects of shared parking would be wasted. Or perhaps the local ordinance permits the analysis of the effects of shared parking, but still requires the use of the base parking ratios stated in the community's zoning ordinance. The developer may attempt to get a variance based on the more refined analysis in *Shared Parking,* but there is no guarantee that such variances will be approved.

Other local policies that can affect parking demand include the imposition of parking taxes on certain types of parkers in certain locations, and the imposition of maximum, rather than minimum parking requirements.

CONCLUSION

A reasonably reliable projection of parking demand depends on three factors:

▷ A thorough understanding of the development program; (and/or of existing conditions)

▷ The availability of sound data; and

▷ The accurate identification of local characteristics, and a careful assessment of their effect on demand.

To ensure that projections are reasonable, particularly where local characteristics are likely to reduce demand


ARNOLD & O'SHERIDAN, INC.

The Third Ward Ramp in Milwaukee, Wisconsin, was designed with sensitivity toward the historic characteristics of the neighborhood.

below the recommended base ratios, studies may be conducted at a comparable site or sites. The use of a spreadsheet program (such as Excel) is recommended; such programs allow the analyst to determine how changes in various factors—such as automobile occupancy, transit use, or shared parking—may affect parking demand. If a project involves more than one land use with integrated parking facilities, the analyst should consider adjustments for shared parking, which is discussed in more detail in Chapter 3. Armed with recommended ratios and a commitment to undertaking the necessary research, parking consultants can provide realistic projections of parking needs.

NOTES

1. Russ Rymer, "Back to the Future: Disney Reinvents the Company Town," *Harpers*, October 1996, 65–76.
2. Victoria Transport Policy Institute, "Online TDM Encyclopedia"; www.vtpi.org/tdm.
3. Donald C. Shoup, *The High Cost of Free Parking* (Chicago: American Planning Association, 2005), 621.
4. Ibid., 25.
5. Transit-Oriented Development Advocate, "What's TOD Got to Do with It?"; available at todadvocate.com/todlessons.htm. The quotation was referring to TOD, but is also applicable to smart growth and new urbanism.

6. The word *virtually* is used because there may be a small number of drop-offs or walkers at a site that is not served at all by public transportation.
7. Mary S. Smith, *Shared Parking,* 2nd ed. (Washington, D.C.: ULI–the Urban Land Institute and the International Council of Shopping Centers, 2005); Institute of Transportation Engineers (ITE) *Parking Generation,* 3rd ed. (Washington, D.C.: ITE, 2004).
8. *Parking Requirements for Shopping Centers*, 2nd ed. (Washington, D.C: ULI–the Urban Land Institute, 1999).
9. A captive-market effect occurs when patrons who are already parked in a facility avail themselves of other nearby services, and thus do not contribute to the incremental parking demand generated by those services. An office building with a restaurant on the ground floor is a good example: since most of the diners are office employees, their cars are already in the parking facility; thus, they are not a source of additional parking demand.
10. Smith, *Shared Parking*.
11. Urban Land Institute, *Parking Requirements for Shopping Centers,* Technical Bulletin 53 (1965).
12. Robert A. Weant and Herbert S. Levinson, Parking (Westport, Conn.: Eno Foundation for Transportation, 1990).
13. Mary S. Smith, "Parking," in *Transportation Planning Handbook,* 3rd ed. (Washington, D.C.: Institute of Transportation Engineers, 2009).
14. National Parking Association (NPA), *Recommended Zoning Ordinance Provisions* (Washington, D.C.: NPA, 2006).
15. See U.S. Department of Transportation, Federal Highway Administration, "Policy Information: National Household Travel Survey"; available at fhwa.dot.gov/policy/ohpi/nhts/aboutnhts.cfm.

CHAPTER 3

Shared PARKING

MARY S. SMITH, JOHN W. DORSETT, AND BOB CHAPMAN

SHARED PARKING OCCURS WHEN MULTIPLE (and usually adjacent) land uses are able to meet their individual parking needs through common parking spaces. When the peak demands of the uses vary by time of day and/or season, shared parking will decrease the total number of parking spaces required. Absent any captive-market effects, the demand of the individual uses may not be reduced; however, the number of spaces required to serve the demand is reduced due to shared parking. It should be noted, however, that to achieve a reduction in required spaces, it must be physically possible to share the parking. Therefore, parking for individual land uses cannot be physically separated; nor can some parking be reserved for particular user groups or tenants. However, the parking supply does not have to be under a single ownership to achieve the benefits of shared parking.

In addition to decreasing the required number of parking spaces, an interrelationship between adjacent land uses can increase the vitality of businesses. The combination of restaurant and office uses is a good example. The restaurant's lunch business will be enhanced by the patronage of visitors and employees of the office building. Because most office employees are already parked at the office site, their use of the restaurant will not increase parking demand (this phenomenon, which is known as the captive-market effect, will be discussed later in the chapter). In the evening, when the demand for restaurant parking is likely to be highest, the demand for office parking will decline, making available some or all of the spaces required for the restaurant. Although shared parking is most often associated with new mixed-use developments, the original—and most visible—model of shared parking is in central business districts.

THE BENEFITS OF SHARED PARKING

When the cost of structured parking is $15,000 or more per space, developers are strongly motivated to avoid building unnecessary parking spaces. Parking studies

FIGURE 3-1: Potential Savings under Shared Parking

Number of spaces required without shared parking	1,500
Reduction attributable to shared parking (10% to 40%)	150 to 600
Total number of spaces required	900–1,350
Dollar savings (at $15,000/space)	$2,250,000–$9,000,000

often demonstrate that shared parking will allow a reduction of 10 to 40 percent, when compared with the total number of parking spaces that would have been required for each individual land use.

Communities benefit from shared parking as well. Many communities are recognizing the problems created by sprawl, and are adopting policies that promote smart growth, new urbanism, and/or transit-oriented development (TOD). All three approaches rely heavily on mixed uses, and employ shared parking to decrease the total number of parking spaces and create better pedestrian connections between uses. An inherent goal in these policies is to minimize the need for automobile travel, as well as to make it possible for visitors to park only once, even when they are visiting multiple uses. Some communities allow reductions in parking supply on the basis of a shared-parking study.

SHARED-PARKING STUDIES

The goal of a shared-parking study is to determine the number of parking spaces needed for a prospective development, an expansion of an existing development, or an infill project in an existing mixed-use district. As part of the study, land uses are identified and quantified, and parking demand is modeled for each land use by hour of the day, day of the week, and month of the year. Adjustments are made for people who use forms of transportation other than private vehicles, and to take account of people who visit multiple land uses during the same trip and may therefore contribute less to parking demand than they would if each

Differences between the First and Second Editions of *Shared Parking*

The first edition of *Shared Parking* focused on cinemas; hotels; and office, residential, restaurant, and retail uses. The second edition includes a significant number of additional land uses: arenas, convention centers, data-processing offices, health clubs, medical/dental offices, branch banks, night clubs, performing-arts theaters, pro baseball stadiums, and pro football stadiums. More importantly, some land uses have been subdivided to provide more refined projections. For example, restaurants—a single category in the first edition—have been subdivided into fine/casual dining (with bar), family restaurant (without bar), fast food, and night clubs.

Another significant change in the second edition is the addition of a so-called 13th month. In recent years, the attendance of movies between Christmas and New Year's Day has increased significantly overall, but with a particular pattern of high attendance at shows on weekday afternoons by families enjoying holiday vacations. It would be inappropriate and inaccurate to overlay the peak parking needs of a cinema on a weekday afternoon after Christmas with the peak-hour demand for parking at retail and office uses before Christmas. Therefore, appropriate adjustments to all uses for the post-Christmas period were developed.

The final significant change in the second edition is that the recommended parking ratios are separated into visitor/customer and employee components, to permit more refined analysis of transportation modes, captive adjustments, and parking-management strategies.

References

ULI–the Urban Land Institute, *Shared Parking* (Washington, D.C.: ULI–the Urban Land Institute, 1983).

Mary S. Smith, *Shared Parking*, 2nd ed. (Washington, D.C.: ULI–the Urban Land Institute and the International Council of Shopping Centers, 2005).

FIGURE 3-2: Summary of Recommended Parking Ratios (Space per Unit Land Use)

Land Use	Weekday		Weekend		Unit	Source
	Visitor	Employee	Visitor	Employee		
Community shopping center (<400,000 square feet/37,160 square meters)	2.90	0.70	3.20	0.80	Per 1,000 square feet (93 square meters) of gross leasable area (GLA)	1
Regional shopping center (400,000–600,000 square feet/37,160–55,740 square meters)	Scaled proportionally between the ratios for 400,000 square feet (37,160 square meters) and 600,000 square feet (55,740 square meters)				Per 1,000 square feet (93 square meters) of GLA	1
Super regional shopping center (>600,000 square feet/55,740 square meters)	3.20	0.80	3.60	0.90	Per 1,000 square feet (93 square meters) of GLA	1
Fine or casual dining	15.25	2.75	17.00	3.00	Per 1,000 square feet (93 square meters) of GLA	2, 3
Family restaurant	9.00	1.50	12.75	2.25	Per 1,000 square feet (93 square meters) of GLA	3
Fast-food restaurant	12.75	2.25	12.00	2.00	Per 1,000 square feet (93 square meters) of GLA	2
Night club	15.25	1.25	17.50	1.50	Per 1,000 square feet (93 square meters) of GLA	3
Active entertainment	Custom to each tenant					
Cineplex	0.19	0.01	0.26	0.01	Per seat	3, 2
Performing-arts theater	0.30	0.07	0.33	0.07	Per seat	2
Arena	0.27	0.03	0.30	0.03	Per seat	3
Pro football stadium	0.30	0.01	0.30	0.01	Per seat	3
Pro baseball stadium	0.31	0.01	0.34	0.01	Per seat	3
Health club	6.60	0.40	5.50	0.25	Per 1,000 square feet (93 square meters) of GFA	3, 4
Convention center	5.50	0.50	5.50	0.50	Per 1,000 square feet (93 square meters) of gross floor area (GFA)	3
Hotel (business)	1.00	0.25	0.90	0.18	Per room	2, 3
Hotel (leisure)	0.90	0.25	1.00	0.18	Per room	2, 3
Restaurant/lounge	10.00		10.00		Per 1,000 square feet (93 square meters) of GLA	2, 3, 5
Conference center/banquet facility (20–50 square feet/1.8–4.6 square meters per guest room)	30.00		30.00		Per 1,000 square feet (93 square meters) of GLA	2, 3, 5
Convention space (>50 square feet/4.6 square meters per guest room)	20.00		10.00		Per 1,000 square feet (93 square meters) of GLA	2, 3, 5
Residential, rental	0.15	1.50[a]	0.15	1.50[a]	Per unit	2
Residential, owned	0.15	1.70[a]	0.15	1.70[a]	Per unit	2
Office (<25,000 square feet/ 2,320 square meters)	0.30	3.50	0.03	0.35	Per 1,000 square feet (93 square meters) of GLA	2

FIGURE 3-2: Summary of Recommended Parking Ratios (Space per Unit Land Use) *(continued)*

Land Use	Weekday		Weekend		Unit	Source
	Visitor	Employee	Visitor	Employee		
Office (25,000–100,000 square feet/2,320–9,290 square meters): scaled proportionally between the ratios for 25,000 square feet and 100,000 square feet						
25,000 square feet (2,320 square meters)	0.30	3.50	0.03	0.35	Per 1,000 square feet (93 square meters) of GFA	2
100,000 square feet (9,290 square meters)	0.25	3.15	0.03	0.32	Per 1,000 square feet (93 square meters) of GFA	2
Office (100,000–500,000 square feet/9,290–46,450 square meters): scaled proportionally between the ratios for 100,000 square feet and 500,000 square feet						
100,000 square feet (9,290 square meters)	0.25	3.15	0.03	0.32	Per 1,000 square feet (93 square meters) of GFA	2
500,000 square meters (46,450 square meters)	0.20	2.60	0.02	0.26	Per 1,000 square feet (93 square meters) of GFA	2
Office (>500,000 square feet/ 46,450 square meters)	0.20	2.60	0.02	0.26	Per 1,000 square feet (93 square meters) of GFA	2
Data-processing office	0.25	5.75	0.03	0.58	Per 1,000 square feet (93 square meters) of GFA	2, 3
Medical or dental office	3.00	1.50	3.00	1.50	Per 1,000 square feet (93 square meters) of GFA	2, 3
Bank branch with drive-in	3.00	1.60	3.00	1.60	Per 1,000 square feet (93 square meters) of GFA	2

Note: Figures represent the peak number of parking spaces required, and assume virtually 100 percent auto use, with a typical proportion of ridesharing for suburban conditions.

a. 1.0 space is reserved for residents' sole use, 24 hours a day; the remainder are shared with visitors and other uses.

Sources:

1. *Parking Requirements for Shopping Centers,* 2nd ed. (Washington, D.C.: ULI–the Urban Land Institute, 1999).
2. *Parking Generation,* 3rd ed. (Washington, D.C.: Institute of Transportation Engineers, 2004).
3. Data collected by the Shared Parking team, as described in *Shared Parking*.
4. John W. Dorsett, "Parking Requirements for Health Clubs," *Parking Professional* (April 2004).
5. Gerald Salzman, "Hotel Parking: How Much Is Enough?" *Urban Land* (January 1988).

trip to each land use were counted separately. A shared parking study typically employs a computerized model and yields a written report documenting the analyst's findings and conclusions. Developers often use such reports as evidence when they apply to a board of zoning appeals for a reduction in the number of required parking spaces.

Until the publication, in 1983, of the first edition of the Urban Land Institute's *Shared Parking,* it was difficult to develop reliable and widely accepted projections of shared-parking adjustments.[1] *Shared Parking,* which was updated in 2005,[2] describes a method for calculating the effects of shared parking without resorting to an inflexible formula.

METHODOLOGY

A competent shared parking study typically relies on a spreadsheet-based model that projects parking demand for a specific development for each hour of the day, on weekdays and weekends, throughout the year. The following steps are essential to a shared parking study:

Step 1: Gather and review project data.
Step 2: Select and apply the base parking ratios.
Step 3: Adjust the base parking ratios according to the time of day, day of week, and season.
Step 4: Develop scenarios for periods of critical parking need.
Step 5: Adjust ratios for modal split and persons per car.

FIGURE 3-3: Selected Time-of-Day Factors for Weekday Parking Demand

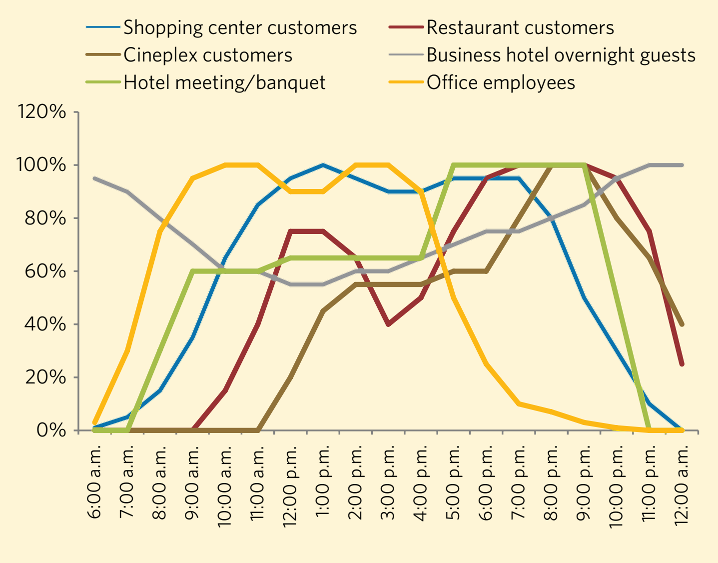
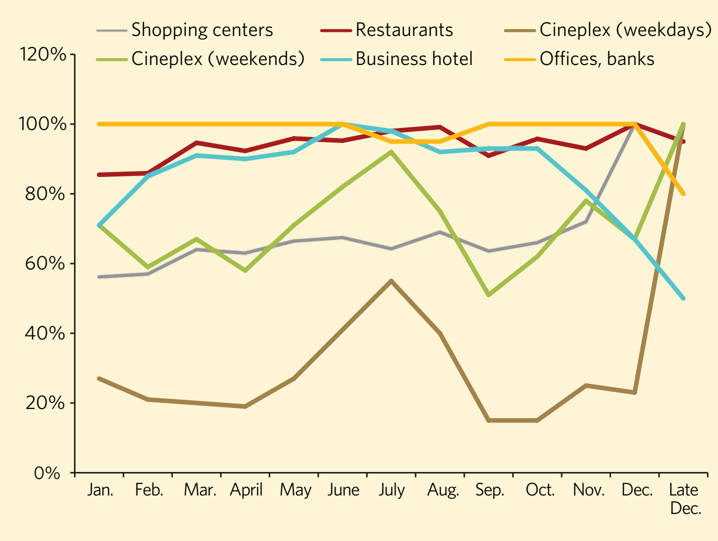


FIGURE 3-4: Selected Seasonal Factors for Customer Parking Demand



Step 6: Make adjustments for captive markets.
Step 7: Calculate the number of spaces required under each scenario.
Step 8: Confirm that the scenarios reflect all critical parking periods.
Step 9: Recommend a parking plan.

In Step 1, the analyst identifies and categorizes the land uses in the development and determines the quantity of each in appropriate unit measures (e.g., square footage). The analyst should also collect information on the following:

- ▷ local zoning standards and practices
- ▷ current conditions, including parking costs, characteristics of local users, and existing competitive facilities
- ▷ transportation characteristics, including modal splits, transit availability, and transportation demand-management programs
- ▷ physical relationships between uses
- ▷ parking management strategies that would be acceptable to the various parties.

In Step 2, the analyst selects and applies base parking ratios to each type of land use; that is, the analyst multiplies the measurement units (square footage, seating capacity, number of rooms, etc.) by the appropriate base parking ratios. (Figure 3-2 lists the base parking ratios recommended in the second edition of *Shared Parking*.)

In Step 3, the analyst adjusts the base parking ratios according to the hour of the day, the day of the week, and the month of the year. Electronic spreadsheets are recommended for keeping track of these many variables. (Figure 3-3 lists time-of-day factors for some common land uses, and Figure 3-4 lists seasonal adjustments.)

In Step 4, the analyst develops multiple scenarios for periods of critical parking need. For example, when there is a combination of retail and office uses, the analyst might assess both weekday and weekend demand in order to ensure that the parking system will work well during both time periods. Another reason to create multiple scenarios is to document why one scenario creates greater parking demand than another. For example, although peak demand for a shopping center might be expected to occur in December, if the center has a large, multiscreen cinema and/or a high proportion of its gross leasable area in restaurants, the peak accumulation of vehicles may occur in late December, or even in July.

In Step 5, the analyst makes adjustments to account for patrons who arrive by means of transportation—such as bicycle, bus, foot, or train—that do not create on-site parking demand. It is important to note that typical transportation data simply reflect modal split—that is, the share of person-trips made by private auto versus the share made by other forms of transportation. But base parking ratios reflect both person-trips and the number of persons per car. Generally, therefore, the analyst adjusts the base parking ratios by dividing the reported modal split by the reported number of persons per car.

In Step 6, the analyst adjusts for "captive" parking patrons who are not incrementally contributing to the overall parking demand at a given time of day. For example, at Continental Towers—a suburban office complex consisting of 975,000 rentable square feet (90,580 square meters) in three 13-story towers situated on 34 acres (14 hectares)—food-service providers serve breakfast and lunch to some of the development's office workers and visitors. Because of the nature of the development, most of the patrons who visit these food-service providers are using the adjacent office space. These diners are considered to be captive because when they dine, their vehicles do not incrementally increase parking demand. Or, to put it another way, when parking demand is measured at this development, the vehicles of these diners have already been accounted for in the demand projections for the office space.

In the Continental Towers example, any parking demand generated by the food-service providers would need to be heavily or completely discounted to account for the captive market. In contrast, if a mixed-use project has restaurants, offices, and a cinema, an office employee who stays for dinner and then goes to a movie must be counted as a source of office parking demand during normal working hours, as part of the parking demand for the restaurant between 6 and 8 p.m., and as part of the parking demand for the cinema starting at 8 p.m. Because the time-of-day factors for office employees reflect the expectation that they go home at the end of the work day, those who remain for dinner and a movie are not considered captive for those uses in the evenings.

Care needs to be taken with the captive-market adjustment. For example, if an employee's car is parked in the same parking space all day and into the evening, the length of stay is much longer than normal for an office building, creating an incremental parking demand in the evening. The key is to determine whether a person who visits multiple destinations in a single trip is already counted as being parked at one land use while patronizing another.

In Steps 7 and 8, the analyst calculates the parking demand under each scenario and confirms that the scenarios reflect all critical parking needs. The shared-parking model developed by ULI projects the peak overall accumulation of vehicles, as well as peak accumulations for weekday and weekend mornings, afternoons, and evenings, so that the analyst can easily pick out data for a particular scenario.

Step 9, the development of a parking plan that will facilitate shared parking, is often neglected. Even when peak parking accumulations are accurately projected, there may still be perceived parking shortages if the parking spaces are inconvenient to the uses served. It is therefore critical to create a practical plan for implementing a shared parking arrangement.

There are three principal elements in the development of a parking plan: (1) confirming that the overall parking supply will be adequate at the different times represented by key scenarios; (2) confirming that the parking demand of individual user groups is met within reasonable walking distances; and (3) determining if any parking-management strategies are required to support element 2. For example, employees of office and other uses can be expected to park farther away than patrons of retail and restaurant uses. If spaces that are needed to serve retail customers are close to office parking, parking-management strategies to discourage or prevent use by office employees who arrive earlier in the day may be required. The base parking ratios in the second edition of *Shared Parking* have therefore been separated into employee and visitor components. *Shared Parking* can be consulted for further guidance on how to develop a parking plan.

NOTES

1. ULI–the Urban Land Institute, *Shared Parking* (Washington, D.C.: ULI–the Urban Land Institute, 1983).
2. Mary S. Smith, *Shared Parking*, 2nd ed. (Washington, D.C.: ULI–the Urban Land Institute and the International Council of Shopping Centers, 2005).

CHAPTER 4

Zoning REQUIREMENTS

MARY S. SMITH, JOHN W. DORSETT,
AND BOB CHAPMAN

ZONING IS THE MEANS BY WHICH LOCAL GOVERNMENTS ensure that development projects meet the community's standards. Zoning ordinances commonly address setbacks, building heights, floor/area ratios and other measures of development density, rights-of-way, traffic flow, and access; many ordinances also include design standards. With respect to parking, zoning standards typically include formulas for determining how many parking spaces must be provided for specific types of land uses; they may also cover parking layouts, particularly the size of parking spaces and the width of aisles. Although many zoning ordinances also include standards or requirements for lighting, surface treatments, and landscaping, such provisions generally apply to surface parking lots, rather than to parking structures. Standards for the design of parking structures—whether open or enclosed, above or below grade—are set in the building code.

The property owner, the community, and the local government staff charged with administering zoning regulations all benefit from well-defined parking requirements. Provisions must be simple enough to be readily understood, yet comprehensive enough to cover most circumstances that can reasonably be expected to occur. Ideally, the parking provisions included in the zoning ordinance will ensure that adequate parking is provided without requiring excessive parking.

SETTING PARKING REQUIREMENTS

As discussed in Chapter 2, a number of variables—including the size of the building, the adequacy of public transit, the price of parking, the modal split, the potential for shared parking, and the characteristics of the zoning district—can affect parking requirements at a particular site. Thus, a single rigid formula—particularly one based on parking accumulations at a suburban location—may not adequately address all land use categories.

Parking Space Design Requirements in Zoning Ordinances

In early ordinances, geometric standards for parking spaces and aisles were reasonably uniform because most were based on the same source: a 1970 study by the Highway Research Board.[1] In the late 1970s and early 1980s, however, many zoning ordinances were revised to reflect changing vehicle sizes, both in the dimensions for standard stalls and also to allow a significant proportion (as much as 60 percent, in Honolulu) of the parking stalls in a facility to be designed for small cars only. Since the mid-1980s, the proportion of vehicles that are appropriately sized to use those stalls has continuously declined, to the point where less than 20 percent of the vehicles on the road can be parked in small-car-only stalls with a level of comfort similar to that provided in standard or one-size-fits all stalls.[2] Today, there is perhaps no section in zoning ordinances that varies more from locality to locality than the geometric standards for parking space design—and the vast majority of these ordinances merit review and updating.

Chapter 7 of this volume provides recommended parking geometrics, and the PCC's *Recommended Zoning Ordinance Provisions* further discusses the appropriate level of detail for parking space design requirements in zoning ordinances.[3]

Notes

1. Highway Research Board (HRB), *Parking Principles*, Special Report 125 (Washington, D.C.: HRB, 1971).
2. Parking Consultants Council, *Guidelines for Parking Geometrics* (Washington, D.C.: National Parking Association, 2002).
3. Parking Consultants Council, *Recommended Zoning Ordinance Provisions* (Washington, D.C.: National Parking Association, 2006).

Moreover, parking requirements change over time—and all too often, zoning ordinances are the last element in the planning process to be appropriately adjusted. At hospitals, for example, the traditional standard for determining the required number of parking spaces was the number of patient beds; but because outpatient treatment has increased dramatically since 1980, parking demand has increased—without any increase (and often with a decrease) in the number of beds. Nevertheless, few zoning ordinances have been updated to reflect more appropriate parking ratios for hospitals.

One of the fundamental problems with developing a zoning ordinance is that there is no one definitive starting point. Some communities attempt to address this difficulty by adopting another community's zoning ordinance wholesale. However, this approach is not advisable. As Donald Shoup has noted, parking requirements in one ordinance are often based on surveys of parking requirements in other cities—which, in turn, were based on surveys of other communities, which surveyed other communities, and so on, with nary a trace of the origins of the requirements.[1]

In *Flexible Parking Requirements,* the American Planning Association recommends the following six steps for the revision of the parking requirements of a local zoning ordinance:

1. Identify the general characteristics of the development (land uses, employment densities, modes of travel, cost of parking, etc.).
2. Review the parking experience of other localities (studies, literature, and zoning ordinances).
3. Survey parking demand and identify problems at existing uses that may be relevant.
4. Identify the desired level of service (LOS), and establish policies that will support it.
5. Develop parking requirements.
6. Monitor the effectiveness of the parking standards.[2]

A sensible approach to developing parking requirements is to start with industry standards that assume 100 percent automobile use, adjust on the basis of the characteristics identified in Step 1, and develop a preliminary model. The model should then be tested for reasonableness by means of occupancy studies conducted at existing land uses. (This is the same approach discussed in earlier chapters for the estimation of parking demand for a particular land use.)

FLEXIBILITY IN ZONING REQUIREMENTS

The traditional means of incorporating flexibility into zoning requirements include

- ▷ a variety of requirements in different zoning districts;
- ▷ planned unit development (PUD) permits;
- ▷ special- or conditional-use permits; and

In the past, the number of parking spaces in a hospital was based on the number of patient beds. Since the rise of outpatient services in the 1980s, hospital parking demand has increased, while the number of beds has remained stable or even decreased.

▷ variances to individual zoning requirements.

Typically, zoning ordinances prescribe "permitted" uses in a district, which do not trigger any need for approval through public proceedings held by an elected or appointed body. Even when all proposed uses are permitted, however, some localities may require additional types of public review or approval, such as site and design reviews to make sure that the details meet community standards.

Conditional uses—that is, uses that *may* be permitted—require public review to determine the compatibility of the use with the site in terms of size, hours of operation, noise, potential traffic, and other factors. Variances to specific requirements also typically require public review and approval. Traditionally, any reduction in the required number of parking spaces, any change in parking dimensions, or any other proposed change that does not meet the standards prescribed in the ordinance is treated either as a variance or a conditional use.

Ordinarily, a developer requesting a variance must demonstrate that complying with the zoning ordinance creates a hardship that is specific to the site. The fact that the ordinance is outdated (with respect to required parking dimensions, for example) or does not allow for reasonable adjustment of requirements (for shared parking, for example) is often not adequate justification for a variance. All too often, a developer who proposes a variance to a parking requirement may succeed in persuading the review board that the current requirement is inappropriate, but instead of granting the variance, the board will direct the staff to study the provision in question and recommend changes to it—a process that can take months, if not years. In cases like this, it might be said that the developer won the battle but lost the war.

Additional flexibility in zoning requirements is often achieved through the following types of provisions:

- ▷ reductions or waivers;
- ▷ fees in lieu;
- ▷ special taxing districts;
- ▷ land banking;
- ▷ administratively approved deviations; and
- ▷ built-in adjustments.

The following six sections discuss these provisions in more detail.

Reductions or Waivers

Many cities have recognized that requiring parking for each building in the central business district (CBD) will destroy the fabric of the downtown. Therefore, they waive parking requirements for buildings constructed in the CBD.

Some cities have taken significant responsibility for developing parking, but such interventions often have an unfortunate side effect: the price of parking becomes politically constrained, which leads to significant underpricing and encourages single-occupancy vehicle (SOV) commuting. There is a general failure to recognize the full cost of providing parking; this lack of understanding leads to significant pressures to keep parking prices low. Moreover, many property owners argue that there is "free" parking at comparable buildings in other areas, and that parking fees must therefore be kept to a minimum, in order for the property owners to compete successfully.

The market for leasable space in a community will reflect all aspects of the cost of development: land costs, parking costs (if any), infrastructure costs, transportation costs, and so on. Marketplaces come to a unique balance that is based on specific local circumstances. While it is difficult to change parking policies overnight, the market will adjust to changing conditions relatively rapidly. Carmel, California, for example, has prohibited off-street parking anywhere in its vibrant, walkable downtown, but collects fees in lieu to build municipal parking on the periphery.[3] A municipality that prohibits all private parking development generally takes responsibility for providing enough parking for the area to thrive, given local public policies and transportation options. Shoup and others have suggested that while prohibiting all off-street parking in a CBD may not be the choice of every community, prohibiting surface parking lots would improve "pedestrian ambience" and otherwise help to achieve new urbanist and smart growth planning goals. Nearly all cities that

DESMAN ASSOCIATES

With a greater number of land constraints and traffic concerns, zoning for parking in central business districts can be a lot more complicated than it is in suburban communities.

reduce, cap, or waive parking requirements in their CBD require parking in other areas.

Fees in Lieu

Given the high cost of acquiring land and constructing off-street parking, plus the competing demands on municipal resources, a number of local governments have tried to find a way for the developers or property owners who create the need for additional parking to contribute some or all of the cost of developing municipal parking facilities. Under the fees-in-lieu approach, private developers have the option of building the required parking on site or contributing a predetermined amount for each required parking space that is not constructed on site. The local government then uses the funds contributed to the in-lieu account to build spaces in municipal parking facilities.

Fees in lieu work well when strong or rapid development is expected in a defined area that can be served by proposed municipal parking facilities. However, problems may arise where development is slow, small in scale, or unpredictable, and money dribbles into a fund that is not sufficient to cost-effectively develop adequate parking in reasonable proximity to the new development. A developer who contributes $150,000 to a fund in lieu of constructing ten parking spaces on site does not want the money to sit in a fund for five years waiting for more money to come in, or to be spent on a structure that is at the other end of the CBD.

Yet another downside to fees in lieu is that they tend to further increase the political pressure to keep parking fees low. Local property owners will ask: “We paid for the spaces already, so why are you charging us to park there?” Thus, while fees in lieu do help to concentrate parking and to support shared parking, furthering some elements of new urbanist planning, they do little to encourage other modes of transportation.

Special Taxing Districts

In a special taxing district, property owners in the vicinity of a proposed municipal parking facility are charged an annual fee. There are multiple variations of this approach, all of which require state enabling legislation; these approaches include, but are not limited to, tax increment financing districts; special assessment districts; and a more recently developed form, parking improvement districts. Like fees in lieu, special taxing districts may help finance parking. However, if fees in municipal facilities are kept artificially low, special taxing districts will run counter to efforts to promote market pricing of parking, and will do little to support alternative modes of transportation.

Land Banking

Developers who propose a significant reduction in parking requirements for a specific reason but who want to avoid the drawn-out approval processes associated with PUDs, special or conditional uses, or variances may be required to provide a plan showing how the required number of parking spaces could be provided if, in the future, the proposed number of spaces proves insufficient. This approach is called a land bank because the space required for the future additional spaces is held in reserve until or unless needed. Typically, the plan will involve future construction of a parking structure. For such an agreement to be practical and effective, it should specify a study period after first occupancy of the project, during which local planning officials will monitor parking accumulations and determine whether the existing number of spaces is adequate. This arrangement is preferable to requiring the developer to make a permanent commitment to add spaces at any time. Such agreements are easiest to implement in a phased project, where approval of site plans for future phases is required in any event. As each phase comes under review, the parking adequacy can be evaluated and appropriate adjustments in parking ratios made.

Administratively Approved Deviations

Administratively approved deviations eliminate the adversarial nature of zoning variance proceedings and avoid the public hearings and proof of hardship required for deviations from code requirements. In some cases, planning and zoning staff may be given responsibility for evaluating and approving deviations from requirements, within certain prescribed boundaries; in others cases, several departments may be involved. For example, the city of Fort Myers, Florida, has a designated staff action committee (SAC) that includes representatives from seven departments: community development, redevelopment, planning/zoning, public works/engineering, parks, fire, and public safety. The SAC reviews all site plans and can administratively approve deviations that meet specified criteria. If the developer wishes to dispute the SAC decision, the city council serves as the board of appeal. Such an appeal does not open the entire site plan to public review—only the specific deviations under dispute.

Millbrae Station near San Francisco is one of the largest intermodal stations west of the Mississippi. Serving BART (Bay Area Rapid Transit) trains, Caltrain commuter trains, and local bus lines, the station also includes approximately 3,000 parking spaces.

Built-in Adjustments

Built-in, or preapproved, adjustments make it possible to alter zoning requirements for a specific site when such adjustments meet community goals, such as smart growth and transportation demand management (TDM). Some communities have flat built-in adjustments for certain zoning districts, the most common of which is a complete waiver of parking requirements in the CBD. Others have more specific adjustments that customize the parking requirements for a particular site. Adjustments that take into account shared parking, ridesharing, and transit credits are examples of deviations from parking requirements that can be interpreted and enforced at the staff level, or by an SAC, as discussed earlier, with the option of appealing an SAC decision through a public review process. Built-in adjustments for shared parking, off-site parking, ridesharing, and transit can be used to achieve an appropriate degree of flexibility in parking requirements.

Shared Parking

Many ordinances today provide built-in reductions for shared parking; some prescribe an overall flat adjustment when multiple uses share parking, and others prescribe flat adjustments for specific combinations of two uses. Neither of these approaches is likely to be accurate, however, and may underestimate parking needs in some situations and overestimate them in others. Typically, because of concerns about parking shortages, the flat reductions permitted are quite conservative, and in most cases result in more parking than is needed. To avoid this outcome, local governments must require and accept site-specific analyses.

The methodology recommended in the first edition of *Shared Parking* has stood the test of 25 years of application. In 1995, an Institute of Transportation Engineers committee reviewed and tested the methodology. Although the committee concluded that the default values needed updating and expansion, it found that the underlying methodology was still the best way to project parking needs for a particular combination of circumstances.[4] The Parking Consultants Council (PCC) strongly recommends that zoning ordinances permit reductions in the required number of parking spaces on the basis of a shared-parking study that is performed by a qualified traffic or parking consultant and is in accordance with the latest edition of *Shared Parking*. The locality can facilitate this process by prescribing acceptable modal adjustments, particularly for employee parking; these adjustments should be based on a study of census data on modal splits in specific areas of the community. The ordinance could also set a maximum reduction for shared parking that can be administratively approved without a public hearing or approval by a zoning board, a board of appeals, and/or the city council, depending on local practice.

Off-Site Parking

Many local zoning ordinances include clauses that allow off-site parking to be substituted for on-site parking under certain conditions. Such provisions increase the administrative duties of zoning officials, requiring them to judge the convenience and location of the off-site parking, and to determine whether it is suitable for the anticipated users. Also, the developer is typically required to guarantee that the parking will be available and maintained for as long as the building use remains.

Ridesharing Programs

Ridesharing includes various forms of carpooling, vanpooling, subscription bus services, and other arrangements. It is generally associated with commuters, but private shuttle services to hotels, airports, and other destinations are also a form of ridesharing. Properly formulated ridesharing programs can significantly reduce both traffic and parking demand. Zoning credits for ridesharing are a particularly effective means of achieving a community's TDM goals.

Transit

Even smaller communities may have certain areas that are well served by public transit, while other areas are not. With the modal-split data now available from the U.S. Census Bureau, it would be beneficial for local governments to purchase the detailed data and prescribe adjustments for various conditions, including reductions in parking requirements for uses or areas that are within a certain distance of a transit stop.

MAXIMUM VERSUS MINIMUM PARKING REQUIREMENTS

As noted earlier, local governments typically set minimum parking requirements for various land uses. In some urban areas, however, street and freeway capacity are so constrained that jurisdictions sometimes restrict parking as a means of encouraging other forms of transportation. In Boston, for example, not only are developers not required to construct parking, but there is also a cap on the total number of parking spaces in the center city. All owners of nonresidential parking must have a license for the number of spaces provided; any developer who wants to develop new parking must "buy out" enough licenses to cover the proposed number of spaces; and the facilities whose spaces have been bought out must close. In some cities, such as New York, land values are so high that new developments provide only the minimum number of spaces necessary to finance and lease the building—and in many cases, no parking is provided at all. Taken together, the parking cap and the high market price of parking do a reasonably good job of limiting vehicle trips to Manhattan.

Instead of capping the overall number of parking spaces, other cities use maximum parking requirements, at least in some districts.[5] London changed its parking policy from minimums to maximums in the late 1960s; the new maximum ratios were generally less than half of the former minimum ratios.

Whether a local government can set maximum rather than minimum parking ratios depends largely on the availability of rail transit. While bus transit is important, it is light rail or heavy rail that significantly reduces suburban-to-city-center SOV commuting. On an average weekday, Bay Area Rapid Transit, in California, carries over 300,000 riders. But it took over 25 years (beginning in 1946, with the first discussions of developing a rail system to traverse the bay, instead of constructing more vehicular bridges) to open the first segment of the system, in 1972. Los Angeles's Metro rail system carried its first rider in 1990, but has already achieved an average daily ridership of over 230,000.

The PCC recommends that the base ratios provided in *Recommended Zoning Ordinance Provisions* and included here as Figure 4-1 serve as a starting point for the development of maximum parking ratios that incorporate adjustments for the price of parking, shared parking, and TDM goals.

NOTES

1. Donald C. Shoup, *The High Cost of Free Parking* (Chicago: American Planning Association, 2005), 21–73.
2. T.P. Smith, *Flexible Parking Requirements*, Planning Advisory Service Report No. 377 (Chicago: American Planning Association, 1983), 23–24.
3. Shoup, *High Cost of Free Parking*, 102–103.
4. ITE Technical Council Committee 6F-52, *Shared Parking Planning Guidelines* (Washington, D.C.: ITE, 1995). The committee also found that many of the default values needed to be updated; recommended that the base parking ratios be expanded to cover more land uses; and suggested other enhancements.
5. Shoup, *High Cost of Free Parking*, 121–122.

FIGURE 4-1: Recommended Parking Ratios

Use	Parking Ratio	Source
RESIDENCES AND COMMERCIAL ACCOMMODATIONS		
Single-family dwelling unit (DU)	■ <2,000 square feet (186 square meters): 1/DU ■ 2,000–3,000 square feet (186–279 square meters): 2/DU ■ >3,000 square feet (279 square meters): 3/DU	1
Multifamily DU		
Rented	1.65/DU	2
Owned	1.85/DU	2
Accessory	Add 1/accessory DU	4
Sleeping rooms	1/unit or room, plus 2 for owners/managers	4
Commercial lodgings*	1.25/room plus 10/1,000 square feet (10.8/100 square meters) of gross floor area (GFA) for lounge and/or restaurant, plus conference/banquet facilities at the following rates: ■ <20 square feet (1.86 square meters)/room: 0 ■ 20 square feet (1.86 square meters)/room: 30/1,000 square feet (32.3/100 square meters) of GFA ■ 20–50 square feet (1.86–4.65 square meters)/room: scaled proportionally between 20 and 50 square feet/room (1.86 to 4.65 square meters) ■ >50 square feet (4.65 square meters)/room: 20/1,000 square feet (21.5/100 square meters) of GFA	2, 4
Housing for seniors	0.5/DU	
Congregate care or assisted living	0.35/DU	1
Group homes, convalescent homes, and nursing homes	0.5/bed	1
RETAIL SALES AND SERVICES		
General and convenience retail*	2.75/1,000 square feet (2.96/100 square meters) of GFA	1
Grocery stores*	6.75/1,000 square feet (7.26/100 square meters) of GFA	1
Heavy/hard goods*	2.5/1,000 square feet (2.69/100 square meters) of GFA, including outdoor sales areas	1, 4
Discount superstores*	5.5/1,000 square feet (5.92/100 square meters) of GFA, including outdoor sales areas	1
Specialty superstores*	4.5/1,000 square feet (4.84/100 square meters) of GFA, including outdoor sales areas	1
Shopping centers with not more than 10% of gross leasable area (GLA) in nonretail sales and service uses, as defined in Chapter 2, "Definitions of Square Footage," page 9.	■ <400,000 square feet (37,160 square meters) of GLA: 4.0/1,000 square feet (4.3/100 square meters) of GLA ■ 400,000–600,000 square feet (37,160–55,740 square meters) of GLA: scaled proportionally between 4.0 and 4.5/1,000 square feet (4.3 and 4.84/100 square meters) of GLA ■ >600,000 square feet (>55,740 square meters) of GLA: 4.5/1,000 square feet (4.84/100 square meters) of GLA	3

FIGURE 4-1: Recommended Parking Ratios *(continued)*

Use	Parking Ratio	Source
Shopping centers with more than 10% of GLA in nonretail sales and service uses, as defined in Chapter 2, "Definitions of Square Footage," page 9.	Should be established in accordance with a shared parking study prepared specifically for the subject project	2
FOOD AND BEVERAGE SERVICES		
Fine or casual dining (with bar)	20/1,000 square feet (21.5/100 square meters) of GFA	2
Family restaurant (without bar)	15/1,000 square feet (16/100 square meters) of GFA	2
Fast food restaurant	15/1,000 square feet (16/100 square meters) of GFA	2
Night club	19/1,000 square feet (20.5/100 square meters) of GFA	2
OFFICE AND BUSINESS SERVICES		
General business offices	■ <25,000 square feet (2,325 square meters) of GFA: 3.8/1,000 square feet (4.1/100 square meters) of GFA ■ 25,000–100,000 square feet (2,325–9,290 square meters) of GFA: scaled proportionally between 3.8 and 3.4/1,000 square feet (4.1 and 3.67/100 square meters) of GFA ■ 100,000 square feet (9,290 square meters): 3.4/1,000 square feet (3.67/100 square meters) of GFA ■ 100,000–500,000 square feet (9,290–46,450 square meters): scaled proportionally between 3.4 and 2.8/1,000 square feet (3.67 and 3/100 square meters) of GFA ■ >500,000 square feet (>46,450 square meters): 2.8/1,000 square feet (3.0/100 square meters) of GFA	2
Consumer services offices	4.6/1,000 square feet (5/100 square meters) of GFA	2
Data processing, telemarketing, or operations offices	6/1,000 square feet (6.5/100 square meters) of GFA	2
Medical offices that are not part of a hospital campus	4.5/1,000 square feet (4.8/100 square meters) of GFA	2
Medical offices within a hospital campus	4/1,000 square feet (4.3/100 square meters) of GFA	4
Government facilities	Should be established in accordance with a study of parking needs prepared specifically for the subject property	
INDUSTRIAL, STORAGE, OR WHOLESALE FACILITIES		
Manufacturing or industrial	1.85/1,000 square feet (1.99/100 square meters) of GFA, plus required parking spaces for office, sales, or similar uses where those uses exceed 10% of GFA	1
Storage or wholesale	0.67/1,000 square feet (0.72/100 square meters) of GFA	1
Mini-warehouse	1.75/100 units	1
EDUCATIONAL OR INSTITUTIONAL USES		
Elementary or middle school	0.2/gym or auditorium seat, or 0.25/student—whichever is higher	1, 4
Secondary school	0.3/gym or auditorium seat, or 0.3/student—whichever is higher	4

Use	Parking Ratio	Source
College or university	Should be established in accordance with a study of parking needs prepared specifically for the subject institution	4
Daycare center	0.3/person, based on licensed enrollment capacity	1
Hospital or medical center	Should be established in accordance with a study of parking needs prepared specifically for the subject institution	4
ARTS, RECREATION, AND ENTERTAINMENT USES		
Convention centers or meeting and banquet facilities that are not within a hotel but that exceed 100 square feet (9.3 square meters) per sleeping room	■ <25,000 square feet (<2,320 square meters): 30/1,000 square feet (32.3/100 square meters) of GFA ■ 25,000–50,000 square feet (2,320–4,645 square meters): proportionally scaled between 30 and 20/1,000 square feet (32.3 and 21.5/100 square meters) of GFA ■ 50,000 square feet (4,645 square meters): 20/1,000 square feet (21.5/100 square meters) of GFA ■ 50,000–100,000 square feet (4,645–9,290 square meters): scaled proportionally between 20 and 10/1,000 square feet (21.5 and 10.8/100 square meters) of GFA ■ 100,000 square feet (9,290 square meters): 10/1,000 square feet (10.8/100 square meters) of GFA ■ 100,000–250,000 square feet (9,290–23,225 square meters): scaled proportionally between 10/1,000 and 6/1,000 square feet (10.8 and 6.5/100 square meters) of GFA ■ >250,000 square feet (>23,225 square meters): 6/1,000 square feet (6.5/100 square meters) of GFA	2, 4
Health club	7/1,000 square feet (7.5/100 square meters) of GFA	2
Cinema	1 screen: 0.5/seat 2–5 screens: 0.33/seat 5–10 screens: 0.3/seat >10 screens: 0.27/seat	2, 4
Theater (live performance), house of worship, or religious center	0.4/seat	2
Arena	0.33/seat	2
Football stadium	0.31/seat	2
Baseball stadium	0.35/seat	2
All other public assembly spaces	Where not seated, 0.25/person, based on permitted capacity Where seated, 0.3/seat	4

*Not in a shopping center.

Sources:

1. Institute of Transportation Engineers (ITE) Parking Generation, 3rd ed. (Washington, D.C.: ITE, 2004).
2. Mary S. Smith, *Shared Parking*, 2nd ed. (Washington, D.C.: ULI–the Urban Land Institute and the International Council of Shopping Centers, 2005).
3. ULI–the Urban Land Institute, the International Council of Shopping Centers, and Walker Parking Consultants. *Parking Requirements for Shopping Centers: Summary Recommendations and Research Study Report*, 2nd ed. (Washington, D.C.: ULI–the Urban Land Institute, 1999).
4. The collective experience of the Parking Consultants Council.

CHAPTER 5

Programming and CONCEPTUAL DESIGN

GARY CUDNEY AND SCOTT HERMAN

THE MOST SUCCESSFUL PARKING projects are often those that begin well:

▷ The goals of the owner and the users have been clearly defined.
▷ The design criteria have been documented.
▷ The project participants fully understand the budget and schedule.
▷ A shared vision has been established for the function, appearance, and quality of the project.

Careful programming and conceptual design help guarantee good beginnings. Programming involves identifying and documenting the project goals, objectives, and criteria. Conceptual design transforms those goals, objectives, and criteria into design concepts and preliminary drawings. These crucial beginning steps are best performed by experienced parking consultants who understand all aspects of parking design, rather than by junior staff or by firms or individuals who are unfamiliar with the unique demands of parking design.

PROGRAMMING

Programming is the research and decision-making process that defines the objectives of the parking project and sets about achieving them. It involves gathering, organizing, analyzing, and evaluating information, then formulating conclusions. The information, analysis, and conclusions are presented in a written and illustrated document known as a program. The program generally includes four main sections: goals, facts, precepts, and concepts.

The information is drawn from the owner, users, zoning requirements, building codes, and the experience of the parking consultant and design team. Information is generally gathered at meetings between the owner and the designers, and perhaps through meetings with user groups or in public forums that provide opportunities for input. A programming checklist can help make sure that the necessary information is obtained and that relevant issues are addressed.

Goals

To identify project goals, the programmer asks the following questions:

▷ What is the purpose of the project?
▷ What are the objectives of the client and the users?
▷ What are the project's characteristics?

The accompanying feature box lists the project characteristics that should be considered.

Project Characteristics

▷ Number of spaces to be provided initially
▷ Future expansion requirements (if any)
▷ Types of users (long versus short term; high versus low turnover; event)
▷ Segregation requirements (e.g., segregating hourly visitors from patrons with monthly parking permits, segregating students from facility in an academic setting, or segregating physician parking from patient parking in hospitals)
▷ Cost of parking
▷ Type of parking (self-park or attendant parking)
▷ Parking operating-system features and performance expectations
▷ Security system features and performance expectations
▷ Requirements for, and locations of, barrier-free parking spaces
▷ Other functions or spaces
- Parking management offices
- Customer waiting areas
- Public facilities
  - Restrooms
  - Information booths or kiosks
  - Bike racks or bike lockers
  - Showers and lockers for bike users
- Storage areas
- Trash and recycling areas

▷ Will the facility be mixed use—that is, will parking be provided above or below other uses?
▷ Will ground-level lease spaces be provided? If yes, what will the uses be?

Facts

"Facts" refers to both quantitative and qualitative issues. Some facts may be available immediately, whereas others will require research. Quantitative issues include site, climate, utilities, traffic, zoning and building codes, design criteria, building quality, mechanical and electrical systems, scheduling, and budget. Qualitative issues include aesthetic characteristics, views, vegetation and wildlife, sensory characteristics, cultural implications, and concerns about sustainability and environmental qualities. The feature boxes on pages 34 and 36 list quantitative and qualitative issues that should be addressed in the program.

Precepts

The precepts are planning commitments that take into account the goals and facts, and set the overall direction of the design of the parking facility. Precepts may be simple (e.g., graphic depictions of the relationships between spaces and uses) or complex (e.g., detailed information on a space and its functional requirements).

Concepts

Concepts are general planning directions suggested by the goals, facts, and precepts. Since the programmer should, ideally, be an experienced parking consultant, the programming process should naturally yield concepts that the designers and engineers can use in the next steps of the design process. The concepts are not the actual design, but are graphic representations of the goals, facts, and precepts that indicate, for the designers, both the opportunities and constraints associated with the project design. Like the precepts, concepts may be simple (e.g., a depiction of the allowed building envelope—that is, the "box"), or complex (e.g., the suggestion of alternative design considerations that might lead to development "outside the box").

For any project, the programmer may generate numerous alternative concepts to address the desired goals; the programmer must indicate which concepts best achieve the project goals. The project designers use the programming

Quantitative Issues

Site

- ▷ A legal description or an American Land Title Association (ALTA) survey is required to
  - Determine the boundaries and dimensions of the site
  - Determine the location of existing structures
  - Document deed restrictions, rights-of-way, and easements (including easements for future street widening)
  - Document the location of all existing utilities (both above- and below-ground)
- ▷ Adjacent and nearby property must be evaluated for
  - Current and proposed uses
  - Size and proximity of structures
- ▷ A topographical survey is required to assess
  - Land contours
  - Drainage patterns
  - Flood risks
  - Slope in relation to surrounding property or streets
- ▷ Geotechnical investigations are required to
  - Assess soil conditions
  - Identify seismic issues
  - Determine whether there are groundwater issues
  - Develop design criteria and recommendations for the building foundation
  - Evaluate the need for underpinning of adjacent structures

Climate

- ▷ Rainfall: volume, frequency, and seasonal variations
- ▷ Sunlight: critical vertical and horizontal angles
- ▷ Temperature: extremes and seasonal variations
- ▷ Wind: velocity, direction, extremes, and seasonal variations
- ▷ Snow: volume and seasonal variations
- ▷ Relative humidity: percentages and seasonal variations
- ▷ Potential natural disasters: tornadoes, hurricanes, floods, earthquakes, etc.
- ▷ Microclimate

Utilities

- ▷ What utilities are available, and what are their capacities?
- ▷ Which of the existing utilities need to be removed?

Traffic

The evaluation of traffic requirements should include input from the public works and/or the traffic department. The following issues should be addressed:

- ▷ Points of entry and exit
- ▷ How much traffic is there on service streets?
- ▷ In what directions does the traffic flow?
- ▷ Is a traffic study required?
- ▷ Will cars have to cross traffic to enter or exit the facility?
- ▷ Can there be separate entrances and exits?
- ▷ Can deceleration lanes be provided?

Zoning and Building Codes

Zoning

- ▷ Is a parking structure an allowed use, or will conditional use permits or zoning variances be required?
- ▷ Is the property affected by covenants or easements?
- ▷ Will an environmental impact report be required?
- ▷ How are the surrounding properties zoned?
- ▷ What are the surrounding uses?
- ▷ What are the zoning requirements for the following:
  - Setbacks
  - Height or floor area
  - Green space
  - Dimensions of parking spaces and drive aisles

Building Codes

- ▷ What building codes apply (e.g., the International Building Code or another model code)?
- ▷ What local amendments have been made to the building code?

Size and Space Requirements

- ▷ What are the minimum floor/area requirements for accessory uses (e.g., offices or waiting rooms)?
- ▷ What relationship will the parking structure have to other uses (e.g., ground-level retail or other commercial space)?
- ▷ Will parking be above grade, below grade, or a combination?

Design Criteria and Building Quality

- ▷ What guidelines in the specific or general plan apply to the project?
- ▷ Will the project be subject to evaluation by design-review boards or commissions?
- ▷ What type of construction is desired (steel, concrete, etc.)?
- ▷ Are the desired materials readily available?
- ▷ What requirements are there for compatibility with site and neighborhood context?
- ▷ Is this intended to be a "statement" project?

Mechanical and Electrical Systems

- ▷ Type of elevator(s)
- ▷ Use of natural versus mechanical ventilation
- ▷ Requirements for fire-suppression sprinklers and standpipes
- ▷ If the project includes mixed-use space, heating, ventilating, and air-conditioning requirements for the mixed-use space
- ▷ Type and quality of lighting
- ▷ Type of emergency power

Scheduling

- ▷ Duration of the entitlement process
- ▷ Duration of the design process
- ▷ Method and duration of bidding
- ▷ Duration of construction

Budget

- ▷ Will the budget be fixed or flexible?
- ▷ What funding methods will be used?
- ▷ How will the project be timed in relation to market demand?

concepts to advance the project; in some cases, the concepts actually become the conceptual design. When this happens, programming and conceptual design are combined, and the programming concepts function as the design concepts.

The Program Statement

The programming phase culminates in a written program statement. This statement can be as simple as the following:

> The parking structure will provide 600 spaces for visitors and staff at the existing parking lot site. The structure will be functionally efficient and will blend in attractively with the surrounding architecture. The structure must be open by Thanksgiving and must be constructed for less than $14,000 per space.

It is preferable, however, to create a more detailed program statement so that all parties—the owner, the users, the general public, and the design team—clearly understand the program. A more detailed statement also helps foster "buy in" on the part of stakeholders. The sample conceptual design included in this chapter features a more detailed (yet still somewhat basic) program statement.

CONCEPTUAL DESIGN

Once the program has been established and the design goals clearly articulated, the conceptual design phase can begin. As noted earlier, conceptual design is sometimes simply a matter of further developing the programming concepts. In most cases, however, programming is followed by a three-part process: the schematic design phase, the design development phase, and the construction document phase. Conceptual design occurs during the early stages of schematic design. (On some projects—typically the more complex ones—there may be a separate conceptual design phase in advance of schematic design.)

Initially, the conceptual design consists of preliminary site plans and floor plans that identify various alternatives for the basic components of a parking structure. Such plans would typically address the following:

- ▷ building massing and siting;
- ▷ architectural designs or themes;
- ▷ the size and shape of the footprint, given zoning regulations and site constraints;

Qualitative Issues

Aesthetic Characteristics
- ▷ Historical characteristics of the site and area
- ▷ Contextual responsiveness to adjacent development
- ▷ Integration of public art into project
- ▷ Opportunities for commercial signage such as billboards
- ▷ Provision of ground-level connections to pedestrians

Views
- ▷ Should important views to and from the site be maintained or enhanced?
- ▷ Should view corridors across the site be maintained?

Vegetation and Wildlife
- ▷ Will existing trees be preserved or relocated?
- ▷ Does the landscape design satisfy green space requirements?
- ▷ Will landscaping (e.g., street trees) be incorporated into the public right-of-way?

Sensory Characteristics
- ▷ What type and intensity of stimuli will the facility produce (e.g., noise, odors, vibration, dust)?
- ▷ What type and intensity of stimuli must be excluded or screened?

Cultural Implications
- ▷ Does the project site have archeological significance?

Environmental Qualities and Sustainability Concerns
- ▷ How will the siting and massing of the building affect shade and shadow patterns?
- ▷ What sustainable design features will be included?
- ▷ Will the facility qualify for certification under LEED (Leadership in Energy and Environmental Design) standards or under other sustainability standards?

▷ the locations of vehicle entries and exits;
▷ provisions for parking access and revenue control;
▷ the locations of pedestrian access, elevators, and stairs;
▷ the design of the ramps and the vehicular circulation system (including the impact of the ramp design on the architecture);
▷ the number of levels and spaces, and the layout of the spaces;
▷ the inclusion of mixed-use space;
▷ provisions for horizontal or vertical expansion;
▷ the amount of above-grade versus below-grade parking; and
▷ accommodations for various structural systems, such as precast or cast-in-place posttensioned concrete.

At the stage when many alternatives are being developed, the floor plans are often simple freehand sketches. Alternatively, preliminary plans may be developed through computer-aided design (CAD). For example, isometrics or other types of three-dimensional computer models may be used to depict the ramping system and architectural elevations.

The goal of the conceptual design phase is to select the best of the proposed alternatives. Typically, the selection is based on both objective data and the judgment of the project team. To present the data, parking consultants often create a matrix that compares the features of each alternative to the program objectives. The simplest type of comparison matrix lists all the program criteria and indicates how each alternative measures up. For more complex projects, points can be assigned to each criterion, creating a weighted evaluation system. Weighted rankings can be particularly helpful to the project team.

The feature box on page 37 lists the elements that are typically included in a comparison matrix. It is important to note, however, that the list of elements should be project specific, and should include only those items that vary between the alternatives. For instance, if all alternatives can achieve natural ventilation, this element would not be included in the list.

The deliverables for the conceptual design typically consist of the following:

▷ site surveys, including topographic and boundary information (it is preferred that surveys be provided by the owner);
▷ a preliminary site plan;
▷ sketches (floor plans and isometrics) depicting alternatives;

Elements Typically Included in a Comparison Matrix

- ▷ Total number of parking spaces
- ▷ Number of parking spaces by user type
- ▷ Total number of levels
  - Below-grade
  - Above-grade
- ▷ Vertical circulation system
  - Ramp type (e.g., single helix, double helix)
  - Express ramps versus parking ramps
  - Direction of traffic (one-way versus two-way)
  - Angled versus perpendicular spaces
- ▷ Simplicity of traffic flow
- ▷ Ease of finding parked car
- ▷ Size of building footprint
- ▷ Ability to achieve architectural objectives
- ▷ Total parking area
- ▷ Parking efficiency (square feet per parking space)
- ▷ Location of mixed-use spaces
- ▷ Total area devoted to mixed uses
- ▷ Passive security features (e.g., openness, visibility, lack of hiding places)
- ▷ Openness of interior (i.e., area occupied by ramps versus area occupied by flat floors; extent of interior walls)
- ▷ Extent of facade that is sloping versus extent that is level
- ▷ Slope of vehicular ramps
- ▷ Presence of cross traffic
- ▷ Presence of dead-end parking areas
- ▷ Dump time (i.e., the time required to completely exit the facility during peak traffic volumes)
- ▷ Ability to segregate users
- ▷ Locations of vehicular entrances and exits
- ▷ Segregation of entering and exiting traffic
- ▷ Setback of entrances and exits from intersections
- ▷ Provisions for reentry of vehicles
- ▷ Ability to accommodate desired parking equipment or systems
- ▷ Provision for vertical or horizontal expansion
- ▷ Points of potential conflict between vehicles and pedestrians
- ▷ Locations of elevators and stairs
- ▷ Possibility of natural ventilation
- ▷ Comparative cost of structure
- ▷ Comparative cost per space

▷ comparison matrix;
▷ floor plans for each level of the selected alternative;
▷ preliminary architectural elevations for the selected alternative;
▷ three-dimensional architectural computer models, renderings, or physical models (optional);
▷ preliminary estimates of construction cost; and
▷ preliminary project schedule.

CONCLUSION

In the rush to begin construction, planning is often sacrificed in order to expedite design. However, taking the time to clearly develop and define the program and to compare alternative conceptual designs helps to make sure that the project starts off on the right foot. Careful groundwork in the early stages yields successful parking structures that satisfy owners, users, designers, operators, and the community.

Sample Conceptual Design

The following example of a conceptual design includes a basic program, several conceptual design alternatives, and a comparison matrix for a parking structure.

CARL WALKER, INC.

Site plan with existing conditions.

Program Statement, Perfect City Parking Structure

A. 2009 IBC Building Code

B. 2009 Perfect City Zoning Ordinance

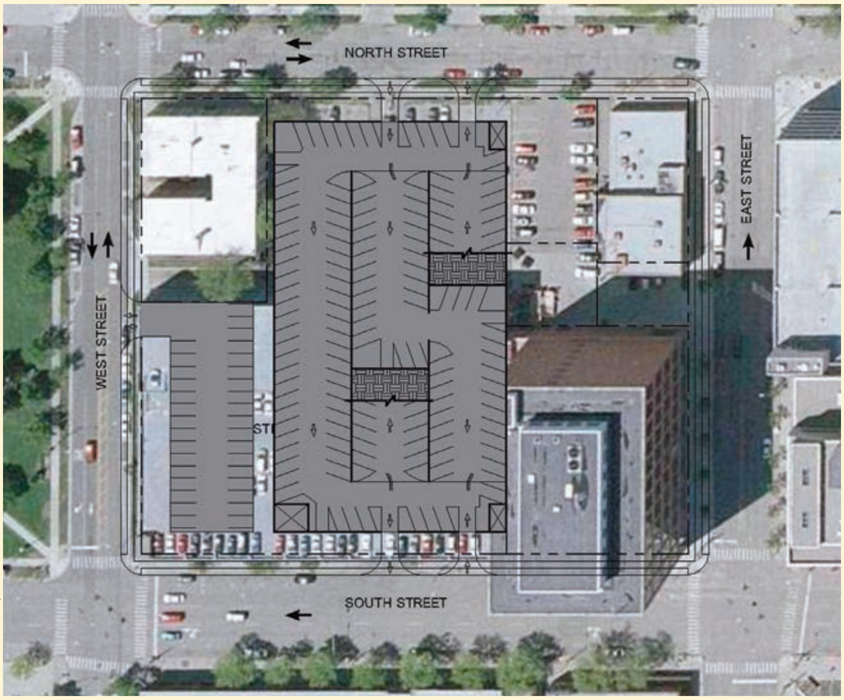
- ▷ Site plan review required by the planning department
- ▷ Zoning: central business district (CBD-1)
- ▷ Parking structures are an allowable use
- ▷ Height limit: 80 feet (24 meters)
- ▷ No setbacks from property lines required
- ▷ No limitations on floor/area ratio
- ▷ Not in a historic district
- ▷ Parking spaces must be 9 feet (2.7 meters) wide

C. Between 1,200 and 1,400 parking spaces are desired, at a budget of $14,500 per space. The client would like a Phase A structure to be constructed on the site of the existing parking lot, then for a Phase B structure to be constructed on the site of the existing parking structure. (The existing structure will be demolished after the Phase A structure is opened). No future expansion is desired.

D. User issues

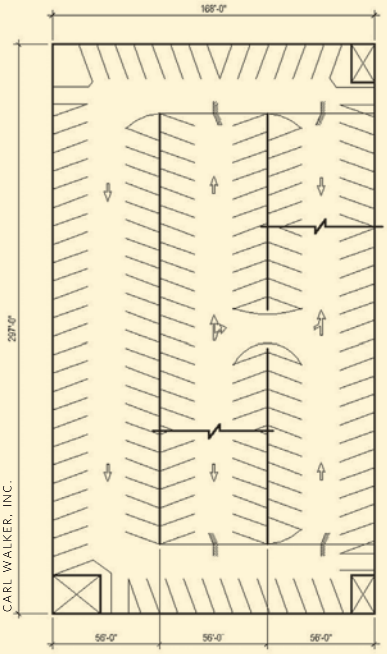
- ▷ Users are primarily monthly contract parkers working in the central business district.
- ▷ 200 of the spaces on the lowest level will be designated for short-term use (a sign at each space will read "No parking before 9:00 a.m. Two-hour limit").
- ▷ The facility will be used evenings and weekends for theatre performances.
- ▷ The theoretical dump time must be less than one hour, assuming that 65 percent of the users exit during the peak hour.

Concept 1



CARL WALKER, INC.

Concept 1 site plan.



CARL WALKER, INC.

Concept 1, diagram of a typical level.

E. Site issues

▷ The site is essentially flat.

▷ There will be no below-grade construction.

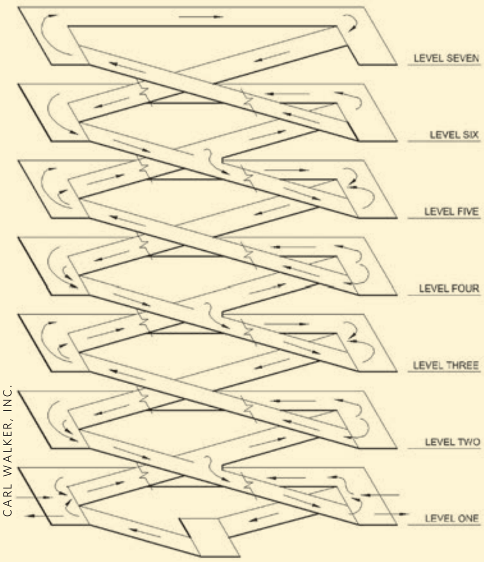
▷ Preferred entry and exit locations are on West Street and South Street.

▷ Pedestrian destinations include adjacent buildings on the same block and on nearby blocks.

F. Functional criteria

▷ The ramp system must be able to accommodate peak-hour entering and exiting traffic without undue congestion or delay.

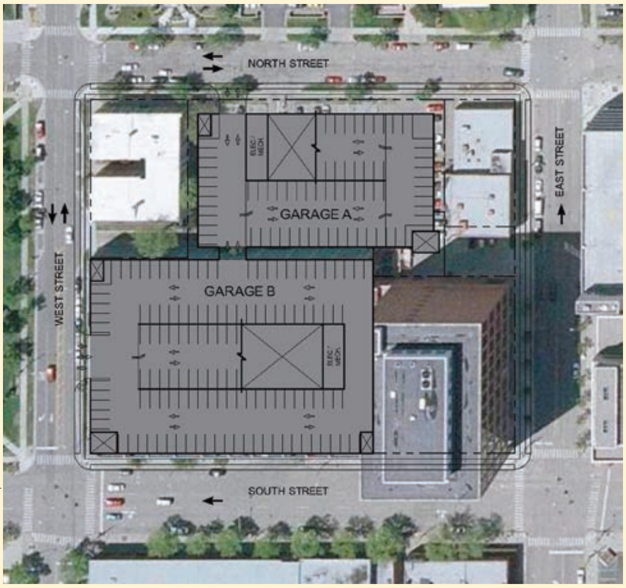
▷ Typical clearance in parking structures is 7 feet (2 meters); for this structure, a clearance of 8 feet, 4 inches (2.5 meters), which assumes a floor-to-floor height of 11 feet, 4 inches (3.4 meters), is desired. This clearance will accom-



CARL WALKER, INC.

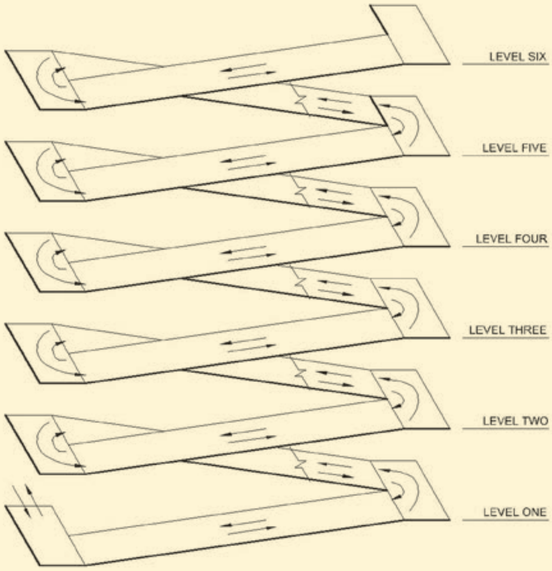
Concept 1, isometric diagram of ramp placement.

Concept 2



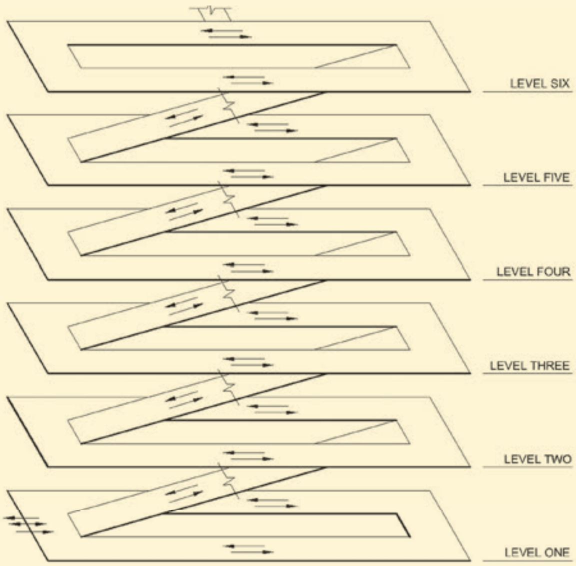
CARL WALKER, INC.

Concept 2 site plan.



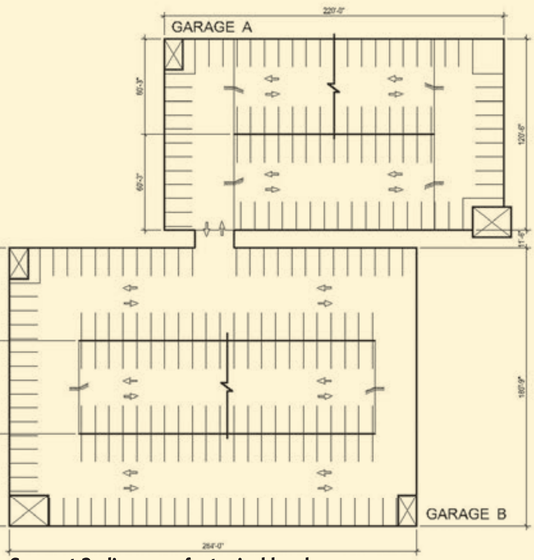
CARL WALKER, INC.

Concept 2, Garage A isometric diagram of ramp placement.



CARL WALKER, INC.

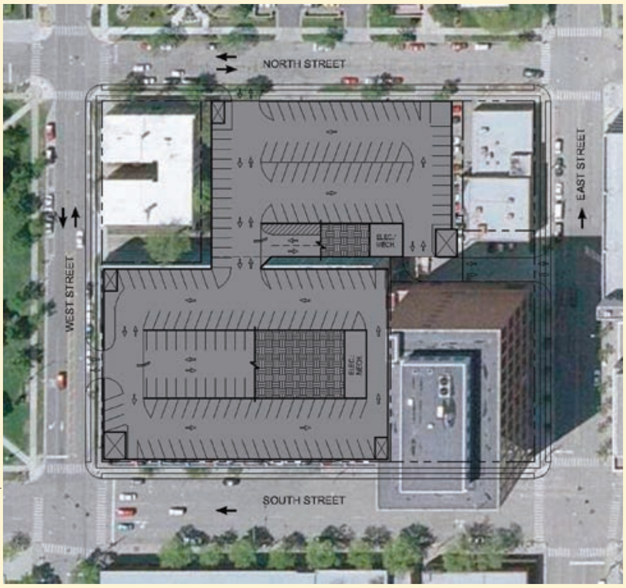
Concept 2, Garage B isometric diagram of ramp placement.



CARL WALKER, INC.

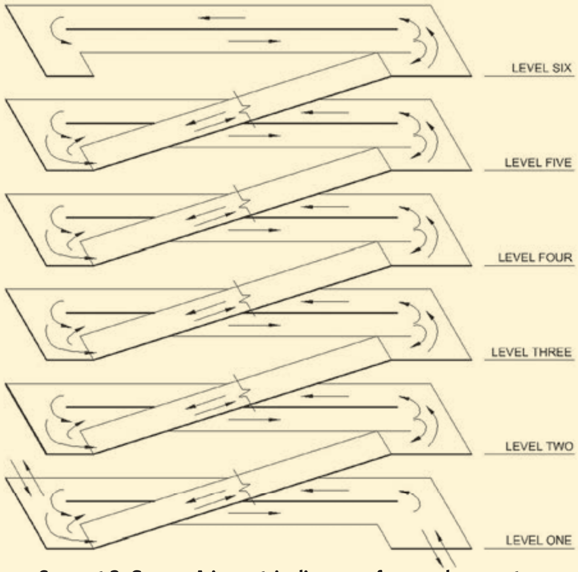
Concept 2, diagram of a typical level.

Concept 3



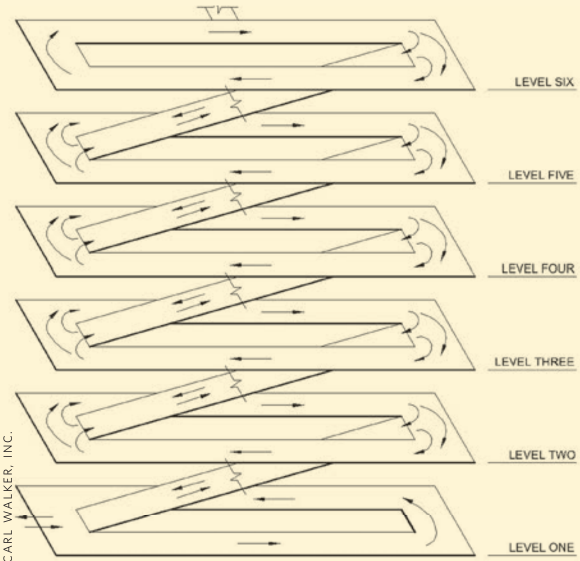
CARL WALKER, INC.

Concept 3 site plan.



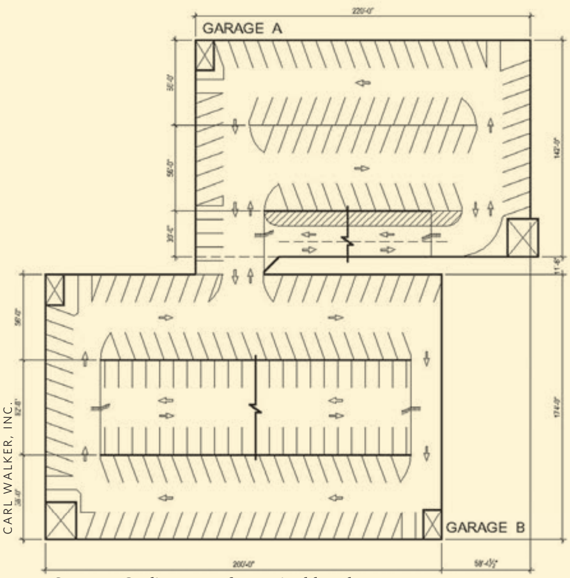
CARL WALKER, INC.

Concept 3, Garage A isometric diagram of ramp placement.



CARL WALKER, INC.

Concept 3, Garage B isometric diagram of ramp placement.



CARL WALKER, INC.

Concept 3, diagram of a typical level.

Sample Conceptual Design *(continued)*

modate most over-height vans used to transport disabled people.

- Parking spaces will be 9 feet (2.7 meters) wide and marked off by double stripes.
- Parking modules will easily accommodate vehicular and pedestrian flow. The 56-foot (17-meter) modules will have spaces angled at 70 degrees, and the 60- to 62-foot (18.3- to 18.9-meter) modules will have spaces angled at 90 degrees.
- To facilitate easier turns and better visibility, small-car spaces will be used at the turn bays at the ends of rows.

G. Other uses

- No other uses will be included in the structure.
- A 300-square-foot (29-square-meter) office for parking operations staff will include the following elements:
  - One unisex rest room
  - A secure room (with a drop safe for counting cash)
  - A manager's area
  - A small area for employee lockers
  - An open area to accommodate a single work station; a counter to separate patrons from staff; cabinets; and a console to house security equipment (intercoms or video monitors).
- A storage room (approximately 1,000 square feet [93 square meters]) will be included at the lowest level, beneath the ramp.
- Utility rooms will be included as required.

H. Security provisions

- "Push for assistance" intercoms will be located in all elevator lobbies, in all stairways, and at parking-control equipment.
- Video cameras will be located in elevator lobbies, in elevator cabs, in the office, at vehicular entry and exit points, and at pedestrian access points.
- Metal halide lighting will be used to provide a bright and comfortable environment (if another, more energy-efficient lighting source, such as fluorescent lights or LED, is used, it must compare favorably in terms of brightness to metal halide).
- To enhance brightness and user comfort, the interior concrete will be stained white.
- Elevators will be glass backed.
- Stairs will be open to the interior and will have liberal amounts of glass on the sides facing the exterior.
- Rooftop stair and elevator lobbies will be enclosed by glass walls.
- All ground-level perimeter openings will have security screens.
- Vehicular entrances and exits will have roll-down grilles.
- To control access after hours, pedestrian doors at grade will be lockable from the interior.

I. Parking operations

- Monthly parkers will use an automatic vehicle identification (AVI) transponder, rather than a key card, to access the parking structure and open the gates. (The transponder is similar to the E-ZPass system used on some tollways.)
- Short-term patrons will access the parking structure by pulling a ticket from a dispenser located at the entrance, and will pay for parking at an automated pay-on-foot station before returning to their parked vehicle.
- Theatre parkers will pay a fixed dollar amount upon entry.
- A computer-controlled parking management and vehicle-counting system will be provided.
- No public restrooms or telephones will be provided.
- One bike rack and ten bike lockers will be provided.

J. Architectural issues

- The facade will be appropriate to the context of the surrounding architecture.
- The facility will look like a parking structure, but will be architecturally enhanced rather than utilitarian in appearance.
- Level facades are preferable to sloping facades.
- The facade will be constructed of brick and precast concrete.
- Glass will be used liberally in elevators and stairwells.
- The elevators will be 3,000-pound (1,361-kilogram) electric traction and will be sized to accommodate an ambulance stretcher.

K. Structural system

The selection of the structural system will take into account the following factors:

- ▷ First cost
- ▷ Maintenance requirements
- ▷ Maintenance costs
- ▷ Life-cycle cost
- ▷ Impact on schedule
- ▷ Impact on functional, security, architectural, and operational goals
- ▷ Impact on car count.
- ▷ The durability system will provide for a 50-year life without major repairs to the concrete superstructure, and will assume the following: :
- ▷ Zone 3 exposure, as defined in American Concrete Institute publication number 362 (American Concrete Institute 362 Zone 3 exposure)
- ▷ Minimum floor slope of 1.5 percent for drainage (2 percent preferred)
- ▷ Use of a corrosion inhibitor in the concrete mix
- ▷ Use of a 40 percent silane floor sealer
- ▷ Use of a 2-inch (5-centimeter) cover over top rebar
- ▷ Use of epoxy coating on top rebar in slabs and beams
- ▷ Use of stainless-steel tee-flange connections (if precast) and hot-dipped galvanized connections for the remainder
- ▷ Minimal use of expansion joints.

L. Mechanical and electrical systems

- ▷ The facility will be naturally ventilated.
- ▷ The structure will include a dry standpipe system.
- ▷ The facility will include a dry wash-down system for cleaning concrete floors, with 2-inch (5-centimeter) risers.
- ▷ Stairs and elevator lobbies will be heated and air-conditioned.
- ▷ Covered parking levels will drain into sanitary systems, and roof levels will drain into the storm system.
- ▷ Lighting will be provided by 100-watt metal halide noncutoff fixtures. There will be two rows of fixtures per parking module, arranged longitudinally at about 20-foot (6-meter) intervals.
- ▷ Lighting conduits will be surface mounted, not embedded in the concrete floors.
- ▷ Electrical outlets will be provided at stair landings and at elevator lobbies.
- ▷ Roof poles will be 25 feet (7.6 meters) high, with 400-watt metal halide cutoff fixtures.
- ▷ Backup power will be provided by an emergency generator.

Selection of the Preferred Concept

Concept 2 was selected because it

- ▷ Provided the number of desired spaces
- ▷ Allowed the existing parking structure to remain open until Phase A was open
- ▷ Was more efficient than Concept 3 and could therefore be built within budget.

Concept 2 is a simple parking facility that meets the functional requirements of the users and the program.

Sample Conceptual Design *(continued)*

Criterion	Concept 1	Concept 2	Concept 3
Number of spaces, Garage A	1,085	483	471
Number of spaces, Garage B	63 (in parking lot)	841	797
Total number of spaces	1,148	1,324	1,268
It will be possible to open Garage A before the demolition of existing garage	No	Yes	Yes
Levels above grade	7	6	6
Building height (feet/meters)	72/22	61/18.5	61/18.5
Vertical circulation system	Double helix	Single helix	Single helix
Express ramps or parking ramps	Parking on ramps	Parking on ramps	Garage A is express; Garage B has parking on ramps
Traffic flow	One-way	Two-way	Both one-way and two-way
Angle of spaces	70-degree angle	90-degree angle	Both 70- and 90-degree angles
Simplicity of traffic flow	Somewhat confusing	Simple	Simple
Ease of finding parked car	Somewhat difficult	Okay (two decks)	Okay (two decks)
Size of footprint (feet/meters)	168 x 297/51 x 91	120 x 220/37 x 67 and 181 x 264/55 x 80	142 x 220/43 x 67 and 174 x 260/53 x 79
Ability to achieve architectural objectives	Good	Slopes toward West Street—which is undesirable	Good
Parking area (square feet/square meters)	332,000/30,845	421,000/39,110	433,700/40,290
Parking efficiency (square feet/square meters per space)	306/28	318/30	342/32
Percentage of flat floors	49	56	82
Slope of vehicular ramps	Okay (5%)	Fair (6%)	Fair (5.6%)
Points of cross traffic	None	At entry/exit, but okay	At entry/exit, but okay
Number of dead-end parking areas	None	1	None
Exiting dump time (minutes)	44	54	51
Ability to segregate short-term spaces	Fair	Good	Best
Locations of vehicular entries and exits	Good	Okay	Okay
Segregation of entering and exiting traffic	Good	Okay	Good
Setback of entries and exits from intersections	Good	Okay	Okay
Comparative total cost (both Garage A and Garage B)	$14.9 million	$18.9 million	$19.5 million
Comparative cost per space (both Garage A and Garage B)	$13,800	$14,300	$15,400

CHAPTER 6

Financial Feasibility and FINANCING

RICHARD A. RICH

UNTIL RECENTLY, PARKING WAS USUALLY PART of a larger development, so the financing of the parking facility was but one component of an overall financing plan. As more and more stand-alone facilities have been constructed, however, developers of parking facilities—including private developers, local governments, hospitals, and universities—have been able to draw on an increasing body of financing knowledge.

FINANCIAL FEASIBILITY

The first step in the development process is the financial feasibility study, the purpose of which is to estimate revenue, expenses, and financial performance. The study is prepared by an experienced parking consultant with a background in two areas: (1) operating and managing parking facilities, and (2) preparing financial projections for parking structures. Using an experienced parking consultant is critical because the lender, bond underwriter, and bondholders may rely on the projections of financial performance in making their investment decisions. They may also prefer that such projections are prepared by a qualified third-party consultant. The credibility of the study may also affect bond ratings—which, in turn, may affect interest rates.

The Preliminary Analysis

A feasibility study is typically undertaken in two phases. The first phase, a preliminary financial analysis, can be performed relatively rapidly and inexpensively as early as the conceptual stage. This analysis will suggest what a project will cost to build, and compare income and costs for future years; thus, it can help the owner/developer estimate the degree of financial exposure associated with the proposal. The goal of the preliminary analysis is to determine whether the project should be pursued, modified, or abandoned; it can also serve as the first step in a more detailed feasibility study.

©MATT FEAGINS/WALTER P MOORE

The parking garage for the international arrivals building at George Bush Intercontinental Airport in Houston.

If the preliminary analysis indicates that the project could succeed, a second study phase is in order. Sometimes, however, the initial examination does not yield a favorable conclusion. In that case, the next step is to undertake a series of sensitivity analyses, to determine whether modifying the original assumptions will yield a satisfactory result. The number of modifications that might be considered is almost endless; for example, alternative scenarios might consider issues such as the following:

▷ Whether increasing garage efficiency (square feet per space) would reduce construction costs.
▷ Whether front-end funds or a downpayment would improve project financing.
▷ Whether reducing operations and maintenance costs would improve project feasibility.
▷ Whether changing the financing method would reduce debt service costs.

If it is warranted by the preliminary analysis, the consultant will prepare a detailed feasibility study well before the owner/developer makes final commitments for land, design and engineering services, and other components of the project.

Components of the Feasibility Study

The feasibility study includes the following components:

▷ project description;
▷ estimates of current and future supply and demand;
▷ a turnover and occupancy study;
▷ historical and current rates for public and private parking;
▷ proposed parking rates, use estimates, and projected revenue;

- ▷ estimates of operating and maintenance expenses;
- ▷ limiting assumptions of the analysis; and
- ▷ an opinion letter.

Project Description

The project description summarizes the principal project characteristics. It includes (1) an estimate of project costs, including land costs; (2) a map of the project location; and (3) schematic drawings showing the dimensions of the parking structure and the means of vehicular and pedestrian circulation. Sometimes the project description will also include specifications and quality standards for material and equipment.

Estimates of Supply and Demand

To estimate supply and demand, the consultant first establishes the project's area of influence—that is, the area that contains the parking-demand generators that the proposed facility is expected to satisfy. The consultant then creates an inventory of existing parking supply and of all demand generators within the area of influence; the inventory of demand generators must include locations and descriptions.

To project future supply and demand, the parking consultant estimates (1) the number of parking spaces available in the area of influence after the proposed facility is complete and (2) the number of spaces that will be required by the demand generators in the area of influence. In formulating these estimates, the consultant must take into account any changes within the area of influence—such as an increase or decrease in demand created by changes in development. When a study is prepared for parking structures that are part of mixed-use projects, the demand for parking associated with each use must be estimated in accordance with the development's projected tenancy.

Turnover and Occupancy Study

A turnover and occupancy study assesses occupancy patterns in the area of influence and may include the site of the proposed facility if it is currently being used for parking. This study is important to establish current use patterns, and is used as the basis for comparisons to projected demand. For example, if the existing parking occupancy is only 50 percent, yet the projected current demand equates to 80 percent occupancy, then there is either an issue with the study, or there is an issue with the assumptions used to estimate the demand for parking.

Historical and Current Parking Rates

The consultant uses current parking rates for public and private parking locations within the area of influence as benchmarks for projecting revenue. Historical data on rate increases suggests to what extent parking rates can be raised in the future.

Proposed Parking Rates, Use Estimates, and Projected Revenue

Using the data on historical and current parking rates, the consultant establishes a proposed rate schedule, then prepares an estimate of the expected number of users (based on data from the projections for demand completed earlier) for each type of parking. Users may include visitors, customers, all-day parkers, employees or residents with monthly permits, and special-event parkers.

Revenue is projected by multiplying the estimated number of patrons for each expected category of use by the rate proposed for that type of use. Because a new facility will not experience full demand from the outset, the consultant will often assume a smaller number of patrons during the early years. A facility usually needs two to three years to achieve near-capacity operation on a fairly consistent basis.

Estimated Operations and Maintenance Expenses

The expenses involved in operating and maintaining a parking facility typically include salaries, wages, and fringe benefits for operating and administrative staff; equipment maintenance; expendable supplies; taxes; insurance; utilities; and minor repairs. Ideally, the owner/developer will establish a sinking fund for major repairs. (In fact, the creation of a repair and replacement fund is a common requirement for revenue-bond financing.)

Because operations and maintenance expenses vary widely with location—depending on factors such as climate, utility costs, and wage scales—the consultant should try to obtain figures from nearby comparable facilities to help guide the formulation of reliable expense estimates. Operating expenses also vary depending on whether the facility is owner-operated or if a management company is employed. (Chapter 20, "Operations and Management," discusses these items in more detail.) In some municipalities, the type of operating arrangement dictates whether union-scale wages must be paid. The municipality may require an operator, and its vendors, to pay union scale wages

WALKER PARKING CONSULTANTS

The seven-story Tampa General Hospital Medical Office Building garage has 1,389 employee parking spaces, plus an emergency helicopter landing pad on its top level.

to both union and non-union workers. The requirement to pay union wages can have a significant impact on financial feasibility.

Limiting Assumptions

A financial feasibility study evaluates the projected financial performance of a proposed project under a given set of circumstances. Thus, the results are subject to error if any of the underlying assumptions change. Because assumptions are so important, they should be listed prominently in the report.

The following list illustrates the types of assumptions that should be addressed. It is important to recognize, however, that certain assumptions will be unique to a given project.

▷ The facility will be designed and constructed so that it will be acceptable to its anticipated patrons, and so that there will be no impediments to its use.

▷ The facility will contain the specified number of spaces and, if applicable, the specified amount of retail or commercial space.

▷ The facility will be constructed and opened in accordance within the specified time frame, and with the estimated construction and financing costs.

▷ Parking fees will be in accordance with projected rates, and rate increases will be implemented as projected.

▷ Operating costs will not exceed estimates.

▷ Maintenance costs will conform to estimates, and the facility will be properly maintained during its service life to ensure continued viability.

▷ There will be no significant changes in the availability and cost of motor fuel, or in competition from transit, during the period of the analysis.

▷ The projected level of new development or redevelopment in the area of influence will occur according to the time frame and development schedule described in the report.

▷ Economic activity (both in the metropolitan area, and in the facility's area of influence); parking demand; and the demand for commercial space will be at normal levels during the period of the analysis.

If these or other assumptions change, it may be necessary to update the financial feasibility study, particularly if a planned project has been on hold for an extended time. The following are examples of some changes that could affect feasibility:

- ▷ A major employer moves into or out of the area.
- ▷ A large generator of evening demand moves into or out of the area.
- ▷ Proposed mixed-use developments increase or decrease in size.
- ▷ New, competing parking facilities are constructed in the area.
- ▷ The direction of traffic flow near the proposed facility changes.

Opinion Letter

The feasibility study contains all the supporting data, and the opinion letter—which is a separate item from the feasibility study—summarizes the results. This letter contains the pro forma, the list of limiting assumptions, and an opinion on the feasibility of the project. Often, the opinion letter is part of the preliminary offering statement. The preliminary offering statement is prepared by the financial consultant or bond underwriter and is provided to potential investors.

BASIC FINANCIAL QUESTIONS TO BE ADDRESSED

Regardless of what is to be financed, some basic financial questions need to be addressed. The next four sections examine the following questions:

- ▷ If money is to be borrowed, what is the source of repayment?
- ▷ What is the value of the revenue stream?
- ▷ What financing structures are available to the private sector?
- ▷ What financing structures are available to the public sector?

Source of Repayment

Revenues generated by the operation of a parking facility are the most common source of debt repayment. Owners/developers may also obtain additional revenue by incorporating retail or commercial space into the lower levels of parking structures, integrating for-rent marquees into facility walls, or leasing or selling space to third parties. Where land values are particularly high, owners whose facilities do not take full advantage of permissible development rights may be able to sell development rights. Transfers of development rights can yield either a one-time payment or a continuous revenue stream.

Local governments can supplement revenues from new parking facilities with revenues from on-street meters, other parking facilities, and parking fines. A limited number of local governments impose impact fees or in-lieu fees. Impact fees are typically charged to a development to pay for some or all of certain infrastructure costs. A fee-in-lieu may be charged to a developer when the developer is unable to provide all of the parking spaces that are required by code. The public sector can also tap tax-revenue sources. From a lender's perspective, the preferred source of tax revenue is the property tax, which is used to repay the general obligations of the municipality. Special assessments—in which parties that benefit from a particular public improvement are assessed a fee to help pay for that improvement—are also sometimes used to repay debt.

Evaluating the Value of a Revenue Stream

Lenders evaluate four key factors in determining the merits of a particular revenue source: the amount of the source, the stability of the source, whether the owner/developer can increase the revenue stream, and whether the owner/developer can legally pledge the revenue source.

Amount

Lenders are concerned about the absolute amount of pledged revenues. If a loan requires payments of $520,000 per month, for example, the proposed revenue source must generate at least that amount for debt service, plus enough additional revenue to cover projected operating expenses and deposits into a sinking fund. Ideally, monies should also be available to finance ongoing repairs and to provide the owner with a return on investment, where applicable.

Stability

Because lenders are concerned about the stability of the projected revenue, they require a debt-service coverage ratio. The ratio compares the amount of revenue (typically the net revenue less operating expenses) available to pay debt service with the debt service itself. A ratio of 1:1 means that one dollar of revenue is available to pay one dollar of debt service. The higher the debt-service coverage ratio, the greater the protection for the lender, should the revenue stream experience some volatility.

WALKER PARKING CONSULTANTS/EAGLE PHOTOGRAPHICS, INC.

In Orlando, Florida, the north and south parking structures at Universal Studios have space for 19,423 vehicles.

For example, assume $500,000 in pledged revenue to support a project, operating costs of $200,000, and debt service of $200,000. If the owner pays operating costs before debt service, $300,000 of pledged revenue is still available for debt service payments—yielding a debt-service coverage ratio of 1.5:1.

Ability to Increase Revenues

Lenders want to know about the developer's legal and practical ability to increase revenues. In the case of a public owner/developer, the lender needs assurance that statutory authority will permit an increase in rates, fees, or charges, so that the required debt-service coverage ratio can be maintained.

Legal Authority to Pledge

A pledged revenue stream has value only if the borrower has the legal right to make such a pledge. Therefore, after determining that revenues are sufficient, stable, and eligible for increases, lenders want to be assured of the developer's legal authority to pledge such revenues. Another important consideration is the developer's position relative to the claim others might have on a particular revenue stream. A lender prefers a superior or parity claim on a revenue stream over a subordinate claim. If the claim is subordinate, the lender will safeguard the investment by discounting the value of the pledged revenue stream (that is, by imposing a higher debt-service coverage ratio) and seeking a greater return on investment (a higher interest rate) as compensation for assuming greater default risk.

Financing Structures Available to the Private Sector

Private developers or operating companies of parking facilities have more financing options than local governments. Usually, private developers are restricted in their financing options only by the economics of the project and the prevailing financing market. In contrast, public developers are constrained by the statutory authorizations that govern various debt instruments.

One distinguishing feature of privately financed projects is the need for equity: whereas the public sector may be able to

Factors That Determine Interest Rates

In purely economic terms, interest rates are a function of the competition for investment dollars. The greater the competition, the lower the rate; the reverse is also true. The more immediate issue is the rate at which a developer can borrow funds. All other things being equal, the cost of borrowing reflects the borrower's credit rating.

Credit-rating agencies require a formal application before they begin their analysis, and their fees are commensurate with the time and effort expended. The rating agencies discuss their conclusions with the issuer before they publish them. If the issuer disagrees with the rating, the agencies are available for a hearing, at which additional information from the issuer may be examined.

There is an inverse relationship between bond ratings and the interest rate on a new bond issue: the higher the rating, the lower the interest rate. Thus, it behooves any public issuer of parking bonds to back those bonds with the highest degree of security that is legally and economically available.

obtain 100 percent debt financing, a private developer must often provide anywhere from 20 to 40 percent of project costs in equity. In other words, no more than 60 to 80 percent of a project can be financed.

The financing structure for a new parking facility is an integral part of the development decision-making process and can have a major effect on profitability. In a normal credit environment, developers can choose from among a variety of financing sources, including real estate investment trusts (REITs), commercial banks, and life insurance companies; and from among a variety of financing structures, including land sale/leasebacks and, until the collapse of the subprime mortgage market, commercial mortgage-backed securities (CMBSs). As of spring 2009, the United States was experiencing a financial crisis that severely limited access to investment capital. It is uncertain what financial tools will be available once the market has recovered.

Although some financing methods may appear more attractive than others, no one financial structure is invariably the best. Terms change weekly, and even daily. Furthermore, lenders who prefer a specific financial structure may not be interested in a particular project. Thus, a developer may have limited choices for a particular project type or location.

Regardless of the chosen financing method, a carefully prepared financial feasibility study is necessary for seeking financing for a proposed parking facility. A lender may also require a study of the underlying commercial venture. The projected cash flow for the overall development will be affected by the results presented in the parking feasibility study.

A large, creditworthy parking company or development company that elects to place its corporate credit behind a stand-alone parking project has a greater range of possible financing options than, for example, a smaller firm with a less established credit history. The choice of option depends on a thorough economic analysis of the proposed project, current interest rates, and the company's overall fiscal policies.

If a proposed parking facility is part of a new development, the level of occupancy by potential tenants will influence the project's financial feasibility. For example, the developer of a project with significant amounts of retail space may seek one or more major anchor tenants that will contribute toward amortizing the project's permanent loan. For large office projects, the developer may seek one or more major tenants to finance a large portion of the facility, then prelease a significant share of the space before seeking project financing. By the time they seek financing, developers of less speculative projects may already have entered into an operating and/or management agreement, or may even have executed a lease with a major tenant that is both the basis for the project concept and serves to guarantee a minimum level of parking revenues.

Financing Structures Available to the Public Sector

Parking facilities can be financed with revenue bonds, special-assessment bonds, tax increment bonds, and a variety of lease-purchase arrangements. Bond financing is governed by state statutes and often by local charters or ordinances as well.

The majority of publicly funded parking facilities are funded using tax-exempt financing. All other things being equal, the chief advantage of a tax-exempt designation is an interest rate that is about 1.5 percent (or 150 basis points) lower than that available under taxable financing, though this spread varies with market conditions. Taxable financing may be required if the structure includes occupied space, or is being built for a business that is classified as private. For example, if a local government builds a parking structure as an incentive to attract a specific company, and that business wants to lease more than 10 percent of the spaces in the parking structure, this would require taxable bonds.

The financing structures that a public developer may use to fund the capital cost of new parking facilities can be grouped into three categories:

- ▷ tax-backed obligations, such as general-obligation (GO) bonds;
- ▷ revenue bonds; and
- ▷ appropriation obligations.

Tax-Backed Obligations

In 1812, New York City reportedly became the first U.S. city to issue bonds secured by property taxes. The following four sections discuss various types of tax-backed obligations.

General-Obligation Bonds. Historically, GO bonds, which are backed by the local government's full faith and credit, have been the principal means of funding local government infrastructure improvements, although the use of such bonds to finance publicly owned parking garages has become increasingly problematic. Competition for scarce property tax dollars, coupled with increasing voter dissatisfaction with property tax increases, has led many local governments to tap other revenue sources.

State statutes govern the issuance of GO bonds for parking facilities or any other capital project. Many such statutes specify the terms of GO bond issues, including maximum term, annual principal requirements, redemption provisions, and method of sale.

GO bonds carry the lowest possible interest rate available to a given local government. Since the local government's full faith and credit is pledged to the repayment of the bonds, the interest rate reflects the local government's creditworthiness. If necessary, a local government can improve its creditworthiness by purchasing insurance.

Special-Assessment Bonds. In some states, municipalities have the authority to issue special-assessment obligations—that is, to repay bonds by levying a fee on a limited area that is expected to benefit from the construction of the public facility in question; in other states, such obligations are ultimately backed by the full faith and credit of the issuing municipality. Special assessments are imposed over and above the regular property tax. Special-assessment districts created to finance a parking facility usually encompass a downtown area whose property owners will benefit from the facility. Special-assessment financing is more prevalent in the Midwest and West than in other regions of the country.

Tax Increment Bonds. Tax increment bonds are generally issued in conjunction with major urban revitalizations or redevelopment projects. The underlying principle is that the development will increase property tax revenues in the affected area. Once a base-year property assessment is established for the tax increment district, any increase over the base year is set aside for payment of the tax increment bonds.

A new parking facility to be financed by tax increment bonds should be of a size and in a location that will serve more than one development project. Before issuing tax increment bonds, the local government may wait until the primary development is well underway, and until there are enough financing commitments to ensure project completion.

Other Tax-Backed Obligations. Other tax-backed obligations include sales-tax bonds, lodging-tax bonds, gross-receipts-tax bonds, and amusement-tax bonds. The characteristics of the revenue streams associated with these obligations make them analogous to revenue bonds. Just like revenue bonds, these obligations require that the revenue streams from the operations are pledged to the debt service.

Revenue Bonds

Parking system revenue bonds, which are payable solely from parking revenues, are usually secured by most, if not all, parking facilities in the system—including off-street garages, lots, on-street meters, and possibly fines. In general, for revenue bonds to be issued, two criteria must be met: (1) for each of the preceding three years, the parking system's net revenues should have been at least 1.3 times the existing debt; and (2) net revenue projections, including those for the new facility and the existing facilities, should be between 1.25 and 1.5 times the annual debt service over the projected life of the new bonds.

Some states permit local governments to issue bonds backed by two revenue sources: specific revenues from the facility, and the issuer's full faith and credit. The interest rate for such bonds—which are commonly referred to as "general-obligation revenue bonds"—is based on the issuer's general-obligation credit rating, despite the pledge of repayment from a revenue stream.

Appropriation Obligations

Appropriation obligations—which include lease agreements; certificates of participation (COPs) in a lease; installment purchase contracts; annual appropriation obligations; and, in some cases, lease revenue bonds—are an increasingly popular method of financing public parking facilities.

The fundamental distinction between a debt and an appropriation obligation is the term of the commitment made by the public entity. With a debt issue, the entity enters into an irrevocable contractual arrangement, much like a mortgage, to make debt-service payments for the full term of the contract. Appropriation obligations, in contrast, are often subject to a governing body's annual recommitment to appropriate funds. In the event that the governing body fails to appropriate money to make the required payments, the investor can reclaim the leased item or other pledged collateral.

PRIVATE CREDIT ENHANCEMENT

Private credit enhancement can, in addition to whatever the issuer may deem to be necessary, provide an adequate level of security for debt obligations. The two main forms of credit enhancement are (1) municipal bond insurance (for tax-exempt bonds) and (2) bank letters of credit (for both tax-exempt and taxable obligations). Municipal bond insurance provides the highest credit ratings, but bond insurers are inherently conservative in their approach to analyzing and securing credits (that is, they require high coverage ratios and rigorous additional bond tests). Letters of credit from commercial banks, which are even more expensive, provide a rating for the proposed bonds that is only as good as that of the bank issuing the letter.

Bond insurance is commonly purchased for the entire life of an issue. In accordance with federal banking laws, letters of credit are frequently limited to seven years, although they often contain "evergreen" provisions that automatically extend or renew the guarantee on an annual basis.

Bond Insurance

Bond insurance guarantees the bondholder timely payment of principal and interest and is granted only after careful analysis by the insurance company and in exchange for a premium that is exacted only once. The premium is generally a fixed percentage of the total principal and interest payments over the life of the bond issue, less any interest that may be capitalized from bond proceeds. The reimbursement agreement, which sets forth the rates charged and the repayment terms for any draws on the policy, is an integral part of the policy.

As a condition for underwriting the policy, the insurer carefully scrutinizes the security provisions of the bond covenants. When the developer is attempting to decide on the merit of bond insurance (or any other credit enhancement), this greater scrutiny (and the more rigorous requirements) must be factored into the cost-benefit analysis (a present-value comparison of the cost of the premium versus the reduction in interest rates).

Letters of Credit

Under the provisions of a letter of credit, a bank agrees, for a specific period of time, to pay the letter holder a specified amount upon demand. The letter describes the procedures to be followed to effect a drawdown of funds, and the procedures that the bank will follow in paying the funds.

A letter of credit is an irrevocable obligation and is always accompanied by a reimbursement agreement that includes the following elements: the application for the letter of credit; the granting of the letter of credit by the bank for a specific amount; the rates charged by the bank; and a statement of the borrower's obligation to repay any amounts drawn down pursuant to letter of credit.

As noted earlier, letters of credit often contain automatic renewal provisions that go into affect at the end of the original term, although the bank also has the option of terminating by notifying the letter holder.

CONCLUSION

As this chapter has presented, the process of evaluating financial feasibility and determining the best way to finance a parking facility is complex and lengthy. Therefore it requires the collaboration of experienced consultants who have vast knowledge of the parking industry and how to finance parking facilities. Each project has its own unique nuances that need to be identified in order to develop the most appropriate financing approach. Each of the consultants plays an important role in this process.

The Role of the Parking Consultant

Many parking administrators or corporate service officers may be able to determine the need for local parking, and a local

Federal Tax Law and Eligibility for Tax-Exempt Financing

The 1986 tax law, its subsequent amendments, and the attendant Internal Revenue Service interpretations have had a major effect on the attractiveness of different methods of financing public and private parking facilities. The revised federal tax code eliminated parking as an activity for which tax-exempt industrial-development bonds could be issued, placed severe restrictions on what constitutes a public purpose for local governments, and repealed many of the tax benefits previously available to real estate investors.

The 1986 tax law clearly distinguishes between what may be financed with tax-exempt bonds or leases and what must be funded with taxable financing. Failure to understand or heed the law could affect a project's eligibility for tax-exempt financing. Thus, both public and private entities should consult with bond counsel (an attorney who specializes in federal tax law) to obtain guidance and a final opinion.

Criteria for exemption from federal income taxes are as follows:

▷ *Public use.* Not less than 90 percent of the available spaces in a financed project must be available to the general public on a daily, monthly, or yearly basis, exclusive of government or nonprofit institutional users.

▷ *Use of bond proceeds.* Not less than 95 percent of total bond proceeds must be spent solely for the construction of public parking spaces, including soft costs related thereto.

▷ *Corporate guarantees.* Not more than 10 percent of the annual debt service may be paid for or guaranteed by a corporate or nonpublic entity on a long-term contractual basis.

▷ *Management agreements.* Any management agreement for the operation of a parking facility must be of limited duration, must provide for either a periodic flat fee or fixed percentage of gross revenues, and must give the owner of the facility the option to cancel at the end of a specified period, depending on the compensation method.

architect may be able to design a structure in which to park cars. But it is a skilled and experienced parking consultant who plans and designs efficient parking facilities that respond to clients' financial requirements. Moreover, a parking consultant's role in planning and designing parking facilities has major implications for project financing. Underwriters are obligated to investigate beyond the obvious forms of security and look into the use to which borrowed funds will be put. Lenders also are much more aware of how their money is to be spent. In the case of new parking facilities, both underwriters and lenders accept the technical expertise of an experienced parking consultant who can demonstrate that a proposed project is planned and designed to perform as anticipated. Clearly, over the last 50 years, the functional and detailed design of parking facilities has become a highly specialized technical art.

Regardless of the method of financing for a public or private parking facility, the developer must propose the most cost-effective facility possible in order to present to lenders the most attractive financial position possible. Given that lenders are concerned with the security of their investment, a parking consultant's estimates of demand, rates, and capital cost—and, thus, economic feasibility—are the most important factors in the lending decision. If the borrower is a private developer or industrial corporation, management has a responsibility to produce a well-designed, operationally efficient parking project while remaining accountable to partners or shareholders. If the borrower is a municipality, elected officials and staff are ultimately answerable to the taxpayers (and voters).

The Role of the Finance Professional

The capital needs and economic risks associated with new parking investments have changed dramatically in recent years. Inflation, recession, and the pressure of increasing economies of scale mean that many new parking investment undertakings are beyond the means of traditional bank financing techniques. As a result, the role of finance professionals—those who assist both public and private owners of new parking facilities—has taken on a greater importance.

The term *finance professional* includes a variety of professional functions or services provided by firms or individuals

WATRY DESIGN, INC./MATTHEW MILLMAN PHOTOGRAPHY

Home to the San Luis Obispo, California, Planning and Community Development Department, the Office and Parking Structure at Palm and Morro has six levels (five above grade), 20,000 square feet (1,900 square meters) of office space, and 242 parking stalls.

that specialize in the development of funding that satisfies lender requirements, while minimizing the cost and degree of effective recourse to the developer. A finance professional can assume many roles, depending on the type of client (public or private), the type of offering to be made (public bid or negotiated sale), and the relationship of the professional to the client (underwriting or advisory). These various relationships include a financial adviser or consultant; a mortgage broker; an investment banker or underwriter; a merchant banker or owner/participant; and venture-capital finders.

The financial adviser and mortgage broker perform a fiduciary function and do not themselves act as principals in the financing on their own account. The financial adviser or mortgage broker represents the interests of developers, acting as a business agent in the analysis, negotiation, structuring, and placement of financial transactions and in long-term capital planning and budgeting. Financial advisers may be investment bankers offering financial advice, or independent financial advisers. While either is competent, an investment banker's views may be limited by what the banker's particular firm can sell, by a desire to negotiate the financing, or by an inherent bias toward representing the interests of investors. In contrast, given that neither an independent adviser nor a mortgage broker buys or sells securities or mortgages, each one adopts the developer's perspective. An independent financial adviser or mortgage broker funds the transaction by turning to any number of prospective firms; thus, each one's view of financing options can be expansive. Each selects the firm whose services best match the developer's needs.

The investment banker and merchant banker perform client services on their own account. That is, by acting as principals in arm's-length transactions, they frequently offer advice to their clients in the process of developing a specific financing package. The primary function of an investment banker is to create investment opportunities for the firm's clients (investors). Similarly, the primary responsibility of a merchant banker is to find investment opportunities for the firm's capital. Venture-capital finders often participate, along with the investors from whom they obtain commitments, by purchasing equity in the financing.

CHAPTER 7

Parking GEOMETRICS

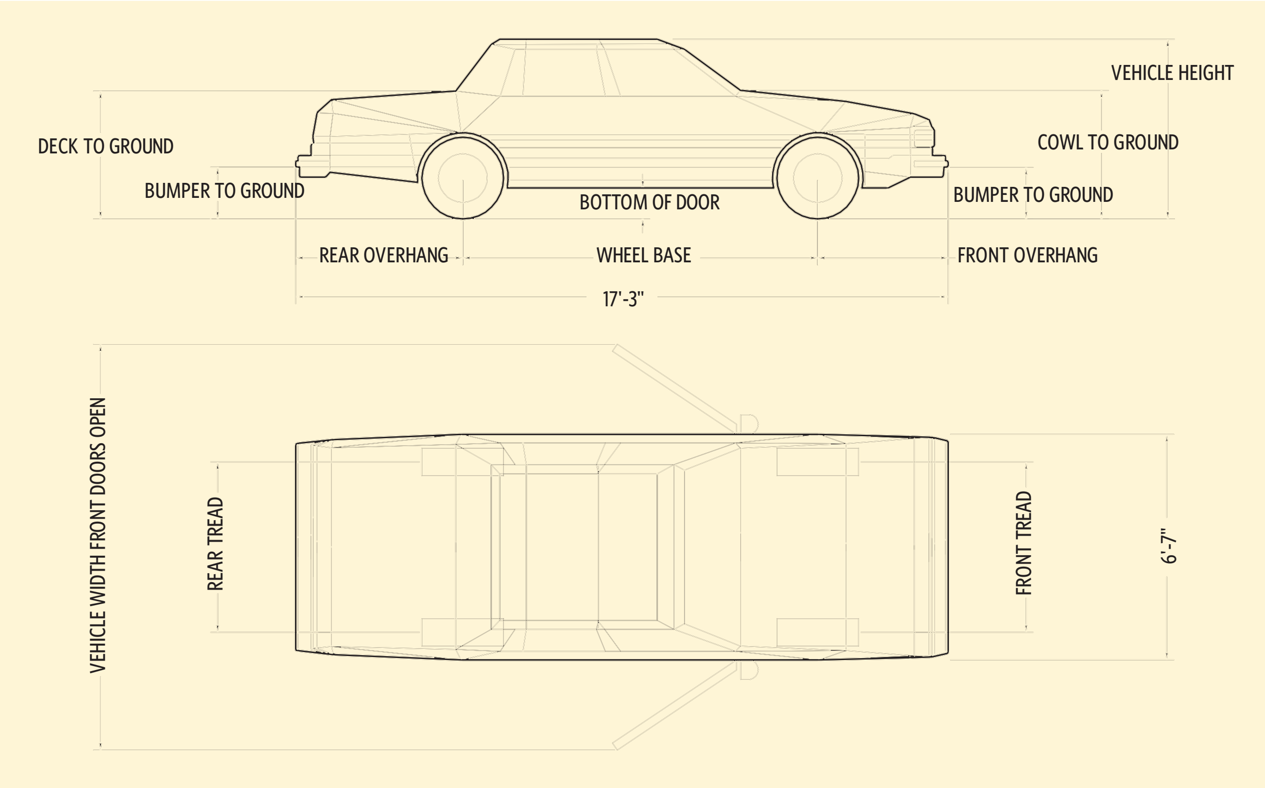
STEPHEN J. REBORA, DAVID LOCOCO, AND MARY S. SMITH

PATRONS MAY BARELY NOTICE WHEN A PARKING FACILITY works well; but when parking is poorly designed and difficult to use, patrons will be frustrated—often to the point where the parking experience will have a negative impact on the business or destination that it supports. To avoid such outcomes, parking consultants have established guidelines for parking geometrics such as the dimensions of parking stalls, the width of aisles, turning radius, and other factors.

Parking geometrics rely on the same basic approach that governs the design of most products, places, and elements of the built environment: namely, that in order to develop a clear program for what is being designed, you must first have a full understanding of what you are designing for. Like nearly all aspects of the physical environment, automobiles are designed on the basis of anthropometric data: measurements of the human form. Parking facilities, in turn, take into account (1) the dimensions and capabilities of vehicles, and (2) the behavior of drivers and pedestrians.

Although vehicle sizes do change over time, they do not change as quickly as one might think. According to the Federal Highway Administration, the average age of passenger vehicles on the road in 2000 was nine years.[1] Moreover, it takes manufacturers several years to redesign and retool their vehicle lineup when consumer appetites change. The increase in gas prices to $4 a gallon in the summer of 2008 caused a significant decline in the sales of sport utility vehicles (SUVs) and pickup trucks, and manufacturers had difficulty meeting the demand for more efficient vehicles. However, SUV and pickup sales increased when the cost of gasoline fell back to below $3 a gallon. In the coming years, gasoline costs and concerns about global warming and reliance on foreign oil are expected to result in a decline in vehicle sizes. However, as of 2009, there has not been a shift in the size of vehicles on the road, nor has there been a shift in size of vehicles sold in the United States. It will take a change in both public policy (perhaps taking the form of higher gas taxes or higher fuel-efficiency standards) and in the desires of the American vehicle purchaser to result in a significant decline in vehicle

FIGURE 7-1: Sample Design Vehicle



sizes. The fact is that pickups, SUVs, and other low-gas-mileage vehicles will be on the road for many years.

Parking geometrics, whether for a surface lot or structured parking, should take into account the following characteristics:

- ▷ the location of the site;
- ▷ the dimensions of the site;
- ▷ site constraints (such as trees, power lines, and buildings);
- ▷ surface conditions;
- ▷ the proximity, layout, and location of surrounding streets;
- ▷ traffic flow;
- ▷ parking demand generators;
- ▷ local zoning and landscaping requirements; and
- ▷ types of patrons likely to use the facility.

Because every location is unique, parking geometrics must be carefully adjusted to maximize the potential of the location being considered.

DEFINING THE DESIGN VEHICLE

Parking designers have found it helpful to select a "design vehicle" and then determine the parking space and aisle dimensions that are appropriate for that vehicle. Instead of using the dimensions of an average-sized vehicle or those of the largest vehicle on the market, the generally accepted approach is to use the dimensions of the vehicle in the 85th percentile (the 100th percentile refers to the largest car size possible).[2]

In defining the design vehicle, designers must include vehicles that are typically used for personal transportation and that are likely to be parked in parking facilities: that is, automobiles and what the industry defines as "light trucks." According to federal fuel and vehicle-safety standards, light trucks include SUVs, minivans, and pickup trucks. In recent years, auto industry analysts have defined a fourth type of light truck: crossover utility vehicles (CUVs), which meet the federal fuel and safety standards for light trucks but are

Why Small-Vehicle-Only Parking Spaces Do Not Work

When the small-vehicle-only parking space was introduced, the mix of automobiles consisted of very large and very small cars; therefore, the "small-car" or "compact-only" rule was largely self-enforcing. In one common layout, angled spaces for large vehicles were placed on one side of the aisle, and 90-degree spaces for small vehicles were placed on the other. The difficulty of making the turn into the 90-degree parking spaces and the restricted clearances for opening doors discouraged drivers of larger vehicles from using the small-vehicle-only spaces.

However, small-vehicle-only parking spaces did not remain practical for long. Following the oil crisis of the mid-1970s, manufacturers first downsized larger vehicles and introduced new, very small cars. However, since the mid-1980s, manufacturers have been able to improve the fuel efficiency of larger cars through aerodynamics, more efficient engines, and lighter construction. Therefore, they were able to increase the size of smaller vehicles and still meet federal fuel-efficiency standards. As a result, car sizes are concentrated in the middle of the size range. By the late 1980s, over two-thirds of the vehicles sold in the United States were within 1 foot (0.3 meters) in length and a few inches in width of the traditional boundary between small and large cars. Therefore, many large cars are able to park in small-car-only stalls, albeit with some difficulty.

If small-vehicle spaces are in a convenient location, drivers of intermediate or even larger vehicles may park in the small-vehicle spaces, thus impeding traffic flow and compromising both the safety and comfort of turning for other users. Moreover, when large vehicles are parked in small-vehicle parking spaces, they often encroach into the adjacent parking spaces, creating a ripple effect along the row that eventually renders a parking space unusable—and negates the improved efficiency offered by small-vehicle parking spaces. On the other hand, if small-vehicle spaces are placed at inconvenient locations, small-vehicle drivers may park their vehicles in standard-sized spaces, forcing later-arriving large vehicles into small-vehicle parking spaces. In sum, specially located small-vehicle spaces are not effective unless a facility is policed to prevent the drivers of large vehicles from using small-vehicle spaces, and vice versa.

typically built on a car platform instead of on a pickup truck platform. Examples of CUVs include the Toyota RAV4 and the Chrysler Pacifica.

To help determine the design vehicle, the Parking Consultants Council (PCC) uses data on annual sales of cars and light trucks that are collected by the weekly *Automotive News*, as well as the publication's specification data for model sizes. Since 1999, the 85th percentile vehicle in the United States has varied slightly, but has remained within an inch or two (2.5 to 5 centimeters) of 6 feet, 7 inches (2 meters) by 17 feet, 3 inches (5.3 meters). Thus, the PCC has adopted these dimensions for its design vehicle.

In addition, to better understand trends in vehicle sizes, the PCC monitors changes in seven classes of vehicles size. Three of the classes comprise what are traditionally considered small cars or trucks, while the remaining classes are reserved for large cars and trucks. Because the size of an intermediate vehicle changes over time, the classifications used by manufacturers and other sources, such as *Automotive News*, are not reliable means of evaluating vehicle sizes. Instead, the PCC compares footprints, or vehicle length multiplied by width, to examine changes in size.

GUIDELINES FOR PARKING GEOMETRICS

First and foremost, the dimensions of parking facilities should be geared to the needs of projected users. For example, facilities that are expected to have high turnover rates, such as those that support convenience stores, should have greater clearances than those that support uses with low turnover rates. Similarly, where a significant portion of users may be elderly people and/or under stress, such as at hospitals, more generous dimensions may be appropriate. It is also important

FIGURE 7-2: Recommended Minimum Widths for Parking Stalls

	Feet	Meters
Low turnover (employees, students, etc.)	8′ 3″–8′ 6″	2.51–2.59
Low to moderate turnover (offices, regional retail centers, long-term airport parking, etc.)	8′ 6″–8′ 9″	2.59–2.66
Moderate to high turnover (community retail, medical facilities, etc.)	8′ 9″–9′ 0″	2.66–2.74

Source: Parking Consultants Council, *Guidelines for Parking Geometrics* (Washington, D.C.: National Parking Association, 2002).

to take account of what kind of parking facilities users are likely to be accustomed to: for example, a self-park facility in a downtown location in a large city can be designed with less generous dimensions than a self-park structure in an upscale suburban mall or in a smaller, rural community.

Finally, designers must be aware that vehicle sizes no longer vary significantly by region and locality. SUVs are just as popular in California and Hawaii as in rural areas and the Snowbelt. The sole exception is in the Southwest, where pickups are more likely to be used for everyday transportation than elsewhere in the country.

Other critical elements determining the dimensions of parking facilities are the width of the vehicles and the ease of maneuvering the vehicles into and out of the parking space. The ease of maneuvering, in turn, depends on three related factors: the width of the space itself, the angle of parking, and the width of the aisle. Within reasonable limits, the same degree of turning comfort can be achieved with a wider aisle and a narrower parking space, or with a wider parking space and a narrower aisle.

DETERMINING THE DIMENSIONS OF PARKING SPACES

Because a parking space that has sufficient clearance for doors to be opened comfortably will be wide enough for vehicle maneuvering if the adjacent aisle is properly sized, the widths of parking spaces have generally been based on required clearances for opening doors (that is, on the necessary distance between vehicles). Door opening clearances should range from 20 inches (51 centimeters) for vehicles in low-turnover facilities to 24 to 27 inches (61 to 69 centimeters) for vehicles in high-turnover facilities.[3] Combining these dimensions with the width of the current design vehicle results in parking-space widths that range from 8 feet, 3 inches (2.5 meters) to 9 feet, 0 inches (2.7 meters).

As noted earlier, turnover plays a strong role in determining parking geometrics; parking spaces are no exception. Figure 7-2 lists recommendations for adjusting stall widths on the basis of turnover.

Unlike width, the length of a parking space is not affected by turnover rate or user type. Currently, the recommended length of a parking space is 18 feet (5.5 meters). This recommendation is based on the length of the design vehicle—17 feet, 3 inches (5.25 meters)—plus nine inches (23 centimeters) to account for the typical distance from the bumper of a parked vehicle to the end of the stall (i.e., the edge of the stall farthest from the aisle).[4]

DETERMINING THE DIMENSIONS OF DRIVE AISLES AND MODULES

The drive aisle is the space between two vehicles that are parked directly opposite each other. The parking design term *module* refers to the distance created by the width of the drive aisle, combined with the length of the vehicle (or vehicles) parked on one (or both sides) of the drive aisle. When a vehicle is located on only one side of the drive aisle, this is referred to as a single-loaded module. When vehicles are located on both sides of the drive aisle, it is referred to as a double-loaded module.

In the early days of the parking garage, the size of parking modules was determined by trial and error. But in the 1950s, Edmund Ricker, an early pioneer in the field of parking geometrics,

FIGURE 7-3: Common Parking Dimensions

Angle (in Degrees)	Base Module	Vehicle Projection	Aisle Width	Single-Loaded Module	Wall to Interlock (8′ 6″)	Interlock to Interlock (8′ 6″)	Curb to Curb	Overhang
Θ	M_1	VP	A	M_2	M_3	M_4	M_5	o
30	41′ 2″	15′ 1″	11′ 0″	26′ 1″	37′ 6″	33′ 10″	38′ 8″	1′ 3″
35	43′ 0″	16′ 0″	11′ 0″	27′ 0″	39′ 6″	36′ 0″	40′ 2″	1′ 5″
40	44′ 10″	16′ 11″	11′ 0″	27′ 11″	41′ 7″	38′ 4″	41′ 8″	1′ 7″
45	47′ 0″	17′ 7″	11′ 10″	29′ 5″	44′ 0″	41′ 0″	43′ 6″	1′ 9″
50	48′ 6″	18′ 2″	12′ 2″	30′ 4″	45′ 9′	43′ 0″	44′ 8″	1′ 11″
55	50′ 0″	18′ 8″	12′ 8″	31′ 4″	47′ 7″	45′ 2″	45′ 10″	2′ 1″
60	51′ 6″	19′ 0″	13′ 6″	32′ 6″	49′ 4″	47′ 2″	47′ 2″	2′ 2″
65	53′ 0″	19′ 2″	14′ 8″	33′ 10″	51′ 2″	49′ 4″	48′ 6″	2′ 3″
70	54′ 0″	19′ 3″	15′ 6″	34′ 9″	52′ 7″	51′ 2″	49′ 4″	2′ 4″
75	55′ 0″	19′ 1″	16′ 10″	35′ 11″	53′ 10″	50′ 10″	50′ 2″	2′ 5″
90	59′ 0″	18′ 0″	23′ 0″	41′ 0″	59′ 0″	59′ 0″	54′ 0″	2′ 6″

All dimensions are rounded to the nearest inch.

Recommendations assume (1) one-way traffic for angles less than 90 degrees, and two-way traffic for 90-degree parking; (2) double-loaded aisles; and (3) a design vehicle that is 6′ 7″ by 17′ 3″.

1. In structures, or in lots where at least 30 percent of the stalls have guides or curbs, 1 foot (0.3 meters) may be deducted from the aisle width and the corresponding module.
2. In stalls that are adjacent to walls, columns, or other obstructions that might interfere with door opening or turning movement into the stall, add at least 10 inches (25 centimeters) to the width of the stall.

developed a series of equations that modeled the movement of a vehicle into a parking space. These equations are still in use, although they have been refined over the years to more accurately simulate the relationship between the aisle and a parking space. The combination of these equations and practical experience has led to a set of recommended minimum dimensions for modules that provide an acceptable level of comfort for the turning movement. (See the shaded portion of Figure 7-3.)

Parking and traffic consultants have long recommended that the geometrics of the parking space and drive aisle be based on the rotation of the design vehicle to a desired angle, rather than on rotation of the actual parking space dimensions. Because the design vehicle is smaller than the dimensions of the parking space, the actual resulting width of the drive aisle is greater, since the distance from the back of the parked vehicle to the end of the parking space can be utilized as additional width to the drive aisle. In simple terms, the drive aisle is the space between two vehicles parked directly opposite each other, not the distance between the parking space lines painted on the floor. By taking this approach, the consultant can achieve a more efficient parking layout (i.e., less surface area per vehicle) with slightly narrower drive aisles while not compromising the level of comfort for drivers.

As noted earlier, recommended stall widths vary depending on the level of turnover. By starting with the module dimensions recommended in Figure 7-3 and adjusting the

Width of Stall							
8′ 3″		8′ 6″		8′ 9″		9′ 0″	
Width Projection	Interlock	Width Projection	Interlock	Width Projection	Interlock	Width Projection	Interlock
WP	i	WP	i	WP	i	WP	i
16′ 6″	3′ 7″	17′ 0″	3′ 8″	17′ 6″	3′ 9″	18′ 0″	3′ 11″
13′ 5″	3′ 5″	14′ 10″	3′ 6″	15′ 3″	3′ 7″	15′ 8″	3′ 8″
12′ 10″	3′ 2″	13′ 3″	3′ 3″	13′ 8″	3′ 4″	14′ 0″	3′ 5″
11′ 8″	2′ 11″	12′ 0″	3′ 0″	12′ 4″	3′ 1″	12′ 9″	3′ 2″
10′ 9″	2′ 8″	11′ 1″	2′ 9″	11′ 5″	2′ 10″	11′ 9″	2′ 11″
10′ 1″	2′ 4″	10′ 5″	2′ 5″	10′ 8″	2′ 6″	11′ 0″	2′ 7″
9′ 6″	2′ 1″	9′ 10″	2′ 2″	10′ 1″	2′ 2″	10′ 5″	2′ 3″
9′ 1″	1′ 9″	9′ 5″	1′ 10″	9′ 8″	1′ 10″	9′ 11″	1′ 11″
8′ 9″	1′ 5″	9′ 1″	1′ 5″	9′ 4″	1′ 6″	9′ 7″	1′ 6″
8′ 6″	1′ 1″	8′ 10″	1′ 1″	9′ 1″	1′ 2″	9′ 4″	1′ 2″
8′ 3″	0′ 0″	8′ 6″	0′ 0″	8′ 9″	0′ 0″	9′ 0″	0′ 0″

3. In stalls that are adjacent to curbs or islands, add at least 10 inches (25 centimeters) to the width of the stall to reduce the risk of tripping.
4. Aisle width may be increased by up to 3 feet (0.9 meters) to provide a higher level of comfort.
5. Light poles and columns may protrude into a parking module a maximum of 2 feet (0.6 meters), as long as they do not encroach on more than 30 percent of the stalls. For example, either a 1-foot (0.3-meter) encroachment on both sides of the aisle, or a 2-foot (0.6-meter) encroachment on one side only, would be acceptable.
6. Where columns, light poles, or other obstructions encroach on more than 30 percent of the stalls in the bay, interlock reductions cannot be taken.
7. For each 1-inch (2.5-centimeter) addition to the width of the stall—to a maximum stall width of 9 feet (2.7 meters)—3 inches (7.6 centimeters) can be deducted from the module without decreasing turning comfort.

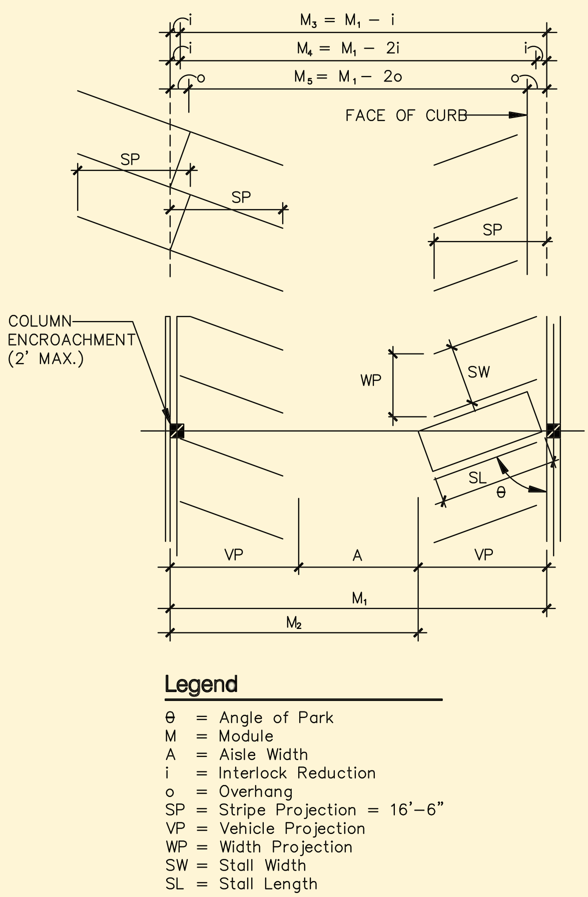
stall widths according to user needs, the designer can ensure comfortable parking dimensions.

It is important to note that the dimensions listed in this chapter are recommended minimums. Depending on the characteristics of the site and the users, it may be prudent to provide larger spaces and modules. Generally, parking consultants have found that to maintain the desired level of comfort it is preferable to increase stall width and decrease module length. Patrons appreciate the additional stall width and barely notice a tighter module. It is recommended that for each additional inch (2.5 centimeters) added to the width of a stall, the size of the module should be decreased by three inches (7.6 centimeters).[5]

Figure 7-3 lists some recommended dimensions for parking facilities. Figure 7-4 provides further definitions of the terms used in Figure 7-3. Note that the only dimension that varies by stall width is the interlock dimension. An interlock occurs with angled parking when two stalls in adjacent modules perfectly align, creating a herringbone pattern. The overlap of one of the stalls into the other's module is the interlock dimension.

In the case of parking lots, the recommended minimum dimensions assume no physical restrictions. When a curb stop is not provided, as is the case in the middle of a shopping center lot, vehicles occasionally pull too far into the parking space, which reduces the aisle width in the adjacent mod-

FIGURE 7-4: Parking Dimensions Illustrated



ule. This can be a particular problem in the Snowbelt, where space markings are sometimes obscured. Therefore, when a curb, wall, or other physical restraint is provided at each parking space, the aisle width (and therefore the overall dimensions of the module) can be reduced by 1 foot (0.3 meters).

In parking structures, columns often extend beyond the face of the bumper wall or other vehicle restraint, into the module. Encroachments into stall length (and thus into modules) also occur at light poles in parking lots. It is recommended that such encroachments not reduce the module by more than 2 feet (0.6 meter) and affect no more than 30 percent of parking spaces. While it applies to all conditions, it is especially critical that interlock reductions not be taken if there are encroachments into more than 30 percent of the stalls. Moreover, the following limitations should apply to the encroachments:

- The module widths recommended in Figure 7-4 may be reduced by no more than 2 feet (0.6 meters); for example, a permissible an encroachment would be 6 inches (15 centimeters) into the parking spaces on one side of the aisle, and 1 foot, 6 inches (46 centimeters) on the other side).
- If there are vehicle restraints (such as wheel stops, curbs, or bumper walls) at every parking space, then the recommended module widths may be reduced by 1 additional foot (0.3 meters).

In short-span parking structures, columns are occasionally allowed to encroach on the width of parking spaces, on the theory that as long as the door clears the column when it swings open, the width of the parking space is adequate. However, the column constrains turning movement into the parking space; assuming that design vehicles are parked on both sides, the clear space for turning into a typical parking space is the width of the parking space plus at least 20 inches (51 centimeters). To maintain the same clear space, the parking spaces adjacent to walls, columns, or other obstructions must be widened by at least 10 inches (25 centimeters). This creates the same level of comfort for turning into the stalls next to the columns as can be found in the middle of the bay. If the parking spaces are not widened, the cars that park in them will park closer to the middle of the bay in an effort to avoid the obstructions, thereby effectively reducing the stall widths of all the stalls in that row.

CONCLUSION

Parking ordinances that require excessively generous parking geometrics waste land and other resources, and stymie development. Such ordinances are also often in conflict with other community goals, such as increasing green space and reducing stormwater runoff. Instead, parking geometrics should reflect the requirements of the vehicles themselves, and those of users. Furthermore, ordinances should be flexible enough to allow modifications based on the principles outlined in this chapter.

NOTES

1. U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information Web site www.fhwa.dot.gov/ohim/onh00/line3.htm.

2. The use of the 85th percentile vehicle parallels a principle used in traffic engineering, which dictates that roadways be designed for the 85th percentile of peak-hour traffic volume.

3. Parking Standards Design Associates, *A Parking Standards Report* (Los Angeles: March 10, 1971).

4. Mary Smith, "Parking Standards," *Parking* (July–August 1985).

5. Ibid.

CHAPTER 8

Functional PLANNING AND DESIGN

MATT FEAGINS, VICTOR IRAHETA, AND CHUCK IGNATZ

THE PHRASE *FUNCTIONAL DESIGN* REFERS to the arrangement of vehicular and pedestrian flows in a parking structure or lot. Functional design varies with the type of user: high- and low-turnover facilities call for different approaches to layout and flow. In addition to varying with the type of user, functional design is affected by parking facility operations, including revenue control and security.

This chapter is divided into three parts. The first part examines the aspects of functional design that are common to most parking facilities, and the second and third parts focus on issues that are specific to surface lots and structured facilities, respectively.

ISSUES COMMON TO PARKING LOTS AND PARKING STRUCTURES

Most parking demand is met through parking lots and parking garages—although in many cities, at least some demand is met by on-street parking. Automated parking is another option, but the cost may be prohibitive. (Such facilities are more prevalent in Europe and Asia, where land is more scarce and thus more costly, than in North America. Chapter 18 discusses automated parking in more detail.) A key question for the design of any parking lot or structure is whether there will be a fee for parking and how it will be charged.

The functional design of parking facilities has to balance the requirements of local ordinances and those of patrons. It is not uncommon for local ordinances to require parking spaces of a particular width or depth, or drive aisles of a particular size. But the specified dimensions may be insufficient to meet the needs of the clientele. At a high-turnover facility such as a convenience store, for example, the most user-friendly design might call for larger parking spaces and wider drive aisles.

It is also essential, when planning or designing any parking facility, to ensure that it adheres to the requirements of the Americans with Disabilities Act (ADA). The ADA and many local zoning codes require parking spaces that are accessible to vehicles carrying or driven by people with disabilities (see chapters 4, 7, and 9 for a more detailed discussion of zoning, parking geometrics, and the ADA). In newly designed lots and facilities, the incorporation of special design features for disabled people is mandatory. In some cases, designated spaces may have to be placed in prescribed locations within the lot.

The functional design of parking lots and structured parking must address a number of the same concerns, including

- ▷ length of stay and user types;
- ▷ facility type;
- ▷ street traffic, entrances, and exits; and
- ▷ parking angles and parking spaces; and
- ▷ striping.

Length of Stay and User Types

Most parking facilities can be categorized according to the anticipated length of stay. Long-term parking facilities are those in which the parking turnover (the number of vehicles that are expected to use one space on a given day) is relatively low. Long-term facilities include airports (many of which have an average stay of approximately three days) and facilities that serve office employees (where a typical stay is between eight and nine hours per day). In short-term parking facilities—such as those that cater to retail facilities and office visitors—spaces typically turn over three or more times a day.

Airports offer a good example of the particular needs of the parking user: lots that are divided into long- and short-term parking areas can have different parking geometrics, depending on turnover. While airport guests stay parked for an average of three days, the average stay for the airport employee falls somewhere between the average stay in the high-turnover short-term parking area and the low-turnover long-term parking area. In airport facilities that combine employee parking and paid visitor parking, optimum revenue and parking control can be achieved by segregating the two, including providing separate entrances and exits.

Parking facilities used for special events—such as those at sports complexes, convention and meeting facilities, theaters, and coliseums—must meet unique parking and traffic demands that may last for only a few hours each day or each week. Because these uses generate high-turnover demand, the major design consideration is usually entrance and exit capabilities. For special-event parking, fees are typically collected upon entry rather than exit, and the selection of parking spaces may be rigidly controlled by parking attendants.

Hospitals, airports, hotels, lifestyle centers, and other mixed-use generators—especially those with a residential component—create parking demand 24 hours a day, 365 days a year. They must accommodate large numbers of employees and visitors, as well as owners and renters. To ensure economy and efficiency in parking facilities that serve mixed-use generators, the design must allow the facilities to be operated with minimum staffing during periods of low demand, while still providing enough entry and exit lanes to handle peak periods of high activity. Although most mixed-use facilities have a number of design considerations in common, it is still important to conduct a detailed evaluation of all facility users and their demands and requirements. Such an evaluation would assess length of stay, optimum parking-space dimensions, peak demand periods, number of paid parking spaces needed, and monitoring and control technologies.

Facility Type

Parking facilities may be designed to support self-parking, valet parking, or some combination of the two (commonly called attendant-assisted parking). In self-park facilities, patrons find their own parking spaces and retrieve their own vehicles; the facilities must therefore be designed to allow for free flow of traffic. In valet facilities, patrons turn over their keys, and attendants park the vehicles for them. Attendant-assisted facilities allow most patrons to park their own vehicles. Where tandem parking is employed, patrons leave their keys so attendants can move vehicles to access blocked vehicles.

Both valet and attendant-assisted parking maximize the number of vehicles that can be parked, generally by stacking vehicles behind each other (see Figure 8-1). However, both approaches require the facility to be staffed for all hours of operation. In contrast, self-park facilities can function largely without staff.

Self-park facilities are the most common type of parking operation in North America (see Figure 8-2). Before committing to a final design, designers of self-park facilities must take the following factors into consideration:

- ▷ traffic volume and the direction of traffic flow;
- ▷ vehicular entrance and exit points;
- ▷ the design of parking spaces and drive aisles; and
- ▷ vehicle and pedestrian circulation.

FIGURE 8-1

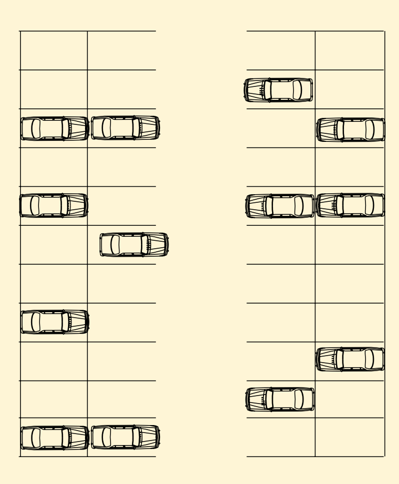


FIGURE 8-2

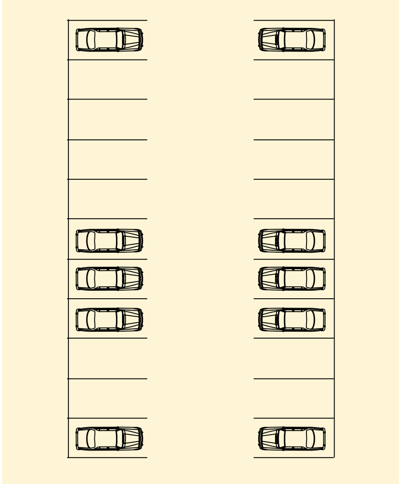
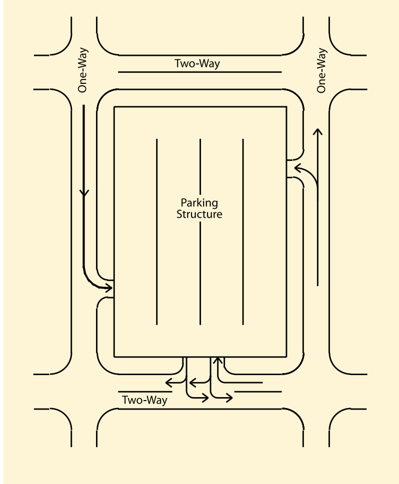


FIGURE 8-3



Street Traffic, Entrances, and Exits

The volume and flow of traffic on adjacent streets has a major impact on the use of a parking facility. It is always best to locate entrances on major streets where the traffic flow is inbound, toward the destination area; exits should be located where the traffic flow is outbound, away from the destination area. If the direction of a one-way street changes after a parking structure has been completed, all flow into and out of the facility's entrances and exits must be reevaluated. To minimize conflicts between street traffic and vehicles exiting from the parking facility, it is best to locate exits on low-volume streets.

Generally, the most efficient approach to designing entrances and exits favors the traffic entering a facility, even at the expense of complicating the exit. Favoring entering traffic expedites the rapid movement of traffic from the street into the facility and prevents vehicles from lining up on public roadways. Moreover, since exiting traffic tends to move slowly, drivers can comfortably negotiate the turns required to reach the exit. Driveways should be designed to minimize interruptions to traffic flow within the facility itself.

Entrances to a parking facility are usually located on high-volume streets that provide direct access from users' points of origin. Larger parking facilities generally have multiple entrances and exits to provide access from various adjacent streets in the event of emergencies, obstructions (such as street repair), or failure of the operating equipment at the main entrance (see Figure 8-3).[1] A traffic study evaluating adjacent streets for all sizes and types of garage facilities can determine the best possible access points. To prevent conflicts between parking facility traffic and intersection traffic, entrances should be located at least 75 feet (22.8 meters) from any intersection. Traffic-engineering principles can be applied to determine the appropriate number of vehicles that can queue up in each lane.

It is ordinarily more convenient to enter a parking facility from a one-way street or by turning right from a two-way street. Left turns into a parking structure from a major two-way street during peak traffic periods can be difficult, if not impossible, because of the volume of traffic approaching from the opposite direction. Where a parking facility is adjacent to a high-volume or high-velocity street, a deceleration lane leading to the entrance helps eliminate rear-end accidents and reduces slowdowns in street traffic (see Figure 8-4).

An entrance lane is usually equipped with a ticket dispenser, a control gate, and an access card reader (see Figure 8-5). If an entry lane includes an access-card reader, it should be placed beyond the ticket dispenser so it is not mistaken for a ticket dispenser. When a single device includes both an access-card reader and a ticket dispenser, the dispenser should be a push-button unit, so that entrance operations and activity reporting remain separate functions. Separate lanes can be designated for monthly and hourly parking (see Figure 8-6). (For more details, see Chapter 21, "Parking Access and Revenue Control.")

FIGURE 8-4

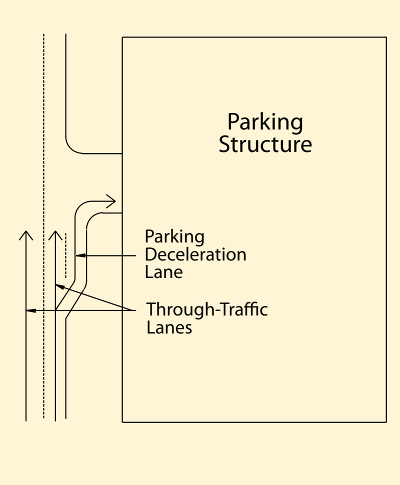


FIGURE 8-5

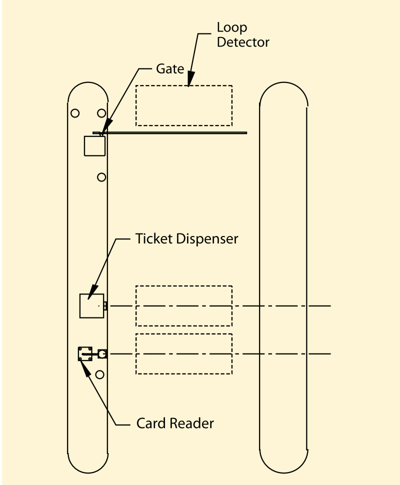


FIGURE 8-6

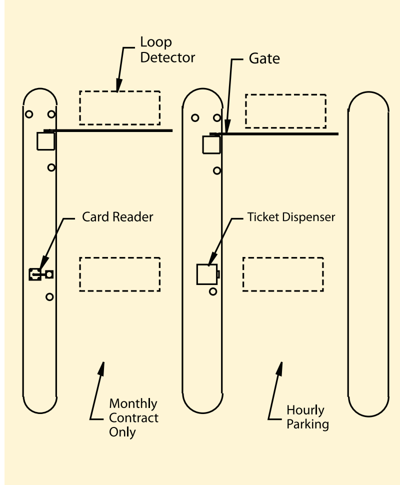
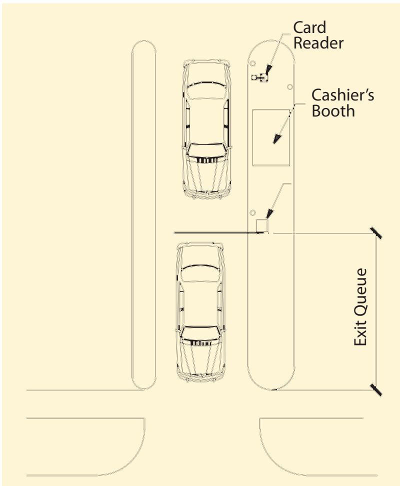


FIGURE 8-7



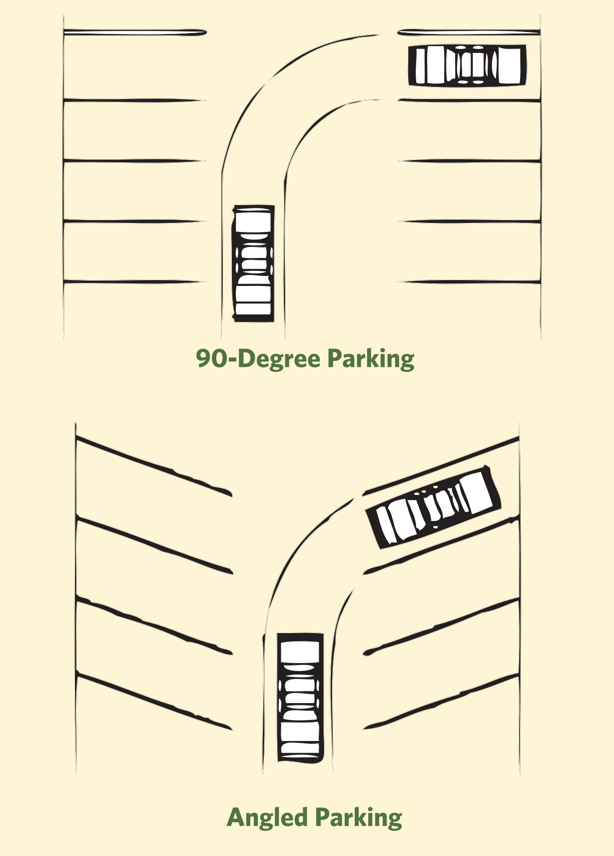
Parking-control devices should be located far enough in from the street so that if a vehicle is at the ticket dispenser or access-card reader, an incoming vehicle can clear the sidewalk. When a deceleration lane cannot be accommodated on high-traffic streets, ticket-dispensing and card-reading equipment should be located at least three or four vehicle lengths into the building or lot to provide queuing space. A large, van-type vehicle should be used as the design vehicle to test clearances.

One inbound lane with a card reader and/or ticket dispenser is adequate for a facility with a peak-hour traffic volume of approximately 300 vehicles. For larger facilities, or for smaller facilities with high turnover, additional entrances, or entrances on different streets, help accommodate the higher volume of entering traffic. Event facilities, such as arenas or stadiums, will need multiple lanes at multiple locations to handle the heavy peak entrance load. Single entrance lanes should be approximately 13 to 16 feet (4 to 5 meters) wide, tapering down to 10 feet (3 meters) at the approach to the control equipment. Double entrance lanes should be at least 24 feet (7.3 meters) wide. If the facility has ramps, there should be a short, level segment after the entrance area and before the exit area, to serve as a transition to the slope upward or downward to the parking spaces.

If possible, entrances that are remote from the cashier's booth or manager's office should be equipped with television cameras, and an audio communication system should be built into the ticket dispenser. These devices can be helpful if an equipment malfunction occurs or a patron wants to ask a question before entering the facility.

Ideally, exits should be located on low-volume streets to reduce delays caused by street traffic. A turn in the drive aisle that leads to an exit lane or plaza can slow exit speeds and help control the rate at which vehicles are released into the street. To keep cashiering delays to a minimum, the cashier's booth should be located far enough from the sidewalk or street to provide space for at least one vehicle that has already completed the payment transaction (see Figure 8-7). There should also be adequate queue space between the street and the control equipment to allow vehicles to exit without unduly backing up traffic into the facility.

FIGURE 8-8



For event facilities, a thorough traffic study is recommended to help position egress points and to optimize the lane throughput. Even with input from traffic engineers, however, some operational guidance from the parking consultant will still be necessary to ensure adequate throughput, given the limited area available in parking structures for vehicular egress.

Parking Angles and Parking Spaces

Right-angle parking does not necessarily yield the most efficient layout in terms of square feet per space. Properly designed, angled parking with one-way end crossovers can sometimes be more efficient. Moreover, the ease of parking in a one-way layout with angled parking often compensates for any decrease in efficiency (see Figure 8-8).

As noted in Chapter 7, the width of parking spaces and the length of parking modules (the distance from bumper wall to bumper wall) can be varied to suit the type of user, angle of parking, or desired level of comfort. High-turnover spaces, such as those for retail use, should have wider spaces than those in a typical office garage. Although some designers still provide separate spaces for large and small vehicles,[2] common practice among several consultants is to call for widths of 8 feet, 6 inches (2.5 meters) for all spaces. (Large-vehicle spaces are typically 9 feet [2.7 meters] wide; small-vehicle spaces are typically 7 feet, 6 inches [2.3 meters] wide.)

Climate is another consideration in sizing parking spaces. Given the inclement winters in some states, it may be desirable to specify a slightly wider space, to permit drivers and passengers to enter and exit vehicles without having heavy outerwear make contact with vehicles that might be splattered with road chemicals and mud.

Some parking consultants use a level-of-service (LOS) approach to specify the size of parking spaces. In highway design, LOS is expressed as a grade (A through F) that ranges from unimpeded traffic flow to gridlock, with LOS A representing the best conditions and LOS F representing the worst. Other consultants prefer the "user comfort" factor (as it is commonly referred to by some consultants). Based on the consultant's and the client's experience, this approach is more subjective and relies less on tabulated benchmarks. Both the LOS and user comfort approaches can be improved by increasing the length of the module or the width of the parking spaces. Both methods take into account many variables, including the following:

- ▷ traffic patterns (one- or two-way);
- ▷ parking angle;
- ▷ width of parking spaces;
- ▷ width of drive aisles;
- ▷ queuing space at entrances and exits;
- ▷ payment systems;
- ▷ circulation patterns and options; and
- ▷ potential vehicle-vehicle and vehicle-pedestrian conflicts.

Striping

Both surface lots and parking garages should be striped in white or yellow paint. In many instances, local ordinances specify the color to be used. In general, yellow tends to stand out better than white from the background parking surface. Because of the higher contrast, white striping works better with asphalt or other dark surfaces than with concrete. White paint on concrete also tends to fade with time, making it difficult to distinguish the striping from the concrete. Because many surface lots have asphalt surfaces, they tend to have white stripes, while garages are almost always made of concrete and therefore often use yellow stripes.

In most facilities, striping consists of single, 4-inch (10-centimeter) painted lines. To separate one parking stall from another, some designers specify double stripes approximately 8 to 12 inches (20 to 30.5 centimeters) apart. Also known as hairpin stripes, a double-stripe pattern consists of a 4-inch- (10-centimeter-) wide stripe followed by an 8-inch- (20-centimeter-) wide gap, then another 4-inch- (10-centimeter-) wide stripe. Designers believe that hairpin stripes help drivers better center their vehicles within the area between the stripes. Some operators, though, discourage the use of hairpin stripes because they require double the amount of paint and time when it is necessary to repaint them.

SURFACE PARKING LOTS

Surface parking lots vary in size from a few spaces to thousands. Most surface parking is provided without a direct charge to the user. Employers may provide free parking for their employees; shopping centers generally provide free parking for their patrons; and many suburban office buildings and hotel developments provide free parking for both employees and patrons.

Urban and Suburban Lots

In general, urban parking lots are smaller than those in suburban areas. Urban parking lots also tend to charge for parking or to use some form of parking access control such as card readers, ticket dispensers, or attendants. Urban lots typically serve a mix of both short-term and long-term patrons.

Parking lots at suburban shopping centers and office buildings tend to be significantly larger than urban parking lots. Moreover, the generous parking geometrics commonly found in suburban lots have now become the norm in many places, and are expected by many users. Shopping center lots vary from hundreds to thousands of spaces, depending on the size of the center. At suburban office buildings, zoning regulations, the lack of public transportation, and inadequate on-street parking have created a need for a greater number of parking spaces per square foot of office area. The ratio of visitor to employee spaces varies with the function of the office building. A medical office building, for instance, might require 50 percent of total spaces to be reserved for visitors and patients, while a general office building might require only 10 to 15 percent of spaces to be reserved for visitors.

In most cases, neither suburban shopping center parking lots nor suburban office complexes charge direct fees for use of their facilities. However, the cost of developing, maintaining, and controlling suburban parking areas is factored into rents, and is then passed on to users indirectly.

Efficient Parking Space Design

The development of surface parking lots in lieu of multilevel parking structures is largely a function of economics. The cost of structured parking is much greater than the cost of surface parking. Thus, structured parking is usually developed when land is extremely costly or in short supply. Structured parking is also developed when convenience is an issue—for example, when the only land available for a lot is deemed to be too far away from the use it would support.

The cost of building a surface parking lot varies with its size, geographic location, and the quality and quantity of associated improvements. Generally speaking, paving, lighting, drainage, and parking-access and revenue-control (PARC) equipment cost between $5 and $15 per square foot ($54 and $161.50 per square meter). Landscaping, fencing, and other types of buffers, which many communities require, can further increase costs.

Construction

The proper construction of surface parking lots involves a number of critical details: pavement; drainage; and the location and design of curbs and sidewalks, lighting, striping, fencing, and landscaping.

Pavement

The durability and serviceability of a surface parking lot depend largely on the quality and type of the surface material. The most important consideration in the structural design of pavement is proper preparation of the subgrade material and selection of the appropriate pavement type and thickness. Excessive thickness results in unjustifiable construction costs; insufficient thickness results in unsatisfactory performance, premature failure, excessive maintenance, and associated costs. Proper subgrade preparation is mandatory, and often requires the supervision of a civil or geotechnical engineer. Concurrent with the subgrade work, the site must be sloped to ensure positive drainage, which often requires the installation of surface drains and drain lines. Surface lots are typically paved with concrete or gravel, or with bituminous or porous materials.

After the site is properly sloped, drains have been installed, and the soil has been compacted to the proper density, well-graded aggregate should be rolled onto the surface and compacted. For a bituminous pavement, asphaltic concrete is added over the prepared base. In some cases, an asphaltic binder course is applied before installation of the top course—the final level of pavement that creates a smooth driving surface. Sealer coats are often applied to the top course to prevent the asphalt from deteriorating as the result of exposure to oil and gasoline.

Drainage

Proper drainage is vital in lots, to ensure that rainwater will be carried away from the site. A surface parking lot should be sloped a minimum of 1 percent toward drain inlets, catch basins, or curb inlets. Further, the drainage slope should not exceed 2 percent at accessible routes for the disabled. Designers should ensure that the lot will comply with local ordinances and stormwater control standards.

Curbs and Sidewalks

The perimeter of the parking lot should incorporate curbs and gutters of cast-in-place concrete, extruded concrete, or similar materials. Concrete is strong enough to withstand wheel impact and outlasts other curb materials, such as asphalt.

Sidewalks should be provided for pedestrian circulation. They should be constructed on top of an aggregate base course and be a minimum of 4 inches (10 centimeters) thick and have downturned, or thickened, exterior edges that are a minimum of 6 inches (15.3 centimeters). The sidewalk surface should be sloped for drainage and should have a light broom finish for safety. Control joints should be placed a maximum of 5 feet (1.5 meters) apart.

Lighting

Large lots are usually illuminated by light standards located in the interior of the lot, between parking stalls. Sometimes the standards are positioned outside the general parking area. Under these circumstances, the designer should be careful to limit unwanted light spill and glare onto adjacent properties. The position of the standards is determined by the type of fixture, the number and height of fixtures per standard, the desired illumination level, and the layout of the facility. Before any design work is undertaken, the designer should be aware that some municipalities have specific guidelines for lighting that must be followed.

Common fixture types include high-pressure sodium and metal halide. The fixture type should be consistent with neighboring uses; for example, cutoff fixtures should be used to shield residential areas from direct lighting. Where security is an issue, lighting levels should be high enough to address security concerns. Parking facility lighting is discussed further in Chapter 14.

Fencing

Fencing may be used to address security concerns, to screen the lot from the headlights of circulating vehicles, or to control access (for example, to limit cut-through pedestrian or vehicular traffic). Local zoning codes may dictate the size, appearance, and material used for fencing and other barriers.

Manufacturers offer a wide range of fencing materials, including plastic-coated fencing in various wire gauges and colors; chain link; wrought iron; treated wood; and composites. To prevent damage from vehicles, fencing should be an adequate distance from circulating drives, parking stalls, and roads.

Landscaping

Properly designed plantings can soften the visual impact of surface parking lots by screening circulating and parked vehicles. Many communities have ordinances and other requirements that govern landscaping for surface lots.

Ideally, landscaping should be located in areas that are unusable for parking or circulation, at an adequate distance from parked vehicles. To avoid adverse impacts on parking, landscaping features, such as plantings and tree wells, should be installed in accordance with the planned dimensions of parking stalls and the specific needs of the plants. For example, to allow adequate space for vehicle maneuvering and to avoid damage to curbs and plants, a 5-foot (1.5-meter) or greater radiused corner is recommended for interior landscaped islands. In addition, islands should be sized and positioned so that they do not interfere with access to parking spaces or with the opening of car doors.

It is not uncommon to allow vehicle overhangs to encroach on landscaped areas; to allow for vehicle overhangs, plantings should not be located within 3 feet (1 meter) of the curb, unless low-lying groundcover is used. To ensure that turning clearances are adequate, designers should also consider holding back plantings from the edges of drive aisles and turning bays.

Vehicle sight lines, particularly at entrances, exits, and pedestrian routes are other important considerations in landscape design. Bushy growth and leaves between 3 and 8 feet (1 and 2.4 meters) above grade will severely reduce the sight lines of drivers at critical ingress and egress locations; low ground cover and tall trees that do not have low branches are preferable.

All planting areas should be mounded to promote drainage and salt runoff and should not be used for snow storage. Plantings should be of capable of surviving in the relatively harsh environment of a parking lot. Underground irrigation systems should be considered to ensure the long-term viability of plantings. And finally, to ensure barrier-free design, landscaping plans should be evaluated for compliance with the ADA.

PARKING STRUCTURES

Although the design of parking structures is similar in many ways to the design of parking lots, a number of elements of functional design are unique to self-park structures, and must be considered in addition to those already discussed for parking lots. Because they are discussed in other chapters, the following elements will not be discussed here; nevertheless, the success of a project hinges on careful consideration of each of these elements:

▷ parking space geometrics;
▷ provisions for resizing parking spaces;
▷ allowances for expansion;
▷ lighting intensity and controls;
▷ drainage;
▷ security systems;
▷ access, revenue-control, and operating systems;
▷ graphics and signage; and
▷ maintenance and durability.

The remainder of this chapter will focus on the following functional design elements as they pertain to parking structures:

▷ the context and character of the neighborhood;
▷ operations systems;
▷ vehicle circulation patterns;
▷ long-span construction;
▷ pedestrian circulation; and
▷ the locations of stairs and elevators.

Neighborhood Context and Character

Except for utilitarian, "back of the house" employee parking facilities, urban design considerations are becoming more prevalent in parking structure design. The impact of urban design on functional design depends on the neighborhood context and character. For example, unless the project budget can support screening to conceal sloping floors, horizontal floors may be required along the main facade. Local regulations often dictate height limitations, to help protect local architectural flavor.

Operations Systems

For a typical parking structure, a minimum of two inbound lanes and two outbound lanes is recommended to allow redundancy in the event of vehicle breakdowns or equipment malfunctions. In structures with two or more outbound lanes, one lane is the primary cashier-staffed exit, and another is a secondary cashier-staffed lane for peak loads. The second lane may also allow exiting monthly parkers to bypass any backup that may occur at the adjacent cashier booth.

In facilities with heavy one-way peak ingress or egress periods, the designer should consider using reversible lanes. These lanes can function as either entry or exit lanes, and are best used where there is little simultaneous vehicular ingress and egress.

To minimize operating costs, all cashier booths should be grouped together so that during low-volume periods, the entire parking structure can be staffed by one cashier. The number of cashier-staffed and access-card exit lanes will vary with the ratio of monthly contract (access-card) patrons to transient parkers. Depending on the complexity of the parking rates and the type of revenue control equipment, a cashier can handle approximately 90 to 180 vehicles per hour. For example, parking rates charged in one-dollar increments permit vehicles to move through the cashier plaza faster than rates that require cashiers to give change in coins. Sometimes the primary cashier booth is an extension of the manager's office. In off-peak periods, the same staff person can serve as both shift manager and cashier.

For special events, it is common to collect a flat fee upon entry; because entering vehicles tend to trickle in at a slower rate than exiting vehicles, this practice helps ensure a free flow for exiting vehicles. If this type of system will be used

FIGURE 8-9

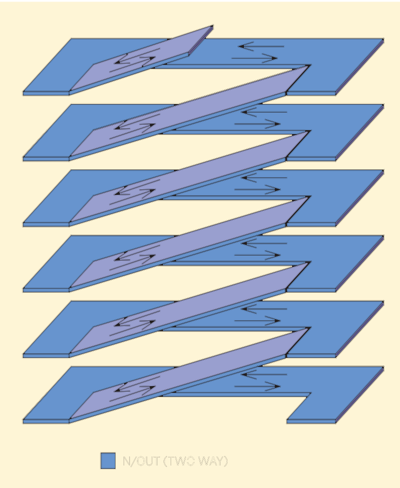
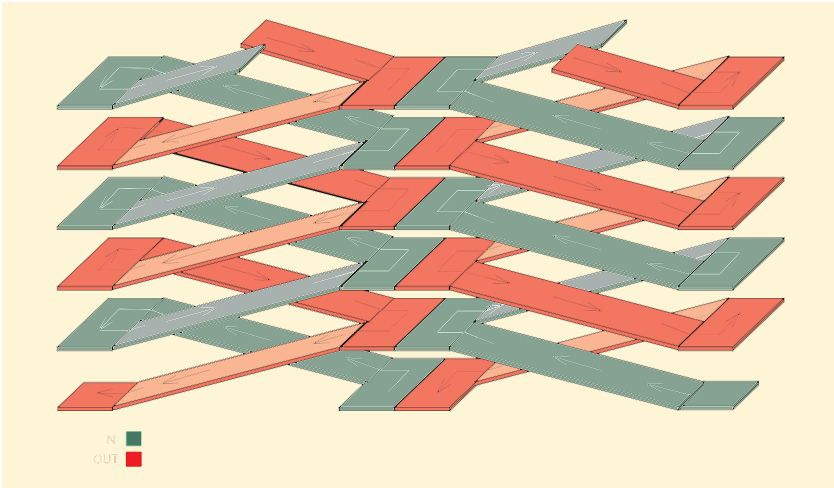


FIGURE 8-10



in a garage, the designer will need to know ahead of time, in order to ensure adequate queue space and lane throughput.

Most self-park facilities in North America still use an exit cashiering system; however, a number of other systems are coming into use: single-space meters, honor boxes, pay-by-space systems, pay-and-display systems, central cashiering, and pay-on-foot systems. These approaches reduce the use of direct labor to collect fees, and/or provide higher lane throughput. (For more information on alternative payment systems, see Chapter 21, "Parking Access and Revenue Control.")

Designers who are considering employing newer technologies should carefully evaluate their costs and benefits before making a final recommendation. For example, because central cashiering and pay-on-foot systems require pedestrians to go to a central point, or points, to pay for parking, parking facilities must be designed so that pedestrians cannot enter the facility without passing the pay stations. As an additional precaution where pay-on-foot systems are in use, it may be desirable to include turn-out lanes, which allow patrons to repark their cars without having to back out of the equipment lanes. That way, if a customer somehow arrives at an exit without having paid first, he or she can easily repark, pay at the payment kiosk, then get back into the car and exit the facility.

Vehicle Circulation Patterns

In North America, one of the most common circulation systems is the continuous ramp, where sloping floors provide both parking space and a circulation route, and parking spaces are located along both sides of a central aisle. The single helix, which is used for 90-degree parking and two-way traffic, is the basic continuous-ramp configuration (see Figure 8-9). Architects generally favor designs that provide horizontal and vertical facade lines; thus, designs that position the ramps on the interior bays—such as the three-bay double-helix ramp or the four-bay side-by-side ramp—may be preferred for aesthetic reasons.

A number of systems are variations on the single-helix continuous ramp: the two-bay end-to-end configuration (see Figure 8-10); the two-bay double-threaded helix configuration (see Figure 8-11); the three-bay double-threaded helix configuration (see Figure 8-12); and the four-bay side-by-side configuration (see Figure 8-13). All these arrangements lend themselves to one-way traffic and angled parking. Although the two-bay split-level configuration (see Figure 8-14) was once a commonly used layout, it requires special interfloor ramps that are not needed in continuous-ramp systems, and that lead to higher structural costs, merging conflicts among vehicles, and poor traffic circulation.

Although 90-degree parking can be used with a one-way traffic pattern, it does not reinforce a one-way traffic flow the way that angled parking does (see Figure 8-15). When the spaces are perpendicular to the drive aisle, nothing prevents a driver from pulling out of a space and turning in the wrong direction (despite arrows and "one-way" signs). One-

FIGURE 8-11

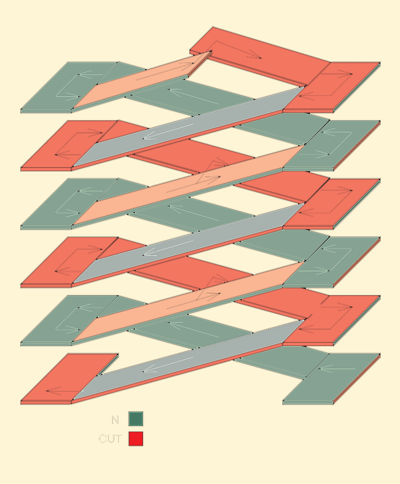


FIGURE 8-12

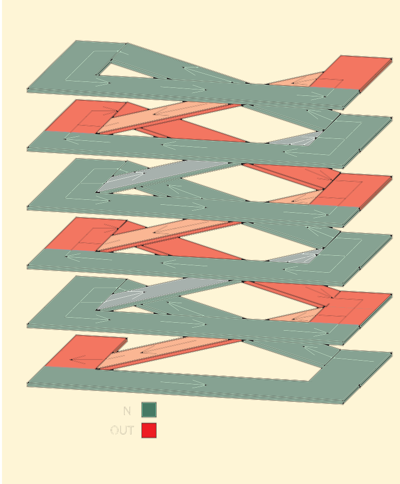
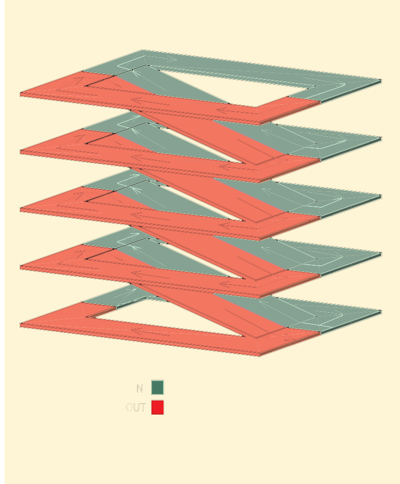


FIGURE 8-13



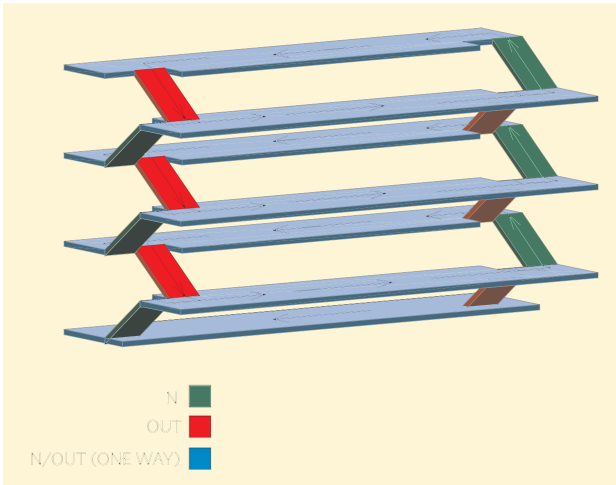
way circulation with 90-degree parking should therefore be discouraged. Moreover, 90-degree parking is often associated with two-way traffic patterns that result in cross-traffic or conflict points within the structure, and larger overall building width. In contrast, angled parking minimizes two-way traffic conflicts and offers easier maneuvering into and out of parking spaces.

Nonetheless, 90-degree parking should not be dismissed outright. A 90-degree, two-way traffic pattern can sometimes operate much the same way as a one-way traffic layout. An employee parking structure, for example, has high inbound traffic in the morning and high outbound traffic in the evening, and effectively operates as if it had a one-way traffic pattern.

Access from floor to floor is typically provided by one or more bays that slope from one level to the next. Although multiple-bay sloped ramps can easily confuse the uninitiated parking patron, where repeat parkers represent the largest share of patrons, users become familiar with the ramp configuration. In general, regular users quickly tire of traveling long distances through the garage, while infrequent users are more willing to put up with more inconveniences. Under such circumstances, the efficiency and shorter travel distances afforded by intertwining ramps, such as those used in the double-threaded helix configuration, are particularly desirable.

In facilities where patrons park only occasionally, such as convention centers and hospitals, the parking layout should

FIGURE 8-14



be as simple as possible. The preferred practice is to replicate the characteristics of shopping-center parking lots by providing level floors and, at the bays located further from the main pedestrian core, continuous-ramp or express-ramp parking that accommodates vehicle ingress and egress. Parking structures that have flat floors and express ramps for interfloor travel are generally more user-friendly than continuous-ramp structures (see Figure 8-16). Flat floors provide better wayfinding for both drivers and pedestrians; allow more light to penetrate into the floor from outside; and improve security by

FIGURE 8-15

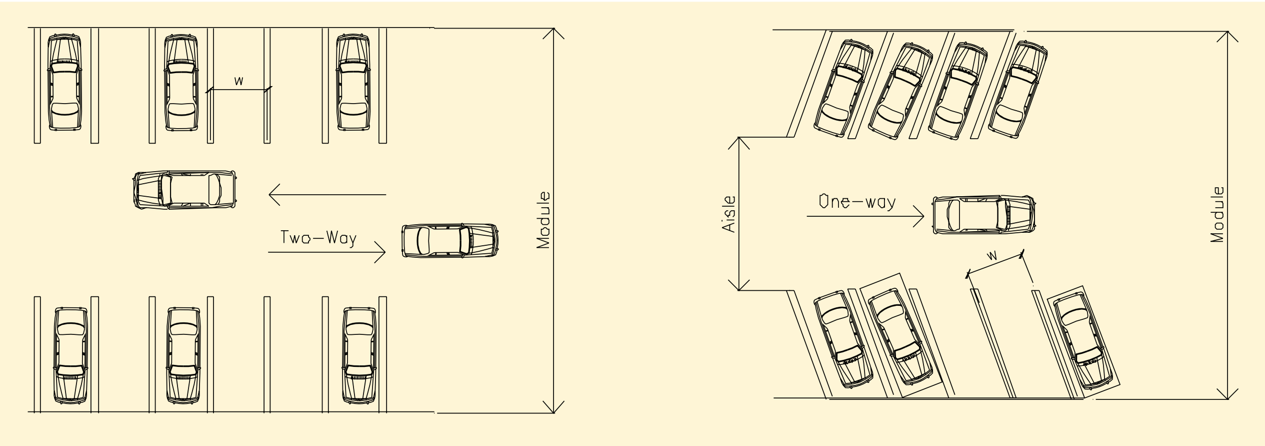
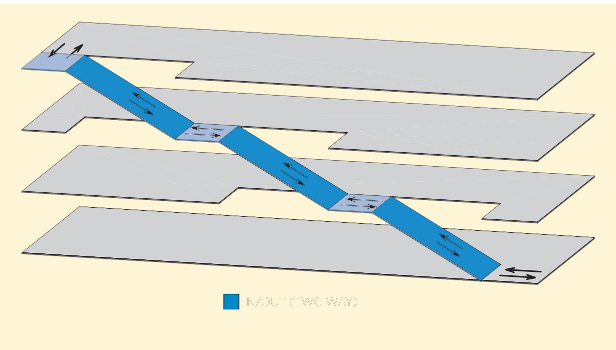


FIGURE 8-16



opening up sight lines. All parking structures, whether they use express or continuous ramps, should maximize flat-floor parking near the elevators.

Ideally, in a continuous-flow circulation system, drivers should not have make more than four to five 360-degree revolutions to locate a parking space. The design should also permit a driver leaving a parking space to move toward the exit as expeditiously as possible. A reentry point providing access to the facility's internal circulation system is desirable, and is usually located on the ground floor or on the first supported level before the garage exit.

Typically, slopes in continuous-ramp facilities do not exceed 6 percent on the parking floors (the International Building Code allows a floor slope of up to 1:15, or 6.7 percent, for parking and circulation). However, the needs of people with disabilities must be considered in determining floor grades. The grade on express ramps (nonparking ramps) should be no more than 12.5 percent, unless signage specifically prohibits pedestrian use of the ramps. Steep grades greater than 12 percent can be psychological barriers to some drivers, particularly on downbound ramps. Also, visibility over the hood of the vehicle is impaired at the top of steep ramps and can be a problem at turns. Nevertheless, in hilly areas, ramp grades of up to 16 percent may be considered.

When the transition from floors to ramp grades exceeds 10 percent, a transition slope should be used to prevent vehicles from bottoming out (see Figure 8-17). Special attention should be given to overhead clearances on ramp breakovers, which should be checked from the wheel line, not from the floor surface (see Figure 8-18).

Some facilities are designed to accommodate oversized vans and recreational vehicles; and in most cases, ADA regulations require an 8-foot, 2-inch (2.5-meter) minimum clearance for van-accessible spaces. But in certain instances, the clearance is required to be 9 feet, 6 inches (3 meters) in vehicle drop-off areas. Often, the requirement for added clearance can be satisfied by simply lowering the grade slab on the grade level. For passenger vehicles, a 7-foot (2-meter) minimum height clearance should be used, although a clearance of 7 feet, 4 inches to 7 feet, 8 inches (2.2 to 2.3 meters) accommodates higher vehicles and conveys a sense of greater openness. In large, level, multiple-bay parking areas, high floor-to-beam clearances can increase users' com-

FIGURE 8-17

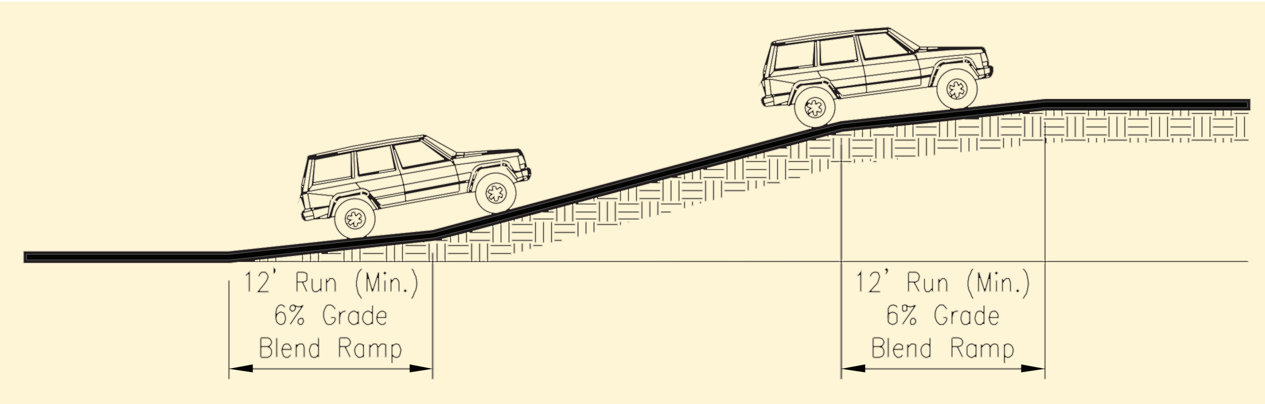
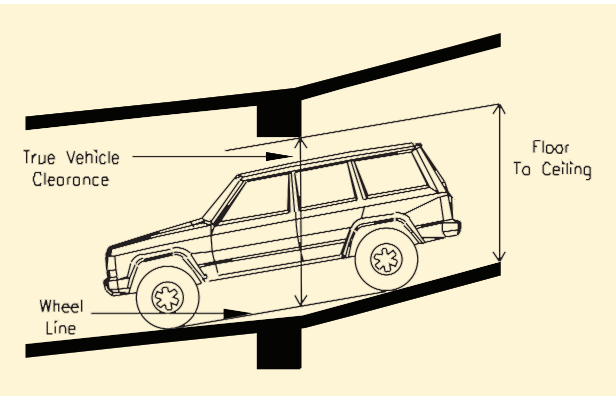


FIGURE 8-18



fort. Floor-to-floor clearances are less useful in this regard because they do not take into account how much of the space between floors is taken up by beam height. Floor-to-beam clearance is therefore a much better measurement of how much clearance is actually available.

Circular and spiral express entrance and exit ramps are an efficient, albeit expensive, means of providing expedited circulation between floors. Airport parking facilities and other high-capacity (2,000 spaces or more) facilities often use flat-deck storage ramps with circular express entrance and exit ramps. The exterior diameters of circular ramps range from 65 to 100 feet (19.8 to 30.5 meters); drive aisles are approximately 15 feet (4.6 meters) wide, with an outer curb width of 18 inches (46 centimeters) and an inner curb width of 12 inches (30.5 centimeters). Sometimes, circular ramps are designed in a double-threaded configuration in which drivers descend two parking levels with each complete turn.

The slope on a circular ramp varies with floor-to-floor height, the width of the drive aisle, the number of floors per revolution, and the diameter of the ramp. The slope also varies from the outer circumference to the inner circumference (i.e., the ramp is banked from side to side). All turns on the ramp should be a continuous ramp slope, and superelevated between 6 inches (15.25 centimeters) and 1 foot (30.5 centimeters), with no reverse superelevation. Circular ramps should be as open as possible. Solid walls on the inner and outer circumferences of the ramp create a sense of confinement and should therefore be avoided. A circular express ramp should be limited to six complete turns—which, in the case of a double-threaded ramp, would serve a 12-story structure.

Long-Span Construction

Long-span construction, which can eliminate columns between parked vehicles, offers several advantages. First, long-span construction eases entry into parking spaces, minimizing the risk of fender-benders. Second, columns consume space that could otherwise be used for parking. Most important, however, the long spans allow parking spaces to be restriped as vehicle sizes change.

Given that columns seldom interfere with parking in long-span structures, the size of the structural bay does not have to be a multiple of the width of a parking space. This allows for more design flexibility. For example, with short-span construction and 90-degree parking spaces that are 8 feet, 6 inches (2.6 meters) wide, the columns would have to be placed at 25 feet, 6 inches (7.8 meters), or at some other multiple of 8 feet, 6 inches.

The maximum acceptable standard that columns may project into the parking module at the front of the stall is 2 feet (0.6 meters), and large vehicles may occasionally park adjacent to a projecting column. Even if such vehicles extend into the drive aisle, however, they may not seriously disrupt operations.

Pedestrian Circulation

Pedestrian travel paths are typically located behind parked vehicles and along the sides of drive aisles; the exception is special pedestrian routes that may be required for disabled people. Facilities with a high rate of turnover, and therefore with high pedestrian volume, might incorporate wider drive aisles.

Stairs and Elevators

Elevators and stairs intended for the use of patrons are usually located at the perimeter of the parking structure. Building codes dictate the positioning of egress. Elevator lobbies and stair towers are often the most visible elements of a parking structure, and may offer opportunities to incorporate glass, special lighting, brick, and ornamental features.

If stairs are the only means of vertical circulation for pedestrians, as in a building with one or two supported levels, at least one stairway should be oriented to major destinations. In parking facilities with four or more parking floors, stair locations may not be critical except in meeting building code requirements. However, even in multilevel facilities with elevators, many patrons use the stairs, at least to travel down. For these users, one stairway should be located adjacent to the elevator tower. The stairs can also provide an alternative route if the elevator is out of order. Where high peak-load pedestrian traffic is projected, extra-wide stairs are recommended to encourage patrons to use the stairs during periods of high activity. Curbs in the vicinity of stair and elevator towers are hazards and should be avoided.

The number of elevators depends upon the speed and load capacity of the elevator, the peak-hour arrival/departure patterns, and the number of levels of parking. Elevators in parking facilities less than 60 feet tall (18.3 meters tall) are generally 3,500-pound-capacity hydraulic units with a speed of no less than 125 feet (38 meters) per minute. If the facility has more than five levels of parking, at least one elevator must be able to accommodate a 24-by-84-inch (61-by-213-centimeter) gurney for medical evacuation. Taller parking facilities should have electric traction elevators.

Other Considerations

If a parking structure is enclosed or located underground and thus does not meet the requirements for natural ventilation in open structures, mechanical ventilation and fire sprinklers are required. Building codes and industry guidelines prescribe the rate of ventilation. Generally, a rate of 0.75 cubic feet (0.02 cubic meters) per minute per square foot of area is required by code. Where extensive interior vehicular queuing occurs, fresh-air intakes should be provided, especially at cashier booths. The installation of carbon monoxide sensors that trigger the operation of fans when levels of the gas are excessively high is recommended for enclosed parking facilities.

In enclosed parking facilities, fire sprinkler systems are installed in a conventional manner. In freezing climates, a pressurized dry system is preferable. In open parking facilities, only a dry fire standpipe system is required at a maximum spacing of 130 feet (40 meters) to any location on the floor.

Overall, experience shows that the likelihood of fire in a parking structure is extremely low. It should also be noted that fire extinguishers in parking facilities pose some risk of theft. Although fire extinguishers are required by code, designers should try to persuade fire marshals to waive the requirement for fire extinguishers in parking structures. In most cases, fire extinguishers stored in the cashier's booth and in the manager's office should suffice.

Often, curbs are used as wheel stops when the design of a facility calls for cable rails instead of concrete bumper walls. Curbs between parking modules on a flat parking deck should be avoided. Patrons may trip over them as they move from bay to bay between vehicles. Only striping is recommended between bays.

Precast concrete wheel stops are not recommended, because they create an area where trash and debris collect. However, if wheel stops are required with angled parking, they should be placed in a straight line, rather than perpendicular to the parking space. When wheel stops are perpendicular to the parking space, the wheel stop in the adjacent space poses a trip hazard for the driver exiting from a vehicle in that space. The hazard is particularly severe with vans, because van drivers sit unusually close to the front of the vehicle.

SUMMARY

Good functional design is critical to the success of a parking facility. The design must ensure that pedestrian and vehicle interaction is safe and efficient. Vehicular and pedestrian circulation—both within, and to and from the facility—must be accommodated through well-designed entrances, exits, parking bays, elevators, and safety features. Strong functional design helps to ensure higher levels of use, lower liability, and efficient and cost-effective operations.

NOTES

1. Another means of addressing potential equipment failure is to place two ticket dispensers in tandem at a single entry lane and cover one with a removable canvas hood.

2. The feature box "Why Small-Vehicle-Only Parking Spaces Do Not Work" (see page 60) explains why it is inadvisable to provide separate spaces for small and large vehicles.

CHAPTER 9

Accessibility and the AMERICANS WITH DISABILITIES ACT

RICHARD BEEBE, MARY S. SMITH, AND I. PAUL LEW

PASSED IN 1990, THE AMERICANS WITH DISABILITIES ACT (ADA) is landmark civil rights legislation that prohibits discrimination against persons with disabilities. Of the five titles in the law, three deal with the accessibility of buildings and facilities:

- Title I covers employment of persons with disabilities, including requirements to accommodate the needs of persons with disabilities in work areas.
- Title II requires, among other things, that programs and services (including transportation) provided by state and local governments be accessible, which usually requires that there be no physical barriers to access to those programs and services.
- Title III requires, along with other requirements, that the areas of privately owned buildings and facilities where the public goes to receive goods and services be accessible; private transportation services, such as shuttle buses, must also be accessible.

For both Title II and Title III entities, all new construction and alterations of buildings and facilities (including areas not serving programs or services used by the public) must be accessible. Title III however, excludes residential units, which were (and still are) covered by the Fair Housing Act. The title also covers areas used solely for religious worship and private clubs. Facilities owned, leased, or financed, in whole or in part, by the U.S. government are not covered by the ADA, because they were (and will continue to be) covered by the Architectural Barriers Act of 1968 (ABA).

On July 26, 1991, the Architectural and Transportation Barriers Compliance Board (ATBCB) published its guidelines for compliance with the ADA's requirements regarding the design of buildings and facilities in the *Federal Register*;[1] the provisions of the Americans with Disabilities Act Accessibility Guidelines (ADAAG) became effective on January 26, 1992. Title III entities must comply with ADAAG; however, Title II entities were given the choice of complying with ADAAG or the older Uniform Federal Accessibility Standards (UFAS),[2] which were developed for compliance with the ABA. Although there have been several updates and clari-

Requirements Affecting Accessible Design at a Transit-Oriented Development

A transit-oriented development offers an example of the range of accessibility requirements that could apply to a single project. Such a development would be covered by state or local accessibility codes; state or local building codes; and the following federal requirements:

Residential Units and Parking Serving Those Units

▷ The Fair Housing Act (1968) may require some units to be accessible. The U.S. Department of Housing and Urban Development (HUD) considers compliance with the International Building Code (IBC) 2000, as amended by the IBC 2001 Supplement, as a "safe harbor" for meeting the requirements of the Fair Housing Act.[1] (Compliance with ADAAG 91 is not currently considered a safe harbor.)

▷ Residential units that are subsidized by the U.S. government are subject to the Architectural Barriers Act of 1968 (ABA). Currently, their design must comply with Uniform Federal Accessibility Standards (UFAS). UFAS is similar to ADAAG, but there are differences; for example, UFAS does not require any van-accessible spaces. It is not known if or when HUD will adopt ADAAG 2004 for either the ABA or the Fair Housing Act.

▷ If the housing is owned by a local government entity, such as a housing authority, the units and the associated parking must meet the requirements of Title II of the Americans with Disabilities Act (ADA). ADAAG 91 or UFAS—whichever was adopted by the local government in the early 1990s—would apply, until the U.S. Department of Justice (DOJ) adopts ADAAG 2004 for Title II.

Transit Facilities

▷ Transit facilities must comply with ADAAG 2004, which was adopted by the U.S. Department of Transportation for the design of transit facilities and airport terminals, effective November 2006.[2]

Commercial Development

▷ Commercial development is covered by Title III of the ADA; ADAAG 91 is currently enforced by the DOJ.

Parking Owned or Leased by Local, State, or Federal Entities

▷ Parking owned or leased by a state or local government entity would be subject to Title II of the ADA. Either ADAAG 91 or UFAS, whichever was adopted by the entity in the early 1990s, would apply.

▷ Parking financed by or leased by a federal agency (for example, as an office tenant) would have to comply with ADAAG 2004, which was adopted by the U.S. General Services Administration in 2006.

Notes

1. U.S. Department of Housing and Urban Development (HUD), *Fair Housing Act Design Manual* (Washington, D.C.: HUD, 1996; revised April 1998).
2. U.S. Department of Transportation (DOT), *Transportation for Individuals with Disabilities; Adoption of New Accessibility Standards*, 49 CFR Part 37 (Washington, D.C.: DOT, 2006); published in the *Federal Register* October 30, 2006.

fications to ADAAG, few had implications for parking. The ATBCB has published (first in 1996, and then republished in 2003) a bulletin on parking issues that is still available on its Web site and contains helpful guidance.[3]

In 2004, the ATBCB published a complete revision of ADAAG (referred to in this chapter as ADAAG 2004).[4] This revision has been "harmonized" with other overlapping guidelines for accessibility, including those for the ABA, the Fair Housing Act, the International Building Code (IBC), and the American National Standards Institute (ANSI). ADAAG 2004 has been adopted and replaces UFAS, under rules already issued by the Department of Transportation, the Post Office, the Department of Defense, the Department of Veterans Affairs, and the General Services Administration. A few specific adjustments and modifications in the requirements for each agency were allowed. ADAAG is further intended to be applicable to residential units under the ABA and/or the Fair Housing Act; however, the Department of Housing and Urban Development (HUD) has not adopted ADAAG 2004 as of this publication.

In June 2008, the Department of Justice (DOJ), which is responsible for enforcing the ADA for most construction in the United States, published draft rules for adopting and enforcing ADAAG 2004 for both Title II and Title III entities. The DOJ received comments, modified the requirements, and submitted the final draft to the Office of Management and Budget for approval in December 2008. The DOJ rules will likely become effective and apply to construction with building permits issued on or after a date six months after final publication. Therefore, ADAAG 2004 is not likely to be applicable to Title II and Title III facilities until at least 2010. Further complicating matters, there are still differences between ADAAG 2004 and IBC/ANSI codes, which are enforced by local officials as part of the building permit process.[5] The requirements of IBC/ANSI are substantially similar to those of ADAAG 2004, except that ADAAG 2004 has higher scoping standards (i.e., more elements must be accessible) than IBC 2006 in several areas that are critical to parking. In the rules issued in 1991, the DOJ stated that the requirements therein do not invalidate or limit the requirements of state and local governments.[6] On its Web site, the ATBCB states that in the event of conflicting state and federal requirements, the most rigorous of the requirements applies.[7]

In sum, a patchwork of requirements currently affects accessible design. This chapter highlights the requirements affecting parking and site access (that is, the removal of barriers along the path of approach to, and at the entrance to buildings), both of which are among the highest priorities of the ATBCB and DOJ in enforcing the ADA.[8]

EXISTING FACILITIES

The ADA is different from building codes such as the IBC because it requires improvements to existing facilities. For existing private sector facilities, Title III states that physical barriers must be removed in areas where the public goes to receive goods and services, if the improvements are readily achievable ("readily achievable" is defined as being without significant difficulty or expense).[9] For public sector facilities, physical improvements must be undertaken as required to make programs and services accessible, unless the improvements would create an undue burden. In both cases, the requirement to make improvements to existing facilities is ongoing. Further, if improvements were not readily achievable or were considered an undue burden when the ADA first became effective but are feasible now, they must be undertaken. Moreover, "ADA Business Brief," a DOJ publication, notes that adding striping and properly sizing parking spaces is readily achievable "in most cases" because restriping is relatively inexpensive.[10] The sole exception would be if the resizing or restriping reduces the total number of parking stalls below a legal requirement, such as zoning or financing covenants. Even then, the U.S. Access Board believes that the legal authority would likely waive the requirement if the reason for the loss is the addition of accessible spaces.[11]

The ongoing obligation to remove barriers is complicated by the adoption of ADAAG 2004. The draft DOJ rules for the enforcement of ADAAG 2004 contain a broad "grandfather clause"; under this clause, if the facility meets the requirements of ADAAG 91 (either because it was designed under ADAAG 91, or because the owner made improvements to meet ADAAG 91), it does not need to be brought up to ADAAG 2004 unless or until the facility is altered. However, if a facility does not meet ADAAG 91 after ADAAG 2004 is enforced, if and when the required improvements are readily achievable and/or not an undue burden it must be brought into compliance with ADAAG 2004. This is essentially a penalty for not having already improved to ADAAG 91.

Requirements for van-accessible spaces offer a good example of how the successive requirements work in practice. Under ADAAG 91, one out of every eight required accessible spaces were required to be van accessible. Thus, the owners of every parking facility built before the 1992 enforcement of ADAAG 91 were legally required to add van-accessible spaces as soon as it was readily achievable to do so.

If a facility now has the total required accessible spaces, with one in eight van-accessible, the number need not be increased to meet the ADAAG 2004 requirement of one in six spaces, unless or until the facility is altered, as discussed in the next section. However, if a facility does not meet the ADAAG 1991 requirements, when ADAAG 2004 is enforced, one in six required accessible spaces must be van accessible if and when such an improvement is readily achievable.

ALTERATIONS AND NEW CONSTRUCTION

All elements and spaces in alterations and new construction must be accessible, with the only limitation being if the alterations are technically infeasible or if new construction is structurally impracticable. These requirements apply to the entire building, including employee-only work areas, not just to the areas where the public receives goods and services. They also apply whether the entity is covered by Title II or Title III.

An alteration is defined by ADAAG 91 as a change that affects the usability of an entire building or facility or a portion thereof. Alterations "include but are not limited to remodeling, renovation, rehabilitation, reconstruction, historic restoration, changes or rearrangements of the structural elements, or changes or rearrangement in the plan configuration of walls and full-height partitions." Painting, wallpapering, reroofing, and replacing mechanical and electrical equipment are exempt and are not considered alterations if they do not affect the usability of the element. For example, if an electrical outlet is to be replaced, it is an alteration and must meet ADAAG. However, if wiring is replaced without affecting any usable component, it is not an alteration. Some have argued that the repair of potholes and other deterioration in parking areas is akin to reroofing. Building roofing, however, does not normally affect accessibility to the building, but the paving in a parking area does.

ADAAG 2004 added "resurfacing of circulation paths or vehicular ways" to this list, clarifying the application to parking areas. A simple, safe rule of thumb is that anything that is taken out should be replaced according to ADAAG specifications. For example, if an expansion joint is being replaced, the new one should meet the requirements for changes in level. In addition, there are requirements to improve the path of travel to the area being altered. These requirements are relatively complicated and are beyond the scope of this chapter. In any event, where an improvement to remove an existing barrier is finally readily achievable due to the alteration activity, it must be completed as well.

This chapter explores key features of ADAAG 2004—which is considered state of the art despite the fact that for most private and public construction, it is not yet being enforced by the DOJ. The chapter will also highlight key differences between ADAAG 1991, ADAAG 2004, and IBC 2006.

NUMBER AND LOCATION OF ACCESSIBLE PARKING SPACES

One of the first considerations for a parking facility is the number and location of accessible parking spaces. Most uses must comply with the ratios of accessible spaces to regular spaces shown in Figure 9-1. Except for the change in the number of van-accessible spaces, the ratios are the same in both ADAAG 91 and 2004. The ratios are to be applied on a lot-by-lot basis. If a project has multiple lots or facilities, the ratios apply to each lot or facility independently from the others. This is a significant difference from IBC 2006, which applies the same standards to the total number of spaces serving a destination (all lots combined). Where there are multiple lots serving a destination, ADAAG will require more spaces, and in some cases significantly more spaces, than IBC. One use not covered by Figure 9-1 is certain medical facilities. (Please see "Requirements for Accessible Parking at Medical Facilities," on page 84, for more details.)

Under ADAAG 91, facilities that are operated only as valet parking were permitted to forgo accessible parking spaces; under ADAAG 2004, this exemption has been eliminated. Therefore, accessible spaces, in accordance with the Figure 9-1 requirements, will be required when ADAAG 2004 is effective.

FIGURE 9-1: Required Number of Accessible Spaces

Total Number of Parking Spaces	Minimum Number of Accessible Spaces Required[1]
1–25	1
26–50	2
51–75	3
76–100	4
101–150	5
151–200	6
201–300	7
301–400	8
401–500	9
501–1,000	2 percent of total[2]
1,001 and over	20, plus 1 for each 100 additional spaces

Notes

1. Medical facilities have higher requirements; see the feature box titled "Requirements for Accessible Parking at Medical Facilities" on page 84.
2. If a requirement is stated in percentage terms, ADAAG 2004 does not permit rounding down. For example, if there are 901 parking spaces in a facility, and 2 percent of the total is 18.02 spaces, the required number of spaces is rounded up to 19.

Requirements for Accessible Parking at Medical Facilities

Under ADAAG 91, the required number of accessible parking stalls for medical facilities is as follows:

- ▷ 10 percent of the spaces serving outpatient facilities must be accessible.
- ▷ If a unit or facility specializes in the treatment of people who have mobility impairments, 20 percent of the spaces serving that unit must be accessible.

ADAAG 2004 clarifies several aspects of the application of these standards:

- ▷ The higher ratios apply only to patient and visitor parking, not to employee parking.
- ▷ The term *outpatient facilities* applies only to facilities that are part of a hospital, not to freestanding, independent outpatient centers (for example, medical office buildings with outpatient services such as X-ray, physical therapy, or ambulatory surgery).

Because both of these clarifications have been included in a bulletin that clarifies ADAAG 91, they can be applied now.[1]

The Architectural and Transportation Barrier Compliance Board (ATBCB) has specifically noted that zoning requirements for medical facilities can be used to determine the spaces allocated to outpatient services, and that the 10 percent ratio can then be applied. For example, if the local zoning code requires four spaces per 1,000 square feet (93 square meters) for outpatient service areas, and the hospital has 25,000 square feet (2,323 square meters) of outpatient services, then 100 spaces are required. Under ADAAG 91, ten accessible spaces would be required. Under ADAAG 2004, however, the 10 percent ratio would be applied only to the patient portion of the 100 spaces serving the outpatient units.

Unfortunately, most local ordinances continue to base parking requirements for hospitals entirely on the number of beds, or to apply a single ratio of spaces per square foot, without delineating specific requirements for outpatient services and without distinguishing between patient/visitor parking and employee parking. Therefore, owners may choose alternative means of determining requirements—such as creating separate lots for outpatients, or undertaking a parking study that will stratify parking demand for outpatients. For example, if a hospital is served by 1,000 spaces in a single parking facility (so that the lot-by-lot calculations do not further complicate things), it might be determined that 80 spaces would serve outpatients, 20 spaces would serve the patients of units that specialize in the treatment of mobility impairments, and the remaining 900 spaces would be for employees, inpatients, visitors, and the general public. On the basis of this allocation of spaces, the minimum number of required accessible spaces would be as follows:

General accessible spaces:	2% of 900 = 18 spaces
Outpatient accessible spaces:	10% of 80 = 8 spaces
Mobility-treatment accessible spaces:	20% of 20 = 4 spaces
	Total = 30 spaces

This compares to only 20 accessible spaces being required for a 1,000-space facility serving other uses.

Note

1. United States Access Board, "Technical Bulletin: Parking," August 2003; available at www.access-board.gov/adaag/about/bulletins/parking.htm.

In anticipation of the adoption of ADAAG 2004 for residential uses, ADAAG 2004 also has added requirements matching those in HUD rules for residential uses under the ABA and the Fair Housing Act.

Once the number of accessible spaces is determined on a lot-by-lot basis, the accessible stalls can be redistributed to the most accessible locations. Generally, the most accessible locations are those that are the closest to the appropriate accessible entrances. ADAAG 2004 has clarified that the required accessible entrances shall be the same ones that are regularly used by pedestrians. For example, a hospital with multiple parking lots would locate the required accessible spaces for several employee parking lots in the lot closest to the employee entrance, and this entrance must be accessible. In addition, the required spaces for outpatients must be closest to the entrance used by outpatients, and this entrance must also be accessible. Further, the accessible spaces must be the closest ones within the lot to the accessible entrance, a provision often violated in practice. The path of travel between accessible stalls and accessible entrances must meet all requirements as an accessible route.

ADAAG 2004 includes further significant changes to the requirements for accessible entrances. Under ADAAG 1991, the required number of accessible entrances was either 50 percent of the number of planned public entrances or equal to the number of the code-required exits, depending on which number was greater. Under ADAAG 2004, the required number of accessible entrances has been simplified to 60 percent of the planned public entrances. This number is determined without any consideration of code-required exits, which eliminates arguments over whether code-required exits can also be considered entrances.

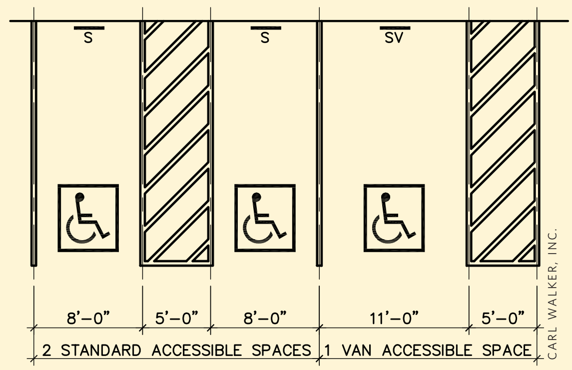
Under ADAAG 1991, if there are direct pedestrian entrances from parking to a building served by the parking, at least one direct entrance had to be accessible. There was a subrequirement that there be an accessible entrance at each direct access to any building from a pedestrian tunnel or walkway. This was confusing when the direct connection from parking to the building was a bridge over or a tunnel under a street or roadway. ADAAG 2004 eliminated this issue by requiring every direct connection from parking to building to be accessible, and by requiring every accessible connection to have accessible parking stalls.

SIZE AND TYPE OF ACCESSIBLE PARKING SPACES

Once the location and number of accessible parking spaces have been determined, the size and requirements of the parking spaces must be defined. There are three types of accessible spaces for vehicles:

▷ standard accessible parking spaces (ADAAG 2004 uses the term *car accessible*);
▷ van-accessible parking spaces; and
▷ passenger loading zones.

FIGURE 9-2: Accessible Space Dimensions



Under both ADAAG 91 and 2004, the car-accessible parking space is 8 feet (2.4 meters) wide and must have a 5-foot- (1.5-meter-) wide access aisle adjacent to it, as shown in Figure 9-2. Note that one 13-foot- (4-meter-) wide car stall is not acceptable; the access aisle must be demarcated separately from the stalls. Under ADAAG 91, van-accessible stalls must also be 8 feet (2.4 meters) wide, but they must have an 8-foot- (1.5-meter-) wide access aisle. However, because persons without appropriate permits were parking in the 8-foot access aisles, ADAAG 2004 requires van-accessible stalls to be 11 feet (3.4 meters) wide, with adjacent 5-foot- (1.5–meter-) wide access aisles. The wider van stalls have added benefits: drivers with disabilities can pull over to the passenger side of the 11-foot (3.4-meter) stall and have room to exit the car; and a van with a lift can pull over to the driver side and have room to operate the lift on the passenger side.

Although the access aisle must be demarcated, ADAAG does not specify particular pavement markings. Typically, however, the access aisle is crosshatched, and the International Symbol of Accessibility is painted on the pavement within the stall. It may be desirable to use a bollard to prevent parking within the access aisle, particularly where 8-foot (2.4-meter) access aisles are provided. However, the bollard must be placed at the end of the stall, and must not interfere with the accessible route.

Signs are required at each accessible stall. Under ADAAG 91, the sign had to be visible when a vehicle was parked in the stall. This was not very precise, and was sometimes difficult to achieve because the ceiling might be only a few inches above the top of a van or a sport-utility vehicle. ADAAG 2004 requires simply that the bottom of the sign be 5 feet (1.5 meters) above the pavement.

Two van-accessible or car-accessible spaces may share the same access aisle. However, for van-accessible stalls, the access aisle must be usable on the passenger side. With 90-degree parking, a vehicle can back into an accessible parking space and have access to the access aisle on the appropriate side of the vehicle. With angled parking, however, the access aisle for a van space must always be on the passenger side when the vehicle pulls in forward.

Vertical clearance for car-accessible spaces can be the same as for the rest of the parking structure (7 feet [2.1 meters] under most building codes), but van-accessible stalls must have a vertical clearance of 8 feet, 2 inches (2.5 meters) along the path of travel from the facility entrance to the stall, and from the stall to the vehicular exit. In a parking structure, all van-accessible spaces may be grouped on one level—thus, they may all be placed at grade and with the necessary extra clear height provided only at that level.

Under ADAAG 91, if one or more passenger loading zones is provided, at least one such zone must be accessible. ADAAG 2004 requires one accessible passenger loading zone for every 100 feet (30 meters) of loading zone; thus, every loading zone must be accessible. Because the clear height from the vehicular entry to the loading zone and back to the exit must be 9 feet, 6 inches (2.9 meters), designated passenger loading zones should be avoided at upper levels of parking garages even if there are pedestrian entrances to the destination served. Accessible passenger loading zones must have a vehicular standing area 8 feet (2.5 meters) wide and at least 20 feet (6 meters) long, with a 5-foot (1.5-meter) access aisle adjacent to the space (see Figure 9-3). The access aisle must be at the same elevation as the vehicle tires; the loading zone cannot discharge to a sidewalk on top of a curb. If there is a raised curb, it must not be within the access aisle, and there must be a curb ramp from the access aisle to the raised curb.

Under ADAAG 2004, the slope of accessible parking spaces and loading zones, including access aisles, must not exceed 1:48 (or 2.08 percent). This is a slight improvement over ADAAG 1991, which allowed a 1:50 slope (or 2.0 percent).

FIGURE 9-3: Passenger Loading Zone

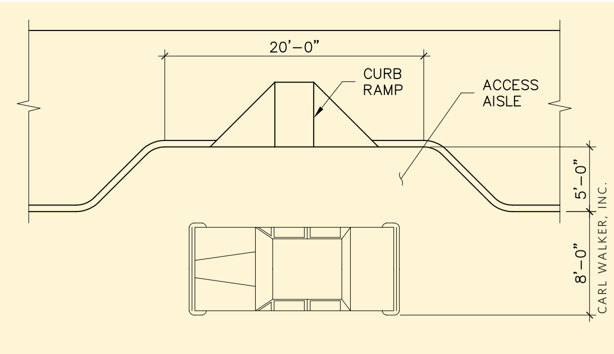
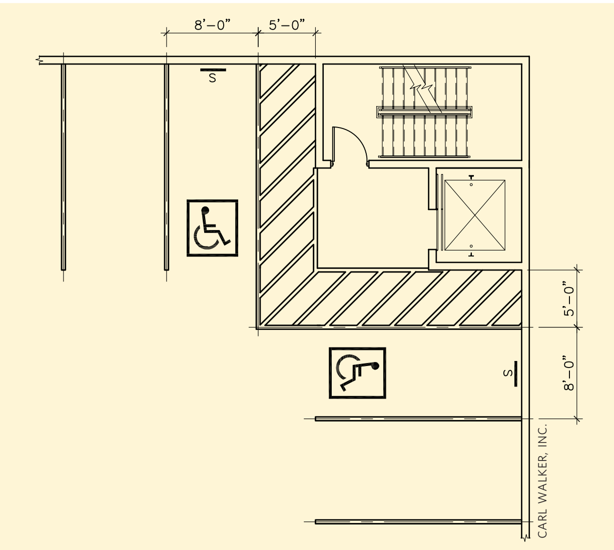
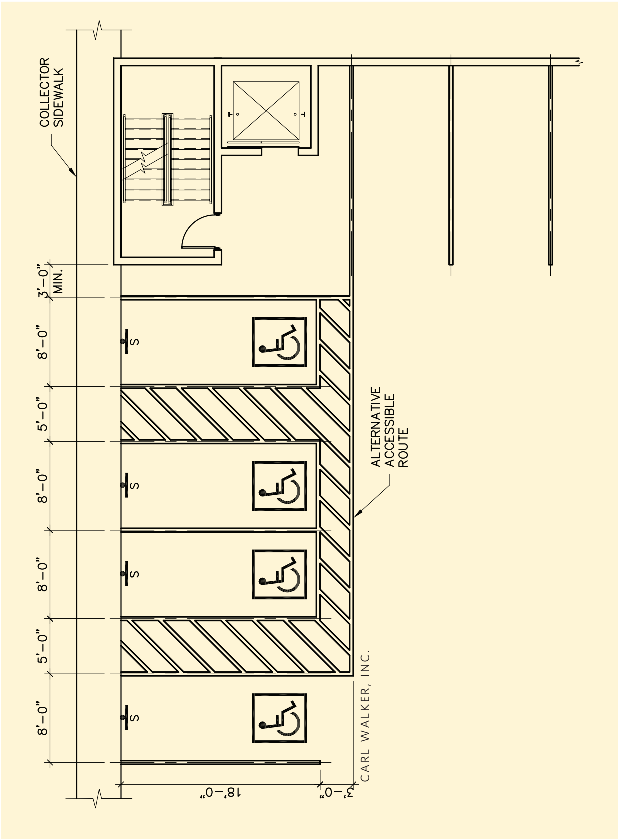


FIGURE 9-4: Accessible Spaces around Elevator Tower



Many states have adopted higher standards than those specified in ADAAG 2004—and, as previously noted, a project's design must meet the higher of each individual requirement if there is a conflict. For example, Florida and Illinois require that all accessible stalls be van accessible (which means they all have to have clearance of 8 feet, 2 inches [2.5 meters]), and California requires the 8-foot, 2-inch (2.5-meter) vehicular clearance to and from all accessible stalls. ADAAG 2004 requires all pedestrian bridges connecting parking to destinations to be accessible and requires acces-

FIGURE 9-5: Accessible Spaces in a Row



sible stalls to be distributed to all such locations. If the project is in Florida, Illinois, or California, then, vertical clearance along the path of travel to the accessible stalls at an elevated pedestrian bridge must be 8 feet, 2 inches (2.5 meters).

ACCESSIBLE SITES AND ROUTES

An accessible site must meet the following minimum requirements:

▷ Within the boundary of the site, at least one accessible route must be provided between an accessible building entrance and (1) public transportation stops; (2) accessible parking spaces; (3) passenger loading zones, if provided; and (4) public streets or sidewalks.

▷ At least one accessible route must connect accessible buildings, accessible facilities, accessible elements, and accessible spaces within the same site. To the maximum extent feasible, the accessible route should coincide with the route for the general public.

All accessible stalls must be connected to an accessible route. Accessible routes may include parking access aisles, curb ramps, crosswalks at vehicular ways, walks, ramps, and lifts. Slopes on an accessible route must be less than 1:20, or 5 percent; if the slope exceeds 5 percent, that section of the route must be designed as an accessible ramp, which has more stringent design requirements. All floor surfaces must be stable and slip resistant. There are also limitations on turns in the path of travel along an accessible route. Finally, there must be no protruding objects along the accessible route that could reduce the clear width of the route.

Neither ADAAG 1991 nor ADAAG 2004 requires that the accessible route from an accessible stall be separated from the vehicular way; in other words, the path from the accessible stall and access aisle to the destination may use the vehicular route, as long as that route meets the requirements for an accessible route. In fact, ADAAG 2004 has an advisory box noting that the accessible route should be the same one as that used by the general public, even if it is also a vehicular way. It is desirable, however, to avoid requiring people in wheelchairs to roll down the drive aisle behind multiple parking stalls, because it may be difficult for drivers backing out of stalls to see someone in a wheelchair. ADAAG 2004 clarifies that it is desirable to minimize the need to pass behind multiple parked vehicles, and states that any stalls that are passed should be accessible stalls—but this is a "should," not a "must."

In a parking lot, or in a structure with only an at-grade connection to the destination, it is desirable to place all the accessible stalls at grade. In this case, a collector sidewalk beyond the edge of the parking area would provide a separate accessible route. However, if there is no space for a separate sidewalk, the drive aisle may have to be used as the accessible route. However, it may be preferable to distribute a couple of accessible stalls on each level, near the elevator tower, in such a way that users of accessible stalls do not need to pass behind any parked vehicles other than their own. In many facilities, accessible spaces are provided adjacent to corner stair and elevator towers (see Figure 9-4). If distributing accessible stalls along the side of the drive aisle would require users of the accessible stalls to pass behind multiple other stalls, it may

FIGURE 9-6: Accessible Spaces across from Vehicular Way: Parallel Orientation

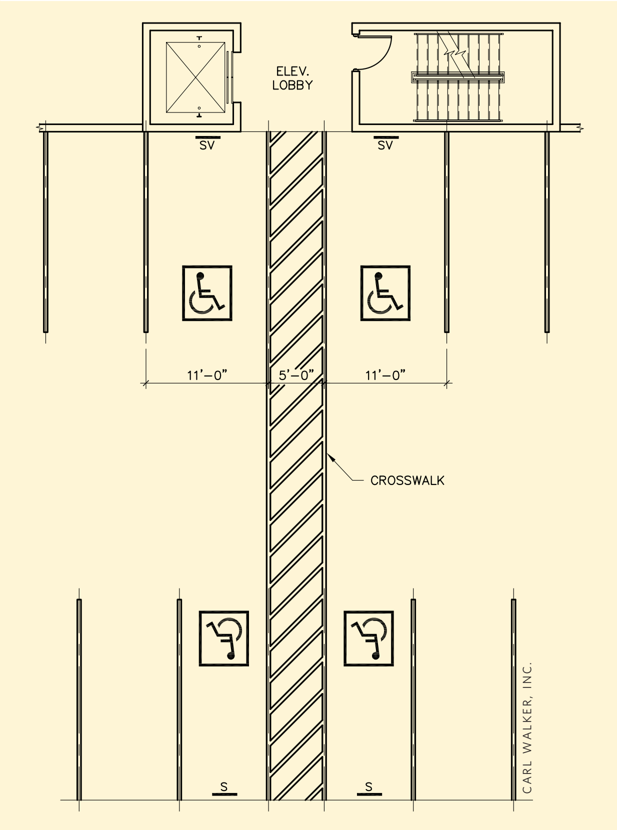
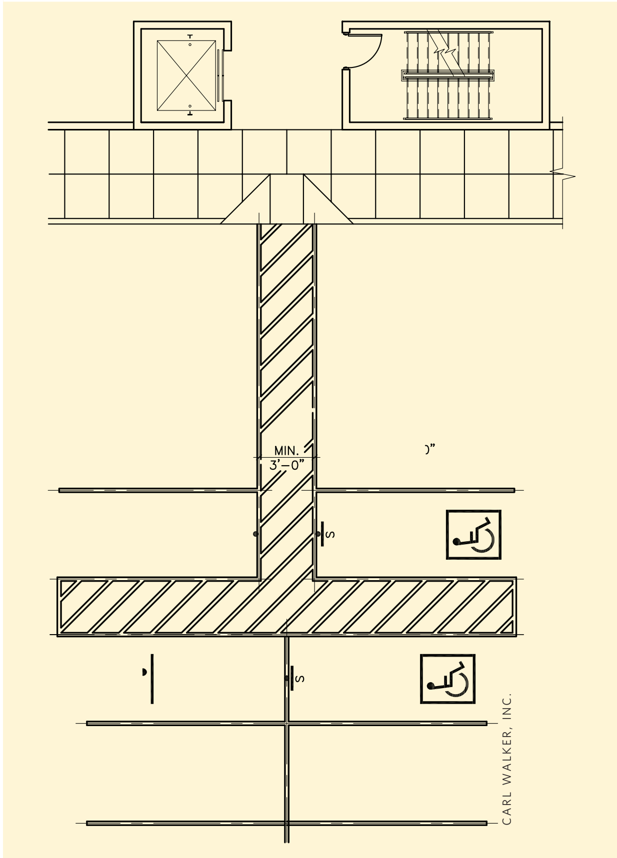


FIGURE 9-7: Accessible Spaces across from Vehicular Way: Perpendicular Orientation



be preferable to place some of the accessible stalls across the drive aisle; if so, ADAAG 2004 recommends, but does not require, a marked crosswalk (see figures 9-5, 9-6, and 9-7).

The minimum width required by ADAAG and ANSI for an accessible route is 36 inches (0.9 meters), although it may be desirable to widen it to allow for two-way pedestrian traffic. There are also requirements for additional space at turning points, as well as at doors in the accessible route. Defining all the variations is beyond the scope of this chapter.

RAMPS

Ramps are one of the major design aspects of an accessible route. A curb ramp is a specific type of accessible ramp with no more than a 6-inch (15-centimeter) rise.

The requirements for accessible ramps and curb ramps are largely the same. ADAAG requires a maximum slope of 1:12, or about 8.3 percent, although a few very limited exceptions are allowed for preexisting conditions that cannot be corrected because of the historic nature of the building, or because of the topography (for example, some streets in San Francisco slope 15 percent). The cross slope, which runs perpendicular to the running slope, cannot exceed 1:50 (2.0 percent). At the top and bottom of ramps, landings are required with a maximum slope of 1:48 (2.08 percent); for accessible ramps, intermediate landings are also required for every 30 inches (0.76 meters) of vertical rise. Beyond the landing, the accessible route can revert to the 1:20 (5 percent) slope. The

Curb ramps must have no more than a 6-inch (15-centimeter) rise, and the sides of the ramp must be flared.

An example of signage indicating accessibility.

details of the landing dimensions are situational, and best met by reviewing the requirements in ADAAG itself.

If pedestrians could walk across a curb ramp, parallel to the curb, the sides of the ramp must be flared. Any built-up curb ramps must not project into the path of vehicular traffic or into an accessible parking stall, an access aisle, or an accessible passenger loading zone.

SIGNAGE AND DETECTABLE WARNINGS

For ADAAG to be effective in improving accessibility, persons with disabilities must know where accessible spaces and routes are located. ADAAG requires signage to direct patrons to accessible entrances, parking spaces, and loading zones, which must be identified by the International Symbol of Accessibility. Under both ADAAG 91 and 2004, the signage does not have to be written in Braille or have raised letters. Site and parking signage typically exceed the minimum standards that do apply. For example, the minimum character height is 3 inches (7.6 centimeters) for overhead signs, while character heights of 4 to 10 inches (10 to 25 centimeters) are typically used in parking facilities, depending on viewing distance. Signs written in Braille or containing raised lettering are required by both ADAAG 91 and 2004 to designate permanent rooms and spaces such as offices, restrooms, stairs, and elevator towers; however, parking facilities are specifically exempted from this requirement in ADAAG 2004.

ADAAG 91 required detectable warnings to be placed on all curb ramps, as well as at hazardous vehicular areas and at the edges of reflecting pools. This requirement was suspended in 1994 because of concerns about maintenance, and about the usefulness and safety of the specifications.[12] On July 26, 2001, the ATBCB decided, in anticipation of ADAAG 2004 (which does not require detectable warnings except at boarding platforms at transit facilities), not to extend the suspension. Currently, therefore, because of the delay in the DOJ's adoption of ADAAG 2004, detectable warnings are technically required at all curb ramps, at hazardous vehicular areas, and at the edges of reflecting pools. Some jurisdictions are aware that the ATBCB has decided not to require detectable warnings within parking facilities, but other jurisdictions are enforcing the requirement because the suspension has expired. It is unclear whether the DOJ is enforcing the requirement; most likely, it is being enforced only if noncompliance is discovered as part of a comprehensive review. If detectable warnings are provided now, for whatever reason, the ATBCB has issued an advisory recommending use of the new design for detectable warnings that has been included in ADAAG 2004, even though the use of this design is not yet an enforceable requirement.

As part of a continuing effort to establish guidelines for accessibility in the public right-of-way, the ATBCB has published draft standards that would require detectable warnings at curb ramps on public streets. (Neither ADAAG 91 nor ADAAG 2004 applies to public rights-of-way, including on-street parking.)

ELEVATORS, EMERGENCY EXITS, AND AREAS OF RESCUE

Under ADAAG 91, elevators are required in all buildings with three or more floors; however, all two-story buildings owned by state or local government entities (including parking facilities); all shopping centers; and all multifloor medical office buildings must have at least one elevator. An accessible ramp or route can replace elevator connections between some or all floors. ADAAG 2004 has the same requirements regarding the number of floors that trigger the requirement, but it reverses the mandated solution by requiring that the floors be connected by an accessible route (an elevator is one way to provide an accessible route). As they are only required between required accessible elements (such as between a parking space and an accessible entrance), accessible routes do not have to be provided everywhere on the floor. However, the requirement to have an accessible route to every floor is a separate, independent requirement and therefore applies whether or not there are any accessible parking spaces on the floor.

In a facility in which an elevator is required, all elevators provided for general use must be fully accessible. Moreover, an accessible elevator must serve all floors; it cannot stop short of the roof level with parking on it. When an elevator serves more than four stories, it must meet additional requirements in both ADAAG and IBC for emergency power, room for stretchers, and other provisions.

ADAAG 2004 mandates that the elevator or accessible route must be roughly equivalent in convenience to the stairs or escalators used by most patrons. Thus, for example, an elevator at the back door, next to the loading dock, is not acceptable if all other patrons come in the front door and travel to other levels by stairs or escalators.

In a parking structure, if the parking ramp between floors meets the requirements of an accessible route (most particularly, if the slope does not exceed 5.0 percent), and if all patrons are expected to use the parking ramp to move through the structure, the ramp can serve as the required accessible route between floors as well. However, if others can quickly circulate up and down between floors on a staircase, the parking ramp may not be considered equally convenient, and an elevator may therefore be required. Certainly, an unprotected exterior sidewalk cannot be considered an accessible route between floors on a sloping site if patrons without disabilities can walk the length of the lower level under protection and reach grade by means of stairs, and patrons with disabilities cannot.

Under ADAAG 1991, areas of rescue assistance (the parallel term in the IBC is *area of refuge*) were essentially required at every code-required exit and at elevators that served as accessible exits. An area of rescue assistance is a small space within an enclosed stair or other smokeproof location where people who are in wheelchairs can wait for someone to carry them down to grade level. In the commentary to ADAAG published in 1991, the ATBCB stated that areas of refuge were not required in open parking structures; however, there was no exemption in the text. ADAAG 2004 yields all emergency-exit requirements, including those regarding accessibility, to the IBC, regardless of whether the IBC has been adopted. The IBC specifically exempts open parking structures from the requirement for areas of refuge.

CASHIERS' BOOTHS

It is important to understand how ADA is applied to employee work areas, because one of the most common mistakes in the accessible design of parking facilities concerns cashiers' booths. Title I of the ADA requires employers to provide reasonable accommodation for the specific needs of a person with a disability sufficient to enable the person to perform a job, unless such accommodation would fundamentally alter the requirements of the job. Thus, for example, a person with severe mobility

STEPHEN J. SHANNON

Under ADAAG 91 and ADAAG 2004, a car-accessible space is 8 feet (2.4 meters) wide, and must have a 5-foot- (1.5-meter-) wide access aisle adjacent to it.

impairments probably cannot be a building's sole security guard, because the impairments might prevent the employee from responding to emergencies in the way that is fundamentally required for the position. A person who can perform the duties of cashier, however, cannot be denied the position just because the booth is not accessible; similarly, a supervisor cannot be fired or moved to another position because he or she is unable to walk to the booth and mentor an employee.

As a result, ADAAG's approach to building and design is that all employee-only work areas need not meet the needs of all potential employees. Instead, if an employee needs specific accommodations (such as a door wide enough for a wheelchair, or shelves and furniture in the work station that can be reached from a seated position), the employer must make those modifications. So that the costs of retrofitting will not be a significant burden, ADAAG includes some guidelines that are requirements for minimum levels of accessibility of work areas and others that are recommendations. If the owner chooses not to follow the recommendations, there is no excuse or relief from the cost of providing accommodation should an employee need them.

Therefore, ADAAG requires all individual workstations in employee-only areas to have an accessible route to and through the door or portal from both the exterior and the shared spaces (such as restrooms and break rooms). In addition, bathrooms and certain other features must be fully accessible. Although there is no requirement that the interiors of all individual workstations be fully accessible, the appendix to ADAAG 91 does recommend that among similar workstations, 5 percent (with a minimum of one) be fully accessible (that is, the workstations must have the ADAAG-prescribed turning space and reach ranges).

When ADAAG 1991 was first published in draft form, the parking industry requested an exemption from the "to and through the door" requirement for cashiers' booths for several reasons—among them the fact that the job responsibilities, such as changing the tickets in dispensers and responding to emergencies in the facility, would make the position inappropriate for a person with significant mobility impairments, particularly if the cashier were the sole employee in the facility. In the Supplementary Information to ADAAG 91, the ATBCB responded to this request by stating that all cashiers' booths in parking facilities are "employee work areas," which must meet the requirements for accessibility to and through the door; the ATBCB noted that a supervisor in a wheelchair might need to roll at least partway into the booth to mentor an employee. The final document included an exception, under which single-occupant structures used as employee work areas are exempt from the "to and through the door" requirement if they can be accessed only from tunnels or overhead bridges, as is sometimes the case at toll road plazas.

ADAAG 2004 provides further clarification through a new exception: if the work area is smaller than 300 square feet (28 square meters) and is raised more than 7 inches (18 centimeters) above the adjacent floor because that is essential to its purpose. However cashiers' booths have always been designed to be positioned on a curb no higher than 6 inches (15 centimeters), in order to make it easy for employees to engage in such tasks as taking tickets or handing back change. It is therefore difficult to now argue that cashiers' booths need to be 7 inches (18 centimeters) or more above the floor to function properly.

Typically, the door is located on the side of booth that is next to the car lane, and the cashier steps up into the booth. However, as all cashiers' booths (since ADAAG 91 was effective) must be accessible to and through the door, the doors may have to be moved to the end of the booth, with a ramp from the pavement elevation up to a landing at the door. Alternatively, the booth may be recessed, and/or the interior floor may be removed, so that the floor inside is at the same elevation as the driving lane outside.

The recommendation that 5 percent of workstations be fully accessible has been dropped from ADAAG 2004 and replaced by an advisory which recommends (but does not require) that all employee work areas be fully accessible wherever it is possible. Nevertheless, in a facility with multiple booths, there is little risk that multiple employees working on a single shift would require a fully accessible booth. If an owner is willing to accept the risk of replacing booths in the future, it seems reasonable to make the first booth at each facility fully accessible, and to make the remaining booths accessible to and through the door, unless there are more than 20 booths.

CONCLUSION

Because the ADA is a civil rights law, the DOJ—and, ultimately, a federal judge—determine if the physical features of a building discriminate against people with disabilities. In practical terms, this means that advice from designers and/or the approval of designs by local building officials does not protect a building owner from being sued or cited by the DOJ for discrimination. It is important to note that ADAAG contains many gray areas that are subject to interpretation by the DOJ. In this respect, ADAAG differs from building codes, which have traditionally been interpreted quite strictly: if the code does not expressly require something, then it is not required.[13] Because of the complexity of the situation, designing for accessibility means relying on both the designers' professional experience in interpreting the many gray areas of the guidelines, and on the owner's involvement, to make decisions that may carry risk.

NOTES

1. Architectural and Transportation Barriers Compliance Board (ATBCB), *Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities; Final Guidelines*, 36CFR, Part 1191 (Washington, D.C.: ATBCB, 1991); published in the *Federal Register* July 26, 1991. An updated copy, as amended through 2002, is available at www.access-board.gov/adaag/html/adaag.htm.
2. ATBCB, *Uniform Federal Accessibility Standards* (Washington, D.C.: ATBCB, 1984); available at www.access-board.gov/ufas/ufas-html/ufas.htm.
3. ATBCB, *Technical Bulletin: Parking* (Washington, D.C.: ATBCB, 2003); available at www.access-board.gov/adaag/about/bulletins/parking.htm.
4. ATBCB, *ADA and ABA Accessibility Guidelines for Buildings and Facilities* (Washington, D.C.: ATBCB, 2004); published in the *Federal Register* July 23, 2004, and amended August 5, 2005; available at www.access-board.gov/ada-aba/final.htm.
5. IBC/ANSI A117.1-2003 (*Accessible and Usable Buildings and Facilities*) contains the technical requirements for how to make each required element (e.g., a parking stall) accessible. IBC 2004, the full building code, contains the scoping requirements (how many elements must be accessible), and is the first version of the IBC to require compliance with A117.1-2003.
6. U.S. Department of Justice (DOJ), 28CFR, Part 36, Nondiscrimination on the Basis of Disability by Public Accommodations and Commercial Facilities, Final Rule. Subpart A, 36.103 (d).

7. United States Access Board, *ADAAG Frequently Asked Questions Web Site*, "Question no. 18"; available at www.access-board.gov/adaag/about/FAQ.htm#mr1.
8. DOJ, *ADA Guide for Small Business*; available at http://www.ada.gov/smbusgd.pdf.
9. Title I only requires changes to employee-only work areas existing as of January 1992, if and when an employee needs the improvements.
10. DOJ, *ADA Business Brief*, http://www.ada.gov/restribr.pdf.
11. ATBCB, *Technical Bulletin: Parking*.
12. ATBCB, "ADAAG Requirements for Detectable Warnings," March 2003; available at www.access-board.gov/Adaag/dws/update.htm.
13. It is also worth noting that many of the cases brought by the DOJ and resolved by consent agreements have required owners to go beyond a "minimalist" interpretation of ADAAG and the advisory materials provided by the ATBCB.

CHAPTER 10

The Architecture of PARKING

J. RICHARD CHOATE

UNLIKE MANY OTHER BUILDING TYPES, parking facilities are conceived from the inside out. Good parking design respects the need for proper function. Whereas architects have the ability to rearrange the functional space in most other building types to achieve a desired shape, form, or exterior expression, this is not the case with parking buildings, which are dimensionally unforgiving. For this reason, architects must have a firm understanding of the key overriding issues in parking structure design. Parking geometrics, vehicle dimensions, turning radii, and ramping, for example, have very precise dimensional requirements. Once the architect has ensured that the design meets functional requirements, there are a multitude of aesthetic choices to be considered. Parking facility design is very much a specialty, requiring specific expertise in parking architecture.

This chapter examines many of the challenges that designers face:

- ▷ designing for users;
- ▷ addressing the large scale of parking structures;
- ▷ dealing with ramp placement;
- ▷ designing for how users spend time in a facility; and
- ▷ balancing the needs of pedestrians and drivers.

While many of the topics touched on in this chapter are elaborated in other chapters, this chapter is intended to serve as an introduction to the ways in which various architectural elements work together to form aesthetically pleasing, efficient, and functional parking buildings.

DESIGNING FOR USERS

At the core of good design is the interface between the user and the building. The quality of design can best be assessed by how well the user is able to interact with,

The facade of a parking garage must fit in with its surrounding urban context. With space for 456 cars, the Midnight Rose Parking Structure in Cripple Creek, Colorado, hides its six levels of parking behind the preserved facade of a historic building.

identify with, and use the building. Therefore, high-quality design hinges on understanding the user.

Buildings, whether they are specialty retail spaces, entertainment venues, restaurants, or health clubs, to name just a few, cater to a specific subset of people and are based on specific needs. When parking structures are paired with single-use buildings or are intended to serve a specific clientele, they can be specifically designed to better aid the intended user group. For example, as discussed in Chapter 9, "Accessibility and the Americans with Disabilities Act," hospital parking facilities require wider spaces so that users with disabilities can more easily get into and out of their cars. As another example, a well-appointed space dedicated to valet parking can be a major tool in attracting high-end shoppers.

Whereas a single-use building may be geared to a specific type of user, the parking building for a mixed-use district must be designed for a wide range of users. For example, it must appeal to the trend-conscious teenager who has come to buy the latest fashions at the hip new clothing store, as well as to the mother of four in search of school clothes, who is trying to maneuver the car, console a crying baby, and referee an argument among her other children.

In addition to knowing who the user is, it is important to know which perspective to design for. There are three primary perspectives to consider when designing a parking building: the perspective from a vehicle that is driving parallel to the facility, the view (either as a pedestrian or as a driver in a vehicle) from across an intersection, and the perspective of a pedestrian walking next to the building.

Since it is usually not economically feasible to embellish an entire parking building, the best approach is to establish visual priorities. The pedestrian core presents a good opportunity

CHOATE PARKING CONSULTANTS, INC.

When establishing visual priorities for the design of a parking facility, it is important to emphasize the pedestrian realm.

for such a design focus. For example, to create a more user-friendly experience, the designer might introduce contrasting materials (such as a limited use of masonry and stone) and use pedestrian-scale components (such as trellises; fenestration that employs glazing or scrims; and color, texture, and composition). The experience of a pedestrian walking next to a parking building can be further enhanced by the proper use of landscaping, hardscaping, canopies, and elements that announce both vehicular and pedestrian entrances and exits.

ADDRESSING THE LARGE SCALE OF PARKING FACILITIES

Parking buildings can usually be placed into two general categories: the "cornfield" context and the "urban" context. The cornfield facility is freestanding and sits on an open site with nothing around it. These facilities can seem massive unless they have visual buffering or a well-thought-out facade. The urban facility, as the name suggests, is situated in a higher-density environment, and requires sensitivity to and integration with its surroundings. Combining a mix of uses—such as office, commercial, residential, and retail spaces—with urban-context parking can create opportunities to reduce the large perceived scale of the parking facility and to more thoroughly integrate the facility into the community.

Parking buildings are large, and a key means of architecturally softening these structures is through three-dimensional relief; in fact, because the cost of embellishing parking facilities with anything very elaborate is often prohibitive, making do with the three-dimensional elements inherent in the building's

The Nutwood Garage at California State University–Fullerton

The Nutwood Garage, at California State University–Fullerton, illustrates how the large size of parking buildings can be broken up. The project features building elements that define pedestrian and vehicle entrances, eliminating the need to rely heavily on wayfinding graphics. The experience of the parking guest is one of openness, light, clarity, and ease of movement. This budget-conscious and award-winning design integrates fast-growing bamboo on two of its sides, along with a "green screen" to embrace the surrounding community. Thoughtfully placed vertical circulation cores and carefully detailed stairs create movement through the building. Canopies successfully frame views and break down the very large structure into a series of vignettes.

CHOATE PARKING CONSULTANTS, INC.

The Nutwood Garage at California State University-Fullerton.

systems and components is a must. Generally, the parking designer's palette includes landscaping, facade treatments, feature elements (such as stairs or elevators), and prominent components like shear walls. In addition, the designer must take into account the surrounding buildings. It is the careful juxtaposition of these elements in the palette that determines the basic design of these large structures. Breadth, depth, setbacks, and landscaping are the building blocks of both the aesthetic and functional design of parking facilities.

Facade embellishment for a parking building must be appropriate to the facility's context (whether urban or cornfield), in order to maintain the integrity and cost-efficiency of a project. Responding to the vernacular of adjacent buildings can be helpful. Taking advantage of the beauty of the repetition inherent in a parking building may be essential. Contrast, texture, tone, and color—especially control of shade and shadow—can yield an effective vocabulary for the architecture of parking buildings.

Thinking in terms of classical architecture can also be very inspiring for the parking designer. In classical architecture, facades were composed in a tripartite organization, consisting of a base, a middle (or field), and a top (or cornice). The beauty of tripartite organization can easily be applied to the design of parking buildings. The parking facility's exterior should be well-proportioned, and should be framed by a strong base and a graceful top. Much as the base, middle, and top break up the vertical expanse, other elements enhance the horizontal. Elevator towers, stairs, and shear walls, for example, can provide such opportunities.

DEALING WITH RAMP PLACEMENT

One of the most challenging aspects of parking design is how to treat the ramp as an architectural component. Often, the designer's first response is to place the ramp within the interior of the facility, concealing it from outside view. Because buildings are typically level and the eye is used to embracing the horizontal, an exterior parking ramp can be a jarring departure from what is expected. Therefore, exterior ramps can undermine users' acceptance of a building. This issue is significant because there is a functional value in locating the ramp on the facility's perimeter: a perimeter ramp maximizes the flat floor area and keeps it uninterrupted, thereby generating a more secure interior environment. An outside ramp can thus produce economy, efficiency, and openness.

Center ramps break up the parking floor and create barriers for pedestrians who are attempting to walk from their

Themed Entertainment Parking Building in Anaheim, California

Many parking facilities around the country have successfully created a sense of arrival. One example is the Themed Entertainment Parking Building in Anaheim, California. Despite its extremely large scale, guests are able to navigate this building with ease, thanks to its large, open areas and clear sense of destination for the pedestrian. Lighting and audio are employed to signal a guest's arrival. The building's qualities, all of which are intended to assist in wayfinding, include design sensitivity, use of color, and the incorporation of familiar icons.

WALKER PARKING CONSULTANTS/PHOTOGRAPHY BY STANDARD WWW.STANDARDSITE.COM

The Themed Entertainment Parking Building in Anaheim, California.

Metro Pointe, in Costa Mesa, California

Metro Pointe, in Costa Mesa, California, offers an example of design that facilitates wayfinding. This two-level, trapezoidal parking building is surrounded on three sides by retail stores, restaurants, and entertainment venues. In an approach that is unique to this structure, pedestrian circulation on each level is oriented toward one of the three uses. On the lower level, pedestrian movement is oriented along an east-west axis to serve the big-box retail stores on the east side and the entertainment and restaurant venues on the west side. On the upper level, pedestrian movement is oriented along a north-south axis to serve the specialty retail stores to the north of the parking building.

CHOATE PARKING CONSULTANTS, INC.

Metro Pointe, Costa Mesa, California.

Elevator and stair cores in parking facilities are major focal points that demand careful consideration by the design team.

parking spaces to the elevator or the stairs. In contrast, maximizing flat, open areas makes the walk from the parking space to the destination easier. Visually, an open, unobstructed space is more comfortable and facilitates wayfinding throughout the project. Finally, ramps placed in the center complicate the structure, increase cost, limit opportunities to create repetition, and require more bulky concrete elements to resist seismic forces.

When evaluating the options for ramp placement, the architect must carefully examine the site, and should seek opportunities to use the topography to create access to parking levels. Most building sites have a natural slope, and a site's length and slope can have a significant positive impact on functional design. The natural conditions of the site can offset the degree of slope required and/or the length of the slope on ramps.

DESIGNING FOR HOW USERS SPEND TIME IN A FACILITY

It is commonly remarked that the users of parking facilities spend more time in the facilities as pedestrians than as drivers. Moreover, parking represents both the first and last impressions of a site, especially for the infrequent visitor.

To enhance the interior environment of a parking facility and to create a pleasing experience for users, the designer must pay careful attention to lighting and ensure that it complements the facility's other systems. Even a limited use of paint can achieve great results. Whether painted concrete or integral masonry walls are used, lighter colors reflect more light and can improve what can sometimes be an ominous space. Light surface colors make parking facilities appear more open, and make ceilings seem brighter and higher.

The elevator lobby is one of the greatest opportunities to architecturally enhance a parking building. Large, ground-level elevator and pedestrian lobbies can help separate the user from the parking areas. Despite limits on both size and cost, an elevator lobby can have a powerful impact on a parking facility. The wide range of options in lobby design include suspended ceilings with indirect lighting, glazed storefronts, walls embellished with multiple materials, colors, and a variety of floor types. Customer acceptance, and therefore the success, of elevator and pedestrian lobbies depends on limiting pedestrians' exposure to the vast, unfinished environment outside the confines of the lobby.

BALANCING THE NEEDS OF PEDESTRIANS AND DRIVERS

Parking buildings are transition zones in which parkers become pedestrians, and vice versa. For this reason, it is essential to plan for navigation into, out of, and through the facility, from the perspectives of both pedestrians and automobiles. One of the first steps in planning navigation patterns is to segregate vehicular traffic and pedestrian traffic, to the extent possible. Proper directional signage and segregated pedestrian pathways are desirable and may be essential, depending on the users being served. Good design should help pedestrians and vehicles anticipate one another. If resources are limited, the developer can choose to focus on the perspective of the pedestrian at the expense of other perspectives.

Designing for pedestrians—especially attempts to minimize intersections between foot traffic and street traffic—is a common design challenge. This component of parking design is important not only for user safety, but also for aesthetic success. Defining pedestrian movement in relation to vehicle movement must be part of the architectural expression. Some elements of the design vocabulary that can be used toward this end include lighting, bollards, hardscape texture and color, trees and plantings, canopies, graphics, and wayfinding cues.

As mentioned in Chapter 12, "Wayfinding," elevator and stair cores are important architectural opportunities. Often, these cores are designed as focal points or destinations that use strong architectural forms (such as accent lighting, material, and colors) to complement the surrounding buildings and community.

Similarly, doors present an important opportunity for the parking facility designer; one of the main differences between a parking building and regular buildings is the doors. For both pedestrians and drivers, the entrances and exits in the parking structure need to be an announcement. Entrances need to be appealing, and to indicate what lies on the other side.

While details like lighting and color are important, every element of the parking building needs to be given careful thought. Speed bumps, for example, may seem like a good way to minimize conflicts between drivers and pedestrians. But when aesthetics, ease of pedestrian movement, vehicle safety, flexibility, and code requirements are taken into account, speed bumps can be detrimental rather than beneficial. Further, accessibility requirements are very specific regarding irregularities in pedestrian travel surfaces.

In addition to impeding pedestrian travel, speed bumps can cause other significant problems. To ensure the durability of the concrete and to avoid slippery conditions (which can be created by occasional standing water), properly designed parking facility floors are not level. Instead, floors are typically sloped toward drains, which are located with consideration for headroom, structural needs, thermal expansion, fire protection, and electrical constraints. Speed bumps can interfere with the drainage that is critical to the functioning parking floor. Moreover, headroom clearances are designed for efficiency down to the inch—which means that a 6-inch (15-centimeter) speed bump can create chaos. And if all this is not enough, speed bumps can contribute to traffic accidents.

The concerns that apply to speed bumps can also be applied to wheel stops. Rarely necessary, these obstacles are a tripping hazard, a source of annoyance, and contribute to cleaning and maintenance concerns. They can also cause user injuries and vehicle damage.

When designing for physical accessibility, wheel stops and speed bumps are just the tip of the iceberg. Parking architects need to understand the profound influence of the Americans with Disabilities Act (ADA) on parking facility design. There are numerous examples of facilities that were already in the later phases of design when it was discovered that they did not comply with ADA design requirements. Good architectural solutions must consider these requirements at the conceptual stage and properly anticipate them during the functional analysis and design phases. (See Chapter 9 for more details on the ADA.)

CONCLUSION

With a use and function very different from other building types, parking facilities present many challenges for parking architects. The issues presented in this chapter—identifying users, addressing the scale of parking buildings, dealing with ramp placement, designing for how users spend time in a facility, and balancing the needs of pedestrians and drivers—illustrate the level of care that needs to be taken in creating parking that is both functional and attractive.

CHAPTER 11

Structural SYSTEMS

GARY CUDNEY, VICTOR IRAHETA, AND JOHN PURINTON

THE STRUCTURAL SYSTEM SELECTED FOR A PARKING FACILITY will affect the construction cost, the project schedule, long-term maintenance, overall durability, appearance, and the patron's experience. Hence, it is essential to select the most appropriate structural system for the needs of a given project. The owner/developer and the design team should carefully evaluate the project-specific advantages and disadvantages of each type of system before making a choice.

The most widely used structural systems in the United States are precast concrete, cast-in-place post-tensioned concrete, hybrid (a combination of precast and cast-in-place), and steel. There are many factors to consider when selecting a structural system: initial cost, life-cycle cost, maintenance requirements, the availability of materials and labor, knowledge or preference of local contractors, construction schedule, intended use (for example, whether it is a stand-alone facility; whether it is above or below grade; whether it is a mixed-use facility with integrated retail, commercial, or residential uses). Options for structural systems should be examined as early as possible, preferably during the early stages of the schematic design phase.

A thorough understanding of the program goals and a detailed comparison of the available systems will help the owner and the design team select the most appropriate structural system. It is not unusual for two or three different systems to be appropriate for a given project. When this is the case, the experience of the design team, contractor, or project owner will usually tip the scales.

This chapter provides a brief history of structural systems, describes the most commonly used systems and their advantages and disadvantages, explains how designers choose structural systems, and examines issues that planners and designers need to keep in mind as a project develops.

BACKGROUND ON STRUCTURAL SYSTEMS

Most early parking structures, some of which are still in operation, used short-span construction, which was typified by large columns with massive capitals, and flat slabs or waffle-slab floor systems. Other early facilities were constructed with steel frames and concrete decks. In the mid-1950s and early 1960s, the advent of precast pretensioned concrete and cast-in-place post-tensioned systems made long, shallow-depth spans both possible and economical. As it became clear that long-span construction improved parking efficiency, long-span structures—which, today, typically span 55 to 62 feet (17 to 19 meters)—became the norm.

PRECAST CONCRETE SYSTEMS

Most precast concrete structures consist of precast concrete columns that support precast beams and spandrels—which, in turn, support precast deck members. Precast structural systems are typically named after the type of precast deck member: examples include the double-tee structure, the single-tee structure, the hollow-core system, the pretopped system, and the precast joist system.

The double tee is by far the most common precast structural system used today. A double-tee slab system consists of tee-units that are eight, nine, ten, 12, or 15 feet (2.4, 2.7, 3, 3.6, or 4.7 meters) wide that span between supports. Today, the most typical double tees are either ten or 12 feet wide, and have a horizontal floor element—the flange—which is supported by two beam elements called stems. The double tees may be manufactured using hard rock (normal-weight) or lightweight concrete, and come in two forms:

▷ a pretopped unit, which has a four-inch- (ten-centimeter-) thick flange; and

▷ a field-topped double-tee system, which has a two-inch- (five-centimeter-) thick flange prepared in the plant to receive a three-inch- (eight-centimeter-) thick hard-rock concrete topping that is cast on top of the double tees in the field.

Normal-weight concrete topping is preferable to lightweight concrete because it improves the durability of surfaces subject to vehicle loads. The depth of double tees is governed by the span, the width of the members, design loads, and availability.

The typical double-tee floor system is supported at the perimeter by either L-beam spandrels or pocketed spandrels. A typical precast interior framing system consists of columns

Selection of a Precast Concrete Structure

A municipality that required additional downtown parking decided to build a parking structure on a city-owned parking lot. The parking lot was in the heart of the retail and entertainment area, and the loss of parking during the construction period was a concern to business owners, patrons, and the city.

Because precast pieces are fabricated off site, then shipped to the site for erection, a precast concrete structure offered a shorter on-site construction period. In addition, there were several precast-concrete manufacturers in sufficient proximity to the site to allow the city to obtain competitive prices. The slightly shorter on-site construction schedule and the competitive first costs led the municipality to select a precast concrete structural system.

CARL WALKER, INC.

The VanBuren Street parking structure in Naperville, Illinois, was constructed with precast concrete.

CARL WALKER, INC.

Consisting of tee units that are eight, nine, ten, 12, or 15 feet (2.4, 2.7, 3, 3.6, or 4.7 meters) wide, the double tee is the most common precast structural system used today.

plus inverted tee-beams and load-bearing walls (called lite walls or ladder walls, depending on the shape and spacing of the openings), preferably with large openings for visibility and passive security. In parking facilities, lite walls or ladder walls are employed at the transitions from sloping bays to flat bays, to support the double-tee stems at differing elevations.

Single-tee systems are seldom used today because double tees are more economical and easier to erect. Single-tee units vary in width from six to ten feet (1.8 to 3 meters), and in depth from 24 to 48 inches (61 to 122 centimeters), depending on span and loading conditions.

A hollow-core slab, a shorter-span precast system with less depth than a double-tee unit, consists of a precast concrete plank with a hollow core. Hollow-core units are manufactured in sections that are four to eight feet (1.2 to 2.4 meters) wide and six to 12 inches (15 to 30 centimeters) deep. Deeper hollow-core units have been used for 60-foot (18-meter) clear spans. In regions where temperatures fall below freezing, holes must be drilled or cast in the low ends of hollow-core units, to prevent water from accumulating in the cores. Typically, hollow-core planks are overlaid with a cast-in-place topping, and joints are tooled into the topping above all the joints between adjacent planks or beams. In addition, all joints must be sealed; and, because this type of structure is prone to leaking, the application of a traffic-bearing membrane is highly recommended.

Pretopped precast systems, which minimize or eliminate the need for a field-cast topping, have gained wide acceptance because of their speed and economy. One type of pretopped precast system incorporates cast-in-place concrete pour strips at the ends of the tees, which allow the diaphragm steel to be put in place in the field and create "washes" that keep water away from critical joints. Other pretopped precast systems function without any field-placed concrete.

The top surface of the pretopped tee should have a medium broom finish for slip resistance. The joints between precast members must be sealed with a high-quality sealant to prevent leakage. Because the joints between pretopped double tees are generally wider than those in field-topped systems, there is more sealant to replace as part of the routine maintenance that is required to keep the joints in pretopped systems from leaking. Differences in camber between adjacent tees may also cause a more noisy drive and make the flange-to-flange connections more difficult.

Field-topped systems generally have a much smoother ride than pretopped systems. Even though the topping involves an additional trade and thus affects the speed and cost of construction, field topping offers two main advan-

Selection of a Cast-in-Place Post-Tensioned Concrete Structure

An airport needed to construct a very large parking structure with a number of special requirements, including the following:

▷ Construction in phases: Phase II would be built on top of Phase I, which would be designed to accept the loads from the vertical expansion.
▷ An automated people mover would run through the parking deck and connect with the terminal.
▷ Offices and "quick turnaround" areas for rental cars (car wash, gas pumps, and cleaning) would be located inside the parking structure.
▷ A two-story plaza, including the parking offices, would be constructed over the exit lanes.
▷ Circular helix ramps would be used for vertical floor-to-floor circulation.

After comparing structural systems, the airport selected cast-in-place post-tensioned concrete for the structural system for the following reasons:

▷ Lower first cost and life-cycle costs.
▷ Less maintenance, especially considering that cars park nights and weekends at airports, making it difficult to maintain floor sealants.
▷ Interior openness.
▷ Circular helixes are more easily constructed of cast-in-place concrete.
▷ The vertical and horizontal expansion would be easier with cast-in-place concrete than with precast.

WALKER PARKING CONSULTANTS, INC.

Cast-in-place post-tensioned concrete was used in the construction of the parking structure at Tampa International Airport in Tampa, Florida.

tages: it reduces the amount of sealant needed at the tee-to-tee joints, and it offers opportunities to smooth out the differences in camber between adjacent tees, which can not only affect the ride but also affect drainage. In regions of high seismic activity, field-topped concrete is preferable to pretopped; however, the topping may have to be much thicker than the standard two or three inches (five or eight centimeters), in order to accommodate the reinforcing steel required to tie the floor diaphragms together.

A precast joist system typically includes deep joists that clear-span a bay and are supported by precast concrete columns. When, the joists support cast-in-place floor slabs and provide some of the shoring required during construction, it is referred to as a hybrid precast system. Joists can be spaced from ten to 25 feet (three to 7.6 meters) on center and can range from eight to 30 inches (20 to 76 centimeters) in depth. The cast-in-place floor slab is typically post-tensioned.

CAST-IN-PLACE SYSTEMS

Cast-in-place concrete systems were developed before precast concrete became an economically competitive option. Cast-in-place systems include two-way flat slabs, pan-joist systems, slab-beam-girder systems, and dropped-beam construction. These systems rely on conventional or post-tensioned reinforcement.[1] In parking structures, cast-in-place post-tensioned construction offers considerable flexibility, with almost no limit to the variety of shapes that can be formed.

A two-way flat-slab structure requires less structural depth than a precast structural system and thereby minimizes floor-to-floor heights. However, this short-span construction requires a large number of columns, which typically fall between parking spaces—reducing parking efficiency, impeding users' comfort, and constraining future re-striping options. A flat slab can be conventionally reinforced or post-tensioned. Today, a two-way flat-slab system is generally only used

WATRY DESIGN, INC./MATTHEW MILLMAN PHOTOGRAPHY

The Community Hospital of the Monterey Peninsula offers parking in a cast-in-place post-tensioned structure.

when the parking structure is beneath another use, such as an office, a hotel, a plaza, or a residential building.

A pan-joist system is sometimes referred to as flat-soffit construction or waffle-slab construction; when the design requires the beams to be deeper than the joists, the system is often called a dropped-beam system. The pan-joist system uses steel or fiberglass pans, approximately 30 inches (76 centimeters) wide, which are placed on designated centers, producing a joist of a certain width. If the pan depths are increased, the joists can span 60 feet (18.3 meters) or more. The system may also use shallow pans, ten to 12 inches (25 to 30 centimeters) deep, which extend between long-span girders. The slab cast on top of the pans varies from two to five inches (five to 13 centimeters) in thickness, depending on structural requirements and local fire codes. It should be noted that in regions where salt is used, the pan-joist system's thin slab is particularly susceptible to cracking, corrosion, and deterioration because of the small amount of concrete cover over the top reinforcement steel, and is therefore seldom used today.

Two-way post-tensioned cast-in-place slabs are more watertight than two-way conventionally reinforced slabs. Because post-tensioned concrete introduces compression

Grade-Level Retail and Parking beneath a Building

A developer who wanted to maximize the return on investment for a valuable piece of property in an active redevelopment area decided to build a mixed-use project that would satisfy both parking demand and the demand for restaurant/entertainment venues and residential condos. The project includes three levels of underground parking, four levels of above-grade parking, a grade-level restaurant, and three stories of condos on top. A cast-in-place post-tensioned structural system was selected to integrate the various uses and to accommodate above- and below-grade construction.

CARL WALKER, INC.

In order to integrate parking, retail space, and residences in the 1890 Wynkoop Building in Denver, a cast-in-place post-tensioned structural system was used.

CARL WALKER, INC.

The slabs in a structural steel system may be either precast or cast-in-place. Pictured here is a steel-framed parking structure with a cast-in-place post-tensioned slab.

forces, it reduces the tendency toward cracking and produces structures that are relatively watertight. In today's parking structures, the most common use of cast-in-place concrete is in the form of columns that support long-span post-tensioned beams—which, in turn, support one-way post-tensioned slabs. To control the shrinkage cracking that can occur in response to drying concrete or temperature changes, the slabs should also be post-tensioned in the direction transverse to their span.

STRUCTURAL STEEL SYSTEMS

A structural steel system has steel columns, beams, and girders, with a concrete slab spanning between the beams. The slab may be precast or cast in place. Steel structures can be adapted to short or long spans, depending on design requirements.

The combination of long-span steel beams and composite concrete floor slabs has made inroads in the parking structure market. In composite construction, steel beams are connected to the concrete slab above them so that the slab and beam act as a unit, resisting bending and deflection—the extent to which the floor sags due to its own weight and the weight of parked vehicles. The benefits of composite steel construction can be obtained not only with cast-in-place slabs but also with various types of precast floor members. High-strength steels have reduced the required tonnage for long-span steel structures. Another system, called a hybrid steel system, consists of steel beams and columns, with precast double tees as the deck members. Whether composite construction or a hybrid system is used, preventive measures should be taken to ensure fire safety and to guard against the corrosion of unprotected steel.

Selection of a Steel-Framed Structure

A hospital required additional parking and decided to build a parking structure on a parking lot. The loss of parking during the construction period was a concern, so speed of construction was a priority, as was minimizing the first cost.

Because the precast manufacturers in the area were very busy, their prices were high. And the high cost of union labor would have made a cast-in-place structure too expensive. To obtain the lowest first cost and to meet an aggressive schedule that would minimize the disruption of parking, the hospital chose a steel-framed structure with a cast-in-place post-tensioned floor slab.

CARL WALKER CONSTRUCTION, INC., AND CARL WALKER, INC.

The Winthrop-University Hospital employee parking facility in Mineola, New York, has a steel-framed structure with a post-tensioned floor slab.

Cast-in-place post-tensioned concrete slabs with a steel frame may sometimes be preferable to a precast double-tee floor because the slab is monolithic and therefore has less potential for leakage; cast-in-place slabs also create a more open feeling in the structure, with higher perceived headroom, better visibility for signage, and more uniform lighting distribution. However, the cost and scheduling advantages of precast floors may be the determining factor in some situations.

Composite metal deck (or any other type of metal deck) is generally a poor choice for forming cast-in-place concrete flooring in steel parking structures: because the slabs are not post-tensioned, they are prone to cracking. This can cause water to become trapped between the slab and the metal deck. Holes in the metal deck may help, but corrosion will still occur, with no outward indication of problems until they become serious.

Steel bar joist systems generally consist of a relatively thin concrete slab over a light-gauge metal-form deck, with closely spaced bar joists supported by steel girders. Although this system is well suited for general office and retail uses, it is not desirable for the load levels and exposure characteristic of a parking facility. Also, when bar joist floor systems are subjected to the high point loads of vehicle wheels, they tend to exhibit undesirable deflections that cause the thin slabs to deteriorate.

COMPARISON AND SELECTION OF STRUCTURAL SYSTEMS

The selection of a structural system is usually based on an analysis of available options that considers the following:

- ▷ owner preference;
- ▷ first cost;
- ▷ life-cycle cost;
- ▷ availability of materials and labor;
- ▷ construction schedule;
- ▷ safety, security, and user comfort; and
- ▷ fire resistance.

The analysis of structural systems often concludes with the development of an evaluation matrix. The project team then scores individual factors, perhaps weighting some factors higher than others. The highest-scoring system is typically selected for the project. See page 110, "Advantages and Disadvantages of Structural Systems," for a summary of the pros and cons of each type of structural system.

Owner Preference

Owners are often familiar with the various options for structural systems and may favor a particular system. An owner who has analyzed systems in the past or has had positive or negative experiences with particular systems may favor a particular choice.

First Cost

The first cost (or construction cost) of various systems can vary significantly. Although first cost alone is not necessarily the best basis for comparing systems, owners are sometimes willing to exchange lower first cost for higher operating and maintenance costs and a shorter service life.

Life-Cycle Cost

Life-cycle cost, a widely accepted measure of total system cost, includes all costs related to the structural system that are expected to be incurred over the life of a structure, including first cost, operating costs, and maintenance costs. The assumed life span of a parking structure varies, but designers often use an expected life of 50 years.

In the calculation of life-cycle cost, all costs are projected over the same time period, transformed into present-value costs, and compared. Several software programs developed in recent years compare life-cycle cost estimates for various structural systems.

Life-cycle costs are particularly important when comparing precast and cast-in-place systems because precast systems often have a lower first cost, but a higher maintenance cost. Reducing life-cycle costs and increasing service life are also important considerations when developing a sustainable "green" parking structure.

Availability of Materials and Labor

Materials are not always available at all project locations. For example, if a project site is hundreds of miles from a precast plant, precast may not be economically competitive. Alternatively, local contractors may not have experience with post-tensioned concrete construction. And, as discussed in the next section, if precast plants are backlogged or contractors are busy with other projects, labor and materials may not be available when they are needed. A careful analysis of potential structural systems will take into account local circumstances that may affect options for labor and materials.

Construction Schedule

The selection of a structural system may be influenced by a number of factors, including the time of year that construction is slated to begin; weather conditions; and the availability of materials and labor (including, in the case of precast construction, the capacity and schedule of the facilities that produce precast concrete). Local preferences, construction customs, and the workload and skill level of available contracting companies may influence both the construction schedule and the choice of structural system.

Safety, Security, and User Comfort

A number of structural characteristics affect user safety and comfort:

▷ *The placement of interior walls and columns.* Users prefer parking structures that are easy to drive through, and that are unobstructed by walls or other concrete elements. Interior walls that block visibility and interfere with a sense of "openness" have a negative impact on user comfort and wayfinding.

▷ *The placement of shear walls.* Precast designs often incorporate shear walls that, if placed in the interior of the structure, can limit sight lines and create hiding places, which may in turn create real

Advantages and Disadvantages of Structural Systems

Precast Concrete: Advantages

▷ Precast members are fabricated at plants certified by the Precast/Prestressed Concrete Institute, so there is typically good quality control.
▷ In some regions of the country, the construction cost may be lower.
▷ The on-site construction schedule may be shorter.
▷ Allows for greater spacing—up to 300 feet (91 meters)—between expansion joints.
▷ More adaptable to winter construction.
▷ Spandrels on the facade also serve as structural load-bearing elements, which may reduce costs.

Precast Concrete: Disadvantages

▷ Because precast concrete structures have a greater propensity to develop floor leaks at the joints between tee flanges—which occur every ten to 12 feet (3 to 3.7 meters)—maintenance costs for sealants are higher, especially in pretopped decks.
▷ The tee stems (vertical elements) are closely spaced (five to six feet [1.5 to 1.8 meters] on center), creating the perception that the ceiling height is lower. The tee stems can also block the visibility of signage and interfere with lighting distribution.
▷ Shear walls and shear frames are used to resist wind and seismic lateral loads. When they are on the exterior of the structure, they affect the architecture; when they are in the interior, they create hiding places, reduce the number of parking spaces, reduce visibility and openness, and interfere with vehicular turning maneuvers.
▷ The warping of double tees may limit drainage slopes, because warping to the desired extent to ensure positive drainage may crack the double tees.
▷ More floor vibrations.
▷ More ledges where birds can roost.
▷ In many areas, precast may not be available.

Cast-in-Place Post-Tensioned Concrete: Advantages

▷ The floors slabs are monolithically constructed, which results in fewer sealant joints.
▷ Positive drainage will not be restricted by the warping of the slab that occurs in precast concrete.
▷ Floor vibration is generally imperceptible.
▷ Post-tensioning forces reduce cracking in slabs.
▷ Column spacing is more flexible than in precast structures, typically ranging from 18 to 27 feet (5.5 to 8.2 meters).
▷ Except in zones with a high risk of seismic activity or in very tall structures, there are generally no shear walls.
▷ Because there is less need for upkeep of joint sealant, maintenance costs are lower.
▷ Wider beam spacing creates the perception of greater headroom; increases the perception of openness and the visibility of signage; and allows more uniform lighting distribution.
▷ The system is more accommodating for unique structures with irregular shapes, and for circular helix ramps, underground parking structures, and parking structures built beneath other buildings.
▷ In many cities (although perhaps not in some smaller cities), construction can be handled by local subcontractors.

Cast-in-Place Post-Tensioned Concrete: Disadvantages

▷ Potentially higher construction cost in some regions of the country, particularly where costs are high for construction labor.
▷ Because of exposure to weather during construction, quality control is more difficult to attain.
▷ May require architectural cladding to improve exterior aesthetics.
▷ Slightly longer on-site construction schedule.
▷ Less adaptable to construction in freezing climates.
▷ Expansion joints are more closely spaced, increasing construction and maintenance costs.
▷ Tendons and rebar can be congested at beam-column joints.
▷ Slightly larger on-site staging requirements.

Steel-Framed Systems: Advantages

▷ Flexible column spacing of 18 to 22 feet (5.5 to 6.7 meters).
▷ Except in zones with a high risk of seismic activity or in very tall structures, there are generally no shear walls.

▷ In many cities, construction can be handled by local subcontractors.
▷ Construction is faster than with a completely cast-in-place system.
▷ Potentially lower construction costs.
▷ Easily accommodates vertical expansion.

Steel-Framed Systems: Disadvantages

▷ Potential problems during construction because of the coordination requirements for three types of contractors: foundation, steel, and precast.
▷ To protect against corrosion, steel must be painted and maintained.
▷ Delivery times for steel can fluctuate.
▷ Depending on project-specific factors and applicable codes, the steel structure may need to be fireproofed. Steel-framed structures are generally not recommended where the steel is required to be fire rated, because fire rating increases construction and maintenance costs and is aesthetically undesirable.
▷ The beam flanges create extensive ledges for birds to roost on.

or perceived security problems. Whatever the structural system, it is preferable to place shear walls at the perimeter; on the interior, it is desirable to use shear frames rather than shear walls. If precast shear walls must be used, they should include openings.

▷ *Vertical clearance and the spacing of beams.* Users prefer facilities that feel more open—that is, facilities that have a higher perceived vertical clearance from the floor to the bottom of the concrete beams. Vertical clearance and the spacing of beams also affect the visibility of signage and the distribution of lighting. The trend today is to provide more headroom: 8 foot, 4-inch (2.5-meter) clearances rather than the 7-foot (2.1-meter) clearances used in old codes.

▷ *Placement of columns.* Columns should be located so that they are not between parking spaces, which would interfere with door-opening clearance; do not impede vehicle movement into and out of the stall; and do not block the walking path between parked cars.

▷ *Vibration.* Excessive vibration affects user acceptance. In general, unless special measures are taken, the vibrations of cast-in-place systems will be less noticeable than those of precast systems.

▷ *Drainage.* Puddles of water caused by poor drainage and/or excessive deflection of structural floor elements affect both user comfort and the durability of the structure.

Fire Resistance

Structural systems must meet the standards for fire resistance set by building codes. Because some structural materials have better fire resistance than others, fire-resistance requirements play a role in the selection of structural systems.

OTHER CONSIDERATIONS

A number of other considerations may need to be taken into account in the selection of a structural system, including durability, sustainability, future expansion, the inclusion of ground-level commercial space, the construction of parking beneath buildings, column location and spacing, loading, lateral loads, expansion joints, and snow and ice.

Durability

Durability is critical in parking structures for several reasons: first, parking facilities are usually completely exposed to the elements (and, in some regions, to deicing salts); second, because the costs of repairing a deteriorating structure are high. Readers are strongly encouraged, at the beginning of the design process, to retain experts who specialize in the design of durable parking structures.

Important durability considerations include the following:

▷ Positive drainage, with a minimum floor slope of 1.0 percent (maximum 2 percent). This is a very important consideration: parking structures should not be designed with floor slopes that are lower than those recommended, even on covered levels.

▷ High-quality concrete manufactured according to strict requirements to prevent cracking, including the following:
- low water-cement ratio;
- the inclusion of a corrosion-inhibiting admixture;
- The inclusion of a high-range water reducer (super–plasticizer);
- low permeability;
- proper air content;
- the inclusion of high-quality aggregates to ensure resistance to alkali silica reaction;
- no chlorides; and
- adequate strength (no less than 4,000 pounds per square inch (psi) (27,579 kilopascals) for slab on grade, and no less than 5,000 psi (34,474 kilopascals) for supported slabs or toppings.

▷ Adequate rebar cover in the concrete.

▷ Proper concrete placement, finishing, and curing.

▷ Corrosion protection for rebar attained by using epoxy coating on conventional rebar and encapsulated sheathing systems for post-tensioning strands.

▷ High-quality joint sealants in tooled joints; no saw-cut joints on supported slabs or toppings.

▷ High-quality expansion joints.

▷ Use of penetrating sealers (such as silane) on the concrete floors.

Sustainability

Sustainable parking structures minimize environmental impact during construction and have greater efficiency and durability throughout their life cycle. Following the durability recommendations listed in the previous section may help a structure achieve points from a green building rating system. Additional structural characteristics that can help achieve sustainability goals include the following:

▷ the use of local or regional materials for aggregate, cement, and precast concrete members;

▷ the use of recycled steel for rebar or for the structural frame;

▷ the use of carbon-fiber reinforcement instead of steel wire mesh in precast tee flanges;[2] and

▷ replacing cement in the concrete mix with recycled fly ash, slag, or microsilica.

Future Expansion

Many new parking structures are designed for future expansion, either vertical or horizontal. Expansion not only has structural implications, but also affects architecture, functional design, and mechanical and electrical systems.

Vertical expansion most often occurs when there is limited land available and the owner/developer wants to meet the current parking needs or budget, while maximizing the future use of the site. Although future building weights, architectural features, and operational requirements can be effectively planned for, changes in building codes cannot always be predicted. As a result, planned vertical expansions carry an additional risk.

Plans for vertical expansion require that the foundation, the columns, and the systems designed to resist lateral loads be designed for the addition of floors. Other elements that must be considered include the following:

▷ the extension of columns and walls;

▷ the removal of spandrels;

▷ the extension of stair and elevator towers;

▷ crane access; and

▷ reshoring requirements for cast-in-place floor systems.

Beyond the structural implications, the following should also be considered:

▷ the appearance of the expanded structure;

▷ the method of expanding stair and elevator towers;

▷ the impact of the expansion on operations;

▷ the number of entrance and exit lanes needed in the expanded structure;

▷ occupant load of the expanded structure (for the design of code-required pedestrian means of egress);

▷ vehicular ramping capacity; and

▷ user acceptance of the ultimate height of the facility.

Horizontal expansion may be advantageous under the following circumstances:

▷ There is enough land available to meet current needs and to allow adjacent land to be reserved for the expansion.

CARL WALKER, INC.

The distance between plant and job site can be a factor in determining whether to use a cast-in-place or precast system.

▷ The disruption of operations associated with vertical expansion is unacceptable.
▷ The owner/developer wants to build up to the acceptable height limits in order to maximize the value of the land.

Ground-Level Commercial Space

The inclusion of ground-level commercial space is now common in parking garages—and, in the case of garages located in areas of high pedestrian activity, is desirable for two reasons. First, commercial frontages are more pedestrian-friendly than plain concrete garage facades, and add a measure of attractiveness to the parking structure. Second, the income potential (dollars per square foot) is generally far greater for commercial uses than for parking facilities. Many multilevel garages are located in areas of high commercial activity, or serve institutions such as universities or medical complexes. Therefore, it may be appropriate to incorporate ground-level commercial space that complements adjacent land uses.

There are a number of considerations to address when including commercial space, including the following:
▷ Fire-rating requirements in the commercial portion will differ from those in the parking facility. Further, the fire rating of the walls and floors that separate the two uses can be difficult to achieve at a reasonable cost.
▷ Waterproofing the floor above the commercial space to avoid leakage from the parking floor into the finished area. The owner will need to choose between a traffic-bearing membrane (which has a lower initial cost but a higher life-cycle cost) and a higher-grade waterproofing system (which has a higher initial cost and a lower life-cycle cost).
▷ Minimizing the transmission of vibration and noise from the parking area into the commercial space. This is especially critical

where vehicles cross an expansion joint. Precast structures tend to transmit more vibrations and noise than cast-in-place structures. In precast structures, decks with deeper double tees and thicker toppings are routinely used to address this issue.

Parking beneath Buildings

The high cost of land and the limited availability of developable sites in urban areas and on university and medical campuses are spurring the development of mixed-use projects—including those in which other uses—such as residential, office, medical, hotel, and retail—sit atop a parking structure. This trend has created challenges related to the structural system of the parking structure, including the following:

- ▷ Fire-rating and fire-separation requirements stipulated by building codes can be costly to attain.
- ▷ Lateral load resistance provided by shear walls and frames.
- ▷ The transition from one structural system to another may be an issue. For instance, the building may be constructed of steel and the parking structure of concrete. If the columns for the building do not align with those in the parking structure, a transfer level—including transfer girders or beams—may need to be constructed on the first floor of the building.
- ▷ The location of expansion joints must take into consideration the layout and function of both the parking structure and the building.
- ▷ Long-span construction is preferable for the parking—but, depending on the use positioned above the parking structure, this approach may not be cost-effective or functionally efficient for the building.

Column Location and Spacing

The use of long-span structural systems greatly improves the efficiency and cost-effectiveness of parking facilities. Whenever possible, designers should maximize the usable area by keeping drive aisles and stalls free of columns. Chapter 7 provides additional information on parking geometrics.

Loading Requirements

Loading requirements for parking facilities can vary from place to place; national codes are often modified to satisfy local conditions or the desires of local officials. In some cases, parking decks must be designed to support the weight of emergency equipment, such as fire trucks or ambulances, and/or delivery trucks. The available headroom and turning radii will also affect the type of vehicles that can enter a parking structure.

Even though the actual live load for a completely full parking structure ranges from 25 to 30 pounds per square foot (1.2 to 1.4 kilopascals), building codes typically require 50 pounds per square foot (2.4 kilopascals). However, most codes allow reductions in live load for some member types, such as columns.

In addition to accommodating the vehicular live load, parking structures must be designed for the code-required snow load. Designing for full snow loads plus full live loads might be excessive, however. A higher snow load should result in a lower vehicular live load because fewer vehicles can be parked in the snow. Thus, where the priority is to prevent the concrete from cracking, the roof level can be designed for full snow plus live loads for ultimate strength (applying code-required safety factors to ensure adequate structural capacity), but for a lower combined load for allowable stress design.

Lateral Loads

Although parking structures require special consideration in regions with high seismic activity, properly designed facilities have performed well during seismic events. The International Building Code's seismic design requirements have significantly affected the design of parking structures nationwide.

Cast-in-place post-tensioned parking structures generally employ moment frames to resist lateral loads caused by seismic activity or wind loads, while precast structures employ shear walls and occasionally precast moment frames. To maximize openness and visibility, precast shear walls often include large openings. The design of the floor diaphragm must consider (1) the possibility that there will be long spans between lateral load-resisting elements, such as shear walls, and (2) the impact of sloping ramps, which can break up the continuity of a floor diaphragm and may circumvent the energy dissipation of a moment frame system.

Diaphragm reinforcement must be continuous, and must properly transfer the lateral load to the lateral-load-resisting system. Framing members that are not a part of the lateral-load system must be connected to the lateral-load system and designed to support their loads under expected seismic drift.

Underground parking structures must be designed for lateral earth loads, which are usually supported either by cast-in-place cantilevered retaining walls or by basement walls that are braced by the structure.


CARL WALKER, INC.

To prevent leakage that can lead to costly deterioration of precast members, it is imperative that the caulk joints between precast tees be maintained.

Expansion Joints

The expansion and contraction of structural materials must be considered in the design of any structure, whether it is used for parking or for commercial purposes. Because steel and concrete expand and contract in response to temperature changes, if the temperature-related contraction exceeds the capacity of the structure or its connections, severe stresses can cause cracking and in some cases structural failure—unless the design incorporates appropriate mechanisms to allow for these movements. In a parking structure with two or more levels, it is not unusual for the top level to reach a surface temperature of 140 degrees Fahrenheit (60 degrees Celsius) on a hot summer day, then to cool down to 75 or 80 degrees Fahrenheit (24 or 27 degrees Celsius) at night. In cold climates, the winter temperature on the top level may drop to 10 degrees Fahrenheit (-12 degrees Celsius) or lower.

In most cases, changes in length are calculated based on published charts of temperature ranges, and the structure is designed to accommodate the anticipated movement. Once the amount of expansion or contraction has been estimated, the design must incorporate an allowance for the change in length. Care should be taken not to design physical restraints inside the structure and/or around the perimeter of the structure, as this can lead to cracking of walls, floor slabs, or other elements.

If a structure is too long to accommodate the temperature-induced movements and loads, then the design should incorporate an expansion joint. The type of structural system should be considered when spacing expansion joints. A cast-in-place post-tensioned structure requires closer spacing of expansion joints than a precast or conventionally reinforced cast-in-place structure. This is because a conventionally reinforced parking structure will relieve temperature strain by means of shrinkage cracks; in a precast structure, in contrast, the joints are positioned between individual pieces, so temperature-related strains are relieved through properly designed connections. However, a post-tensioned cast-in-place structure must be able to accommodate all changes in volume—including elastic shortening, creep, and shrinkage—without cracking. As a general rule, expansion joints in precast structures should be a maximum of 300 feet (91 meters) apart; in cast-in-place post-tensioned structures, expansion joints should be a maximum of 250 feet (76 meters) apart.

Structures that are completely below grade do not typically experience the temperature swings that above-grade structures do. As long as the initial shrinkage of the concrete is accounted for in the detailing, expansion joints may not be required for building lengths of up to 400 feet (122 meters). In fact, it may be detrimental to have expansion joints in below-grade structures, for two reasons: (1) the disruption of the floor diaphragm for transferring lateral earth loads and (2) the potential failure of the joints, which are costly to replace.

The spacing of expansion joints must be evaluated on a project-specific basis considering a range of factors, including the following:

▷ the location of the project;
▷ whether pour strips will be used;
▷ the degree of rigidity or restraint caused by structural or other elements, below or above grade; and
▷ the height of the first story.

In parking structures with larger spacing between joints, special detailing may be used to accommodate the movements; however, such detailing carries an additional cost, and is not the norm in the industry.

Once the width of the expansion joint has been calculated, the design and detailing of the joint follow. The material that will allow the joint to expand must be highly durable and capable of withstanding the weather conditions to which it will be subjected. The joint itself must be kept free of all extraneous materials and restrictions. If an electrical conduit or mechanical piping crosses an expansion joint, the conduit or piping must have expanding couplings.

An expansion joint should be completely sealed to prevent water leakage. When choosing a joint, the designer must be sure to take account of accessibility concerns for all users, including those with disabilities. When parking structures are irregular in shape, the expansion joints are not aligned at right angles; thus, they must be designed to account for movement in two directions and to accommodate "shearing" along the joint.

Snow and Ice

Snow is customarily removed from surface lots by plowing and stacking. Large amounts of snow should not be stacked on parking structures, however, because the excessive loads can damage the structure. When annual snowfall is heavy and there are few winter thaws, snow must often be hauled away to maintain the maximum parking capacity of a lot. If snow piles thaw on warm days and the runoff freezes at night, proper ice control measures must be used.

After a heavy snow, the roof of a parking structure should be blocked off, with no parking allowed until most of the snow has been removed. It is more difficult to remove snow from the roof of a parking garage than from an on-grade parking lot. Because there is a risk of exceeding the maximum floor load, large trucks cannot go to the roof: only lightweight, rubber-tired equipment should be used to haul snow from a roof. To minimize damage to sealants, expansion joints, and membranes, it is best to use a snowplow blade with rubber-tipped edges.

A number of methods have been devised to remove snow from garages. In one approach, the snow is plowed to the edge of the roof, and then dumped over the side of the building. Snow chutes can also be used to dump the snow over the side. (If the top parking level has wheel stops, however, snow removal is more difficult. And depending on the height of the rails, the roofs of parking structures may need to be outfitted with removable rail sections.)

Both the plowing and the dumping of snow can be done by a small front-end loader whose weight does not exceed the permissible floor load. To avoid impeding the movement of pedestrians and vehicles at grade, this method should be used only in garages that have adequate setbacks from sidewalks or alleys, and any dumped snow should be removed from the site as soon as possible. To protect landscaping and the building facade, it is advisable to create paved snow-dumping zones. A solid wall at grade level is also desirable, to prevent dumped snow from piling up and falling back into the lowest level of the parking structure.

Another approach is to create a snow-melting pit filled with water heated by steam or by hot-water coils. The snow is dumped or pushed into the pit, then drained into the sewer system. The pit can be built as part of the garage structure, or it can be portable. The bottom of the pit should have a drain with a shutoff valve. Because mud, dirt, and trash accumulate in the pit, it should be cleaned regularly. Some operators use a portable snow melter, so that it can be moved to different locations.

CONCLUSION

The structural system of a parking facility is a significant investment, often amounting to 60 to 70 percent of total construction costs. And the selection of a structural system is a complex process that must address a number of factors, including first cost, life-cycle costs, sustainability goals, desired ceiling height and column spacing, the availability of labor and materials, and aesthetics. Each type of system—precast concrete, cast-in-place concrete, and steel-framed systems—has advantages and disadvantages that may be of varying importance, depending on the owner's needs. Owners need to carefully evaluate available options to make informed decisions.

NOTES

1. Conventional reinforcement consists of steel rebar. Post-tensioned reinforcement consists of very high strength steel tendons. Once the concrete has been placed and attains the required initial strength, the tendons are pulled so that they apply a high tensile force.
2. This change is being promoted by an alliance of precast concrete manufacturers to reduce costs and because it is environmentally advantageous.

CHAPTER 12

WAYFINDING

VICTOR IRAHETA, FORREST HIBBARD,
STEPHEN J. REBORA, AND MATTHEW FEAGINS

A WELL-DESIGNED PARKING FACILITY IS AN OPPORTUNITY to create a good "first and last impression" for patrons. And a properly designed wayfinding system is an essential element in a well-designed facility. The benefits of good wayfinding are obvious: satisfied tenants will renew their leases, and patrons who find a parking facility easy to negotiate will become repeat customers. Staff will spend less time escorting or caring for lost or frustrated customers, and have more time to spend maintaining and operating the parking facility. Most importantly, increased patronage will increase revenues.

This chapter describes the basic principles of wayfinding and explains how those principles relate to parking facility design. It also provides guidelines for the design of signage and graphic systems to assist in wayfinding.

THE BASICS OF WAYFINDING

Wayfinding—a term introduced in the late 1970s—is a relatively new concept. It refers to the process of reaching a destination, whether that destination is located in a familiar or an unfamiliar environment. In a parking structure, the primary purpose of a wayfinding system is to guide patrons safely along a pleasant and efficient route made up of four segments:

- As a driver, from the roadway to a parking space located as near as possible to their destination.
- As a pedestrian, from the parking space to their destination.
- As a pedestrian, from their destination back to their parking space.
- As a driver, from their parking space back to the roadway.

Wayfinding can be thought of as spatial problem solving; it involves information processing, decision making, and the development of a plan of action. Fundamental to wayfinding is the creation of a cognitive map—an overall mental representation

Wayfinding starts on the street. Drivers must be able to recognize that a structure is a parking facility, and to easily locate the entrance.

of a setting that cannot be obtained from a single viewpoint. Patrons making their way through a parking garage create cognitive maps, and draw on the information in those maps in order to make and execute decisions about where to go and what to do next.

Most settings are laid out in a plan or shape that people can relate to, and that allows them to determine their location within the setting, recognize where they are in relation to their destination, and formulate a plan of action that will take them to their destination. People tend to feel disoriented when they (1) cannot situate themselves within a parking facility and (2) cannot develop a plan to reach their destination. Following the basic wayfinding principles can minimize this disorientation.

ENVIRONMENTAL DESIGN

Environmental design is a global approach to design that focuses on the natural environment of human interactions and responses. Simplifying the parking experience is a key component in creating a physical environment that can be both functional and adaptable. Architectural systems and functional design are integral to successful wayfinding. The design must help patrons make correct intuitive decisions, which are then reinforced by information they gather from what is around them. As patrons approach a parking facility, they form a mental image of the shape of the structure (circular or rectangular, number of levels, and so forth). As they circulate through the facility, they develop mental images of the interior layout. Repeatedly passing the elevator cores creates landmarks that organize patrons' mental image of the interior space. Ramping systems, which are mirrored on each level, assist in cognitive mapping by further reinforcing the mental image of the interior space. Thus, the environmental design of the space has as much to do with wayfinding as directional signage.

The functional characteristics of a parking facility—that is, its size, its organization, and the nature of its circulation systems—all work against or contribute to a patron's wayfinding. The following characteristics make wayfinding particularly difficult:

- *Poor visibility.* A number of factors—including low ceilings; poor lighting; sight lines that are disrupted by internal ramps; and views that are obstructed by columns, shear walls, or pipes—interfere with users' efforts to locate destination points and may even prevent them from forming a cognitive map.
- *Too many floors.* Structures with seven or more levels can compromise the user's perception of which floor they parked on, resulting in anxiety and frustration.
- *Large floor areas.* Floor areas with more than four parking modules (bays made up of a drive aisle and parked vehicles on either side) on each floor make it difficult to grasp or to recall the layout of the space.
- *Multiple vertical circulation systems.* Patrons tend to get confused in parking facilities that have more than one ramp between parking levels, or more than one stair or elevator tower.

Legibility versus Readability

In wayfinding design, *legibility* and *readability* are not interchangeable terms. Legibility refers to the ease with which information can be *perceived*; readability refers to the ease with which information can be *understood*. In other words, a sign may be legible without being readable.

Poorly designed signs cannot be understood because the information is obstructed, poorly located, too small, garbled, illegible, or too busy to be perceived. To avoid these flaws, the design team must understand and apply accepted graphic standards and be aware of the importance of content, placement, sight lines, sight distances, and lighting levels.

SPATIAL PLANNING

Spatial planning is another major component in wayfinding design. It provides the context for wayfinding and sets the stage for problem solving. It is during the spatial planning phase that the design team determines the location of a facility's entrances and exits in relation to major destinations; the organization of the facility's spaces; and the areas from which patrons will be able to see their destinations.

As noted earlier, good wayfinding enables parking patrons to find parking spaces, walk to their destinations, find their vehicles, and then return to the roadway system. By identifying paths of travel and decision points within each facility, designers can provide patrons with visual cues and the information they need at the right time, and in the right location.

ENVIRONMENTAL COMMUNICATION

Once the circulation system is determined, the design team can study each trip segment and develop a set of cues for navigating within each segment and from one segment to the next. Cues between and along trip segments—visual, tactile, architectural, and in some cases audible—make up the wayfinding system. The use of these cues to communicate to users where they are and where they want to go is called *environmental communication*.

The architectural features that identify the route to users' destinations should be designed to provide an intuitive path of travel. In other words, the layout should be in keeping with the users' most direct route to their parking spaces and to their final destinations. Whenever possible, signage should be placed near or on prominent architectural features (like stair and elevator towers), and should provide users with additional cues and directions as they move into, through, and out of the parking facility.

CONTENT AND LOCATION OF SIGNAGE

A parking structure that relies entirely on signage for wayfinding is likely to frustrate its users. Nevertheless, the content and location of signage are critical to ensuring smooth vehicular and pedestrian flow through a facility. In practical terms, this means that signage should convey a message to the user in a quick and easily comprehended format, and should be located at or slightly before decision points, such as intersections. Information that is provided too late may go unnoticed.

Use of the trip-segment approach facilitates the design of sign content and location. By imagining the driver's route through a facility, the design team can identify patrons' likely behavior or path of travel to and from each of the facility's primary destinations. The team can then focus on each decision point to determine the size, content, and placement of specific signs. To identify an acceptable location for a sign, the team must also take into account physical characteristics such as light levels, ceiling heights, aisle widths, and potential obstructions.

WAYFINDING IN PARKING STRUCTURES

While on the street, the driver must find and recognize the structure as a parking facility. The most important consideration is the vehicle entrance, which should be clearly identifiable to drivers, who may be dealing with many visual distractions. Canopies or portals placed perpendicularly to patrons' approaching path of travel are useful. Signs that indicate when a facility is full help drivers avoid unnecessary searching. Although it is highly desirable for the architecture of a parking facility to complement that of the surrounding area, the entrance to and exit from the parking facility should not be camouflaged or otherwise hidden, unless the project program requires it.

The facility's entrance area must be welcoming and well illuminated. Parking-control equipment should be situated to give patrons time to recognize its presence and react. Where exit or restricted lanes are located in the same area as entrance lanes, drivers need both signage and adequate sight distance to determine which lane to enter. It is best to avoid requiring drivers to make any choices immediately after entering the facility: driving into the structure for some distance before any further decisions are required helps drivers become acclimated.

Wayfinding depends largely on visual cues. A simple, easily understood traffic pattern that is repeated on every floor greatly eases decision making. Drivers should be routed past visual anchors, such as the main stair or elevator tower, shortly after reaching each floor. Visual anchors orient patrons and prepare them for the shift to the pedestrian mode. In large facilities, light wells and other architectural features may also serve as visual anchors.

The ability to see a destination across a parking floor is another component of wayfinding. For example, why are shoppers willing to walk relatively long distances across parking lots in suburban shopping centers, when they complain if they have to park around the corner from their destination in a downtown environment? The answer is that shoppers can see the shopping center entrance from the moment they leave their cars.

Factors that affect visibility include the parking facility's floor-to-floor height and the choice of structural system. For example, even with similar floor–to-floor heights, cast-in-place concrete parking facilities typically feel more open than precast concrete facilities, because of wider beam spacing. Wider beam spacing may also enhance other aspects of wayfinding: signage may be more visible because sight lines can be more direct, and lighting maybe more uniform because of fewer obstructions. Cast-in-place construction also results in more openness along bumper walls, both at exterior walls and along interior sloping ramps. When precast concrete is chosen as the structural system, the design team can improve sight lines by increasing the floor-to-floor height.

Concerns about security and wayfinding have led the parking industry to reduce the use of complicated, sloping-floor designs in favor of simpler layouts that maximize the number of spaces on flat floors. Particularly where a site is long, designers are maximizing the slope of ramps, minimizing the length of sloping parking floors, and increasing the number of parking spaces on flat floors.

DESMAN ASSOCIATES

At Baltimore/Washington International Thurgood Marshall Airport, wayfinding is assisted by a space-counting system that lets drivers know how many spaces are available on each level.

Minimizing the number of 360-degree revolutions along the path of travel has long been a priority for parking designers. Drivers have a tendency to become disoriented when the path of travel requires several turns.

Wayfinding is greatly improved when patrons' instinctive behavior can be reinforced. Thus, it is generally desirable to orient parking aisles toward the pedestrian destination—which, in a parking facility, is most likely to be the main stair or elevator tower. When bays are oriented transverse to the main route to their destination, pedestrians may be inclined to walk between parked vehicles, potentially causing security and safety problems. If pedestrian volumes are sufficient, dedicated pedestrian crosswalks may be created perpendicular to vehicle traffics flows to define the most direct path to stair or elevator towers. If crosswalks are provided, they should be aligned with the stair or elevator tower or the building entrances.

It is also important to minimize the number of decision points. The best parking circulation systems allow drivers to see all the spaces as they progress through a facility. When drivers are in the exit mode, however, they will prefer short driving circuits that minimize cross traffic and limit travel distance.

At some point, patrons might find themselves searching an excessive number of parking spaces to locate an available

CARL WALKER, INC.

CARL WALKER, INC.

Wayfinding at the 10th and Chestnut Parking Structure in downtown Philadelphia is aided by a system in which each level is named after one of Benjamin Franklin's "Seven Virtues."

CARL WALKER, INC.

space. In larger facilities, it is desirable to break the facility into smaller "compartments," and to provide express-ramp systems to speed users to another floor, where they can search a limited area for a vacant parking space. Depending on the size of the facility, another option is to create two (or more) structures with independent circulation systems.

Once the driver has found a space and parked the car, pedestrian considerations come into play. The first goal is to help patrons remember where they parked their cars by providing visual references or markers. Directly related to the size and configuration of the parking facility, wayfinding solutions for pedestrians are impacted by the location of vehicle ramps between parking levels. The ramp becomes a marker for pedestrians who are returning to find their parked cars. Other markers may include interior light wells that help to create parking zones within a larger parking block, designated pedestrian walkways, and mid-aisle vehicle cross-overs. Easy-to-remember signage and graphics, coupled with distinct imagery, will enhance the patron experience. The simplest solution is a high level of visibility across each floor.

Figure 12-1 presents guidelines for acceptable walking distances for different levels of service.[1] As in highway design, level of service is expressed as a grade ranging from A to D.

The proper location of stair/elevator towers in the overall path of travel relative to the user's ultimate destination is important. Just as pedestrians want to see the tower from within the structure, they use the tower as a beacon when returning to the parking facility. Accordingly, circuitous routes to and from towers should be avoided. Once patrons have retraced their route to the parking stall, they return to a vehicular wayfinding mode. The exit route should be equally simple and understandable, and

FIGURE 12-1: Recommended Design Standards for Wayfinding

Level of Service	A	B	C	D
Maximum walking distance within parking facilities (feet/meters)				
Surface lot	350/107	700/213	1,050/320	1,400/427
Structure	300/91	600/183	900/274	1,200/366
From the best parking spaces to the destination (feet/meters)				
Climate controlled	1,000/305	2,400/732	3,800/1,158	5,200/1,585
Outdoors, covered	500/152	1,000/305	1,500/457	2,000/607
Outdoors, uncovered	400/122	800/244	1,200/366	1,600/488
Floor-to-floor height (feet/meters)[1]				
Long-span, cast-in-place[2]	12.5/3.8	11.5/3.5	10.5/3.2	9.5/2.9
Long-span, precast	13.5/4.1	12.5/3.8	11.5/3.5	10.5/3.2
Percentage of spaces on flat floors	90	60	30	0
Slope of parking ramp (%)	5	5.5	6	6.5
Number of 360-degree turns to top	2.5	4	5.5	7
Maximum distance to a cross aisle in a parking bay[3] (feet/meters)	250/76	300/91	350/107	400/122
Distance to crossover (feet/meters)[4]	300/91	450/137	600/183	750/229
Number of spaces searched, or compartment size[5]				
Angled parking	400	800	1,200	1,600
Perpendicular parking	250	500	750	1,000

Notes

1. Minimum vertical clearance for van accessibility is 8′ 2″, which requires minimum floor-to-floor height of 11′ 0″ based on an assumed structure depth of 2′ 10″.
2. LOS D floor-to-floor height for long-span cast-in-place design (9′ 6″) is set by minimum 6′ 8″ overhead clearance, plus an assumed 2′ 10″ structure depth; most codes require a minimum clearance of 7′ 0″.
3. Only needed if the cross aisle shortens the path to the exit.
4. In one-way designs, drivers must continue on the inbound travel path before changing to the outbound path. This change from the inbound path to the outbound path is called a crossover.
5. The numbers represent the number of spaces a driver passes on the primary search path—or, where there is an express ramp, the number of spaces on each floor.

follow the shortest path of travel between the facility's parking spaces and the public roadway system.

CONCLUSION

Some parking facilities are labyrinthine structures that defy logic. Searching for the facility entrance from the street, finding a parking space within the facility, navigating pedestrian paths en route to one's destination, and locating one's vehicle upon returning from the destination—all can contribute to a less-than-positive experience. Good wayfinding helps ensure that bad memories are not what patrons take away when they leave a facility.

The overall objective of the wayfinding system is to provide a concise and informative series of messages that are understandable by the full range of facility patrons. Proper wayfinding design starts during the early stages of facility planning. A well-designed wayfinding, signage, and graphics program enhances a patron's parking experience. It also creates a positive image for the facility owner and operator, increases patronage and customer satisfaction, and may even help to create new opportunities for both owner and operator.

NOTE

1. For further information on the development and application of these guidelines, see Smith, Mary S., and Butcher, Thomas A. "How Far Should Parkers Have to Walk?" *Parking* (September 1994).

CHAPTER 13

Safety, Security, and SECURE DESIGN

RICHARD C. RICH AND RICHARD A. RICH

SAFETY PROCEDURES AND SECURITY MEASURES help protect patrons and staff from accidental injuries and criminal attacks. This chapter discusses safety and security measures and describes design strategies that can facilitate security.

SAFETY

One of the principal safety concerns in parking facilities is tripping hazards, which may be created by snow buildup, ice, oil or fluid spills, poorly maintained joints, surface spalling or cracking, potholes, debris, or wheel stops. Parking garage safety is largely a matter of proper maintenance—for example, removing accumulated snow from pedestrian pathways, deicing, routine inspection and repair of joints and floor surfaces, and cleaning floors of debris. When regular maintenance procedures are followed, most tripping hazards can be controlled. (Many maintenance issues that are related to safety are covered in Chapter 22). The following are additional safety considerations:

▷ Inspect automatic door openers to be sure that they are in good working order.
▷ To eliminate the possibility that pedestrians wil be struck by a vehicle or a descending gate, provide defined and/or dedicated pedestrian walkways that direct patrons safely out of the facility.
▷ Wherever possible, avoid wheel stops.
▷ To reinforce vehicle circulation and pedestrian pathways, use crosshatch markings on the floor.

SECURITY

Security measures are usually classified as active or passive. Active security measures, which include security patrols and the monitoring of closed-circuit televisions

THP LIMITED

Separating pedestrian paths from vehicular circulation patterns to the fullest extent possible can reduce the chances that a vehicle will strike a pedestrian.

(CCTVs), require human action. Passive security measures, which include lights, fences, and screening devices, do not normally require human action in order to be effective.

The goal of security measures is to create an environment in which potential perpetrators feel that they can be seen, sense that they will be caught, and realize that criminal activities are not worth the effort in this parking area. CPTED—crime prevention through environmental design—uses elements of facility design to prevent or thwart crime. Many of the measures described in this chapter are elements of CPTED.

When a parking patron is the victim of theft or a personal attack, the owner and/or operator of the facility may face a lawsuit alleging inadequate security. In the event of a lawsuit, security is typically evaluated according to a "reasonableness" test: would a reasonable person, under similar circumstances, have provided similar security measures? If a reasonable person would have employed more extensive security measures—or measures that would have been considered state of the art at the time the facility was designed and built—then the owner and/or operator may be held liable. If the security measures in place are equal to or exceed those that would have been undertaken by a reasonable person under similar circumstances, then the actions of the owner and/or operator are defensible.

The decision to implement security measures generally begins with an initial risk management assessment. This should be done during the design process, and periodic assessments should be performed once the facility is open and in operation. The assessment evaluates possible security issues and describes passive and active means of addressing them. The consultant in charge of the risk assessment is likely to do the following:

- ▷ Review the surrounding neighborhood to determine whether there is evidence of previous criminal activity, such as vehicle break-ins, theft, or crimes against persons. The risk manager will also contact the local law enforcement agency to obtain data on the extent of criminal activity.
- ▷ Review the capability of the owner/operator, to determine whether security needs can be met by existing staff or whether outside security is warranted.
- ▷ Review the design and layout to determine whether changes can be made that might improve security.
- ▷ Review signage and wayfinding.

The completed assessment will typically address issues such as the following:

- ▷ whether active security measures, such as foot patrols, CCTV, or voice-activated monitors are required—and if so, how such measures will be implemented; and
- ▷ the locations and security characteristics of cashiers' booths, payment areas, and the parking management office.

Active Security Measures

One of the best forms of active security is foot patrols. The patrols should occur throughout the operating day, but the routes and times should vary.

CCTV is an increasingly common approach to security in parking structures. If CCTV cameras are used, they should cover all parking floors, the vertical transportation cores, vehicular and pedestrian entrances and exits, the areas in the parking management office where payments are made, and where money is counted. Monitoring of the cameras is critical. There is a risk management issue if cameras are not monitored, because patrons have the expectation that someone is monitoring the facility at all times.

To ensure that staff remain alert, employees assigned to monitor the cameras should have regularly scheduled breaks, and other staff members should be available to continue monitoring the cameras during the breaks.

The following issues should also be kept in mind where CCTV is in use:

Landscaping along the perimeter of a facility should either be avoided or kept low enough that it does not provide cover for potential criminals.

▷ All cameras on parking floors should face in the same direction, so that staff monitoring the system can easily orient themselves.
▷ Cameras should be positioned so that they do not directly face morning or afternoon sun, or bright lights.
▷ Cameras should be adjusted to function properly under average light levels.
▷ In colder climates, cameras should be enclosed and heated.
▷ The monitoring room should be located in an area of high pedestrian traffic and should have as much glass as possible, so that people can see that they are being watched.
▷ Monitors should be set up to view four cameras at one time per monitor (this is known as a quad split screen arrangement); the monitoring room should also be equipped with a monitor on which the operator can pull up a larger view from any camera.
▷ Cameras must be monitored during all hours that the facility is open.
▷ CCTV cameras and digital video recorders (DVRs) must be properly maintained.
▷ Monitoring should be recorded on a DVR.
▷ There should be written procedures describing how to respond to an incident, and the staff monitoring the cameras must be trained in the use of those procedures.

Cashiers' Booths, Payment Areas, and the Parking Management Office

Cashiers' booths are at risk from holdups for three reasons: they are located near the exterior; they are subject to periods of low activity; and perpetrators have the opportunity to use a vehicle to escape. The following are security recommendations for cashiers' booths:
▷ Install a drop safe in the booth, with a sign stating that the cashier keeps only enough change for $20, that all cash is dropped in the safe, and that the attendant has no key.

▷ Install a silent alarm in the booth that rings at a central security location—or, if possible, at a police station.
▷ If the location warrants such measures, install bulletproof glass and armored walls in the booths.
▷ Create policies and procedures for attendants to follow in the event of a robbery attempt or other criminal behavior.
▷ Locate cashiers' booths in well-lit areas that have active vehicular and pedestrian traffic.

Cashierless revenue-control systems—such as pay-on-foot machines located in lobbies, or pay-in-lane machines located at facility exits—are becoming increasingly popular. Where these payment methods are in use, the following recommendations apply:
▷ Use CCTV to monitor the area, and post signage accordingly.
▷ Locate machines in open areas with lots of visibility.
▷ Vary the times that machines are serviced, and do not wait until money vaults are full before changing them out.
▷ Do not allow staff to handle money in unsecured locations.
▷ Provide two-way communication between the machines and a central station, in case patrons have difficulty operating the machines.
▷ Include a panic alarm on each machine.

The parking management office should be located near the entry or exit, and should have as much glass as possible so that staff can see what is going on outside. Ideally, there would be a drop safe located in the office, in addition to those at the cashiers' stations. A CCTV camera should be located in the office, so that the reception area where payments are made, the drop safe, and the money-counting area can be monitored.

Other security considerations include the following:
▷ regularly scheduled maintenance of the lighting system to replace lights that have burned out or are about to burn out;
▷ testing of communications systems; and
▷ regular reviews and updates of the operating manual.

SECURE DESIGN

Even before a parking facility is built, steps can be taken to make it more secure. The principal strategies involve perimeter control, control of vehicular access, control of pedestrian access, line of sight, stairways, elevators and lobbies, lighting, alarms and emergency communications, and signage.

Perimeter Control

Perimeter control thwarts unwanted pedestrian access to a facility. It typically requires the perimeter to be fenced and is more common in parking structures than parking lots. Landscaping, another critical element in perimeter control, should make it difficult to hide along the perimeter of the facility. Ideally, bushes or shrubbery should be kept away from the perimeter, but if plantings are required, they should be low enough so that they do not provide cover. In addition, plantings should not be located near pedestrian or vehicular points of access to the facility.

Control of Vehicular Access

Control of vehicular access can be an effective security tool. Potential perpetrators can be deterred by the prospect of being seen by staff or patrons, or being recorded by CCTV or a recording device, such as a DVR. Given that control of vehicular access is primarily a function of operations, and is therefore related to the types of users and the hours of operation, security measures at vehicular access points must be complementary to operations.

The following are key points for vehicular access:
▷ Limit the number of entrances and exits.
▷ Where possible, locate inbound and outbound lanes near pedestrian pathways, cashiers' booths, or security monitoring areas.
▷ In facilities with cashierless operations, install CCTV and sound monitors at vehicular entrances and exits.
▷ Include either rolling grilles or bifold doors in the design of the facility, so that vehicular access can be shut down during off-peak hours, and traffic can be directed to one point of control.

Control of Pedestrian Access

The key to controlling pedestrian access is to direct patrons to areas of high pedestrian activity and away from areas of low pedestrian activity. Controlling pedestrian access also means concentrating activity along preferred routes. One way to control pedestrian access is to close stairwells that are intended for emergency egress only and to outfit the doors to these stairwells with alarms.

The following are some of the key issues for pedestrian access control:
▷ Pedestrians entering the parking area on foot should have specific (and limited) points of entry, which should be located

NELS AKERLUND

Covering stairwells with as much glass as possible helps eliminate potential hiding places.

so that they must pass by or near attendant booths, security-monitoring offices, or other places of activity.

▷ Stairs and exits to the outside that are required by code should be locked from the outside and have panic hardware (alarms that are activated when a door is opened) on the inside. In addition, alarms should be installed to alert security when doors are propped open.

▷ Where possible, CCTV cameras should be located to provide views of the exterior doorways and stair and elevator lobbies.

Line of Sight

The more the design of a parking structure approaches that of an open parking lot, the easier surveillance becomes. Clear sight lines do not conflict with the facility's other functional requirements; thus, interior walls should be minimized unless economic considerations dictate otherwise. In multilevel parking structures where interior shear walls are required, holes or windows may be created in the shear walls to allow visibility.

Ramps located near the center of a parking structure may be functionally preferable for circulation, but they limit sight lines within the parking floor. Exterior, vehicle-only express ramps (either straight or helical), in contrast, afford a relatively unobstructed view of level, open parking floors. The added cost of these types of ramps, however, typically limits them to large parking structures (over 2,000 cars) that serve airports or shopping centers. If a parking structure is three modules or more wide, the vehicular ramps or sloped floors should be located on the perimeter modules, so that the remaining modules can have contiguous flat floors. This approach increases visibility for both drivers and pedestrians, and makes it easier to use CCTV and to patrol the facility.

Major security issues can arise when a parking structure is below another use, such as a residential or office building. In such structures, columns from the building above are typically positioned not only at the front bumpers of vehicles in parking spaces, but also at the sides of vehicles, thus greatly reducing sight lines across parking levels. Furthermore, pedestrians often encounter columns when opening the doors to their vehicles. Finally, columns that fall between parking spaces provide places for people to hide. Where security conditions dictate, active security measures should be instituted.

Stairways

Parking structures are required by code to incorporate a minimum of number of stairways for emergency egress. However, for security reasons, it is prudent to limit the use of these stairways, and to encourage patrons to use highly visible and active stairs. Remote emergency staircases should be alarmed and signed to limit use. These remote stairways should not have ground-level access and should only allow for emergency egress.

The following are important considerations for stairway design:

- ▷ Use as much glass as possible on the exterior walls of stair towers.
- ▷ Position stair towers in such a way that they can be seen from the outside, and so that those within the stairway can see out.
- ▷ To eliminate hiding places, keep stairways as open as possible, so that the interior of the stairway can be viewed from within the facility.
- ▷ Glass in the doors to stairwells must comply with fire codes.
- ▷ Use corner mirrors, so that patrons walking up or down stairs can see other people in the stairwell.
- ▷ Where possible, install CCTV and voice-activated sound systems in stairwells.
- ▷ To prevent someone from hiding under staircases on the ground floor, enclose the underside of the lowest run of the stairway on the ground floor with screening.
- ▷ Fence off and lock the stairs that lead to elevator penthouses.

Elevators and Lobbies

Elevators are the main means of vertical pedestrian circulation in parking structures. Probably the most accepted method of elevator surveillance is the glass-backed or -walled elevator, which is a stock item for most elevator manufacturers. Glass-walled elevators should face areas of high pedestrian activity.

Most elevators are equipped with audible alarms. Two-way communication between elevators and the facility attendant or security station is also important.

Lobbies that lead to elevators or stairs should include as much glass as possible to allow pedestrians to see into or out of the lobby, and to be seen by others. If possible, lobbies should face public or well-traveled areas, such as streets, so that people outside the facility can see into them.

Lighting

Lighting is a major factor in security. Proper lighting is important for visibility and for the operation of CCTVs. (Chapter 14 discusses lighting in more detail.)

Alarms and Emergency Communications

Alarms and emergency communications go hand in hand. Alarms can be located in elevators, elevator lobbies, stairwells, and in prominent locations in parking areas. Typically, alarms are connected to an intercom. When the alarm button is pushed, it activates a pulsing blue light that indicates where assistance is sought. Signs should clearly indicate the locations of alarms.

Signage

Signage is important to security. Wayfinding signs should be clear, so that patrons can remember where their vehicles are parked and are able to find them when they return. Patrons should be able to easily identify their destinations, such as elevators or stair towers. A patron who is lost, or looks lost, is a likely target. Finally, signs used to notify patrons that the facility is equipped with CCTV or a voice-activated sound system, or that there is active monitoring of the facility, should be carefully worded. For example, if CCTV cameras are provided, there is the presumption that they are monitored full time. If the cameras are only monitored at specific times, the signs should indicate this to patrons. If the cameras are not continuously monitored, this information should also be disclosed.

CONCLUSION

While this chapter offers guidance for improving security, it should not be perceived as a checklist of measures to be included in a specific facility. Security in a parking structure is not a simple matter, and it is always advisable to seek the advice of a security specialist, particularly as new security systems are constantly entering the marketplace. Security will always be a major issue in the design and operation of any parking facility, and knowledge of available measures is essential for ensuring proper use.

CHAPTER 14

LIGHTING

DONALD R. MONAHAN

THE PRIMARY PURPOSE OF LIGHTING IN PARKING FACILITIES is to permit the safe movement of vehicles and pedestrians. Lighting that exceeds the bare minimum for visibility may be necessary for guidance, space definition, and crime deterrence. The lighting design must balance safety and security considerations with the need to minimize cost—both first costs and long-term operations and maintenance costs.

The purpose of this chapter is to assist owners, designers, and operators in making informed decisions about lighting for parking facilities. The chapter covers visibility issues, lighting industry standards, lighting system design, and economic considerations.

VISIBILITY

For drivers, the lighting system in a parking facility should provide enough visibility to see signs, physical obstructions, and pedestrian movements; for pedestrians, the system should provide enough visibility to see signs and tripping hazards.

Two quantifiable factors determine the minimum and maximum amount of beneficial illuminance in a parking structure: (1) object detection, the amount of illuminance required for adequate visibility of objects such as curbs and wheel stops; and (2) crime deterrence, the amount of illuminance required to make out the facial characteristics of potential perpetrators of crimes.

Object Detection

Injuries caused by slipping, tripping, or falls represent approximately 75 percent of the liability claims in parking facilities. Two steps can be taken to prevent such injuries: eliminating all use of wheel stops, and minimizing the use of curbs or islands. Alternative means of channeling cars or providing bumper protection include pipe bollards and guardrails. In existing facilities that already have curbs that cannot

Lighting Industry Standards

Except for emergency lighting (typically 1 foot-candle [10 lux] along the path of egress), most state and local governments do not legislate lighting levels in parking lots or parking structures. Nonetheless, to minimize the owner's risk of liability for personal injury caused by poor lighting, light levels should meet minimum industry standards.

The Illuminating Engineering Society of North America (known as IESNA or IES) publishes illuminance guidelines for a variety of building types and activities, which are generally considered industry standards. IES document RP-20-98, *Lighting for Parking Facilities*, specifies design guidelines for lighting surface parking lots and parking structures.

IES guidelines for covered parking areas recommend a minimum maintained horizontal illuminance of 1 foot-candle (10 lux) at the floor level, and a minimum maintained vertical illuminance of 0.5 foot-candles (5 lux) 5 feet (1.5 meters) above the floor. Because of the lower background luminance in asphalt-surfaced parking lots at night, the minimum horizontal and vertical illuminance should be 0.5 foot-candles (5 lux) and 0.25 foot-candles (2.5 lux), respectively.

Recommended Maintained Illuminance Values and Uniformity Ratios for Parking Lots

	Basic	Enhanced Security
Minimum horizontal illuminance on floor	0.2 foot-candles (2 lux)	0.5 foot-candles (5 lux)
Minimum vertical illuminance at 5 feet (1.5 meters) above floor	0.1 foot-candles (1 lux)	0.25 foot-candles (2.5 lux)
Uniformity ratio (maximum to minimum)	20:1	15:1

To meet the IES standards for vertical illuminance, noncutoff light fixtures should be used where mounting heights are less than 10 feet (3 meters). Cutoff luminaires are typically recommended where mounting heights are greater than 12 feet (3.7 meters), such as for surface parking lots and the roofs of parking structures. The ratio of spacing to mounting height should be approximately 4:1 (half that distance to an unlighted perimeter). The accompanying tables outline the 1998 design standards.

Recommended Maintained Illuminance Values and Uniformity Ratios for Parking Garages

	Minimum Horizontal Illuminance on Floor		Minimum Vertical Illuminance at 5 Feet (1.5 Meters) above Floor		Uniformity Ratio (Maximum to Minimum)
	Foot-candles	**Lux**	**Foot-candles**	**Lux**	**Ratio**
Basic	1.0	10	0.5	5	10:1
Ramps					
Day	2.0	20	1.0	10	10:1
Night	1.0	10	0.5	5	10:1
Entrance areas					
Day	50	500	25	250	
Night	1.0	10	0.5	5	10:1
Stairways	2.0	20	1.0	10	

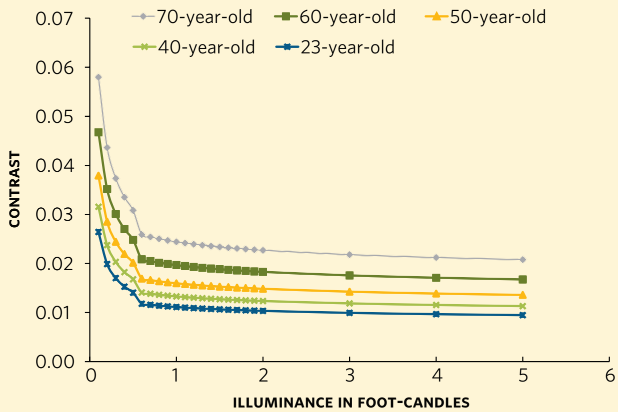
Source: Illuminating Engineering Society of North America (IES), *Lighting for Parking Facilities*, RP-20-98 (New York: IES, 1998).

Horizontal Illuminance at a Glance

The amount of light falling on a horizontal surface is called *horizontal illuminance*. By contrast, *vertical illuminance* is the amount of light falling on a vertical surface (such as a wall). It is measured at 5 feet (1.5 meters) above the floor in the direction of the observer.

The average horizontal illuminance is calculated using computer software or is measured with a light meter that determines the horizontal illuminance at points along a grid spread throughout the entire parking facility floor area. The maximum spacing of the grid points is approximately 6 feet (2 meters). The sum of the illuminances at each point is then divided by the number of points, to determine the average illuminance. Minimum horizontal illuminance is the lowest light level at any point on the floor in the parking facility and usually occurs in the perimeter corners. Maximum horizontal illuminance is the highest light level measured or calculated at any point on the floor and usually occurs directly below a light fixture. The maximum to minimum uniformity ratio should not exceed 10:1 in a parking structure or 15:1 in a surface parking lot.

FIGURE 14-1: Required Contrast versus Illuminance for Viewers of Different Ages



Source: The Roadway Lighting Committee of the Illuminating Engineering Society of North America.

Note: The figure indicates the degree of contrast required to obtain a 99.9 percent probability that an observer will see a 6-inch- (15-centimeter-) high concrete curb at a distance of 20 feet (6 meters). Contrast is defined as the luminance of the target, minus the luminance of the background, divided by the luminance of the background.

be removed, the owner or operator should protect against personal-injury claims by improving the visibility of the hazards by painting them with a color (such as yellow) that will contrast with their backgrounds.

The visibility of hazards such as steps, wheel stops, curbs, and islands is a function of (1) the illuminance on the hazard and (2) the contrast between the reflectance of the hazard and that of its background (i.e., the *reflectance contrast*). Illuminance is the amount of direct light falling on a surface; it can be measured with a light meter. Reflectance is the fraction of light reflected from an object, as compared to the direct light on an object, and varies for different colors. Paint manufacturers can provide information on reflectance percentage for different colors. The light reflected from a surface or object is called *luminance*. Luminance is a function of both illuminance and reflectance, and is calculated as follows:

luminance = illuminance x reflectance/π

In practical terms, reflectance is important because the greater the contrast between an object and its background, the greater the visibility of the object. A concrete wheel stop and a concrete floor, for example, will have similar reflectance, and therefore minimal contrast. Painting the wheel stop yellow will greatly enhance its visibility.

The Roadway Lighting Committee of the Illuminating Engineering Society of North America (known both as IESNA and IES) has conducted extensive research on the amount of contrast required for adequate visibility of an object. Figure 14-1 indicates the degree of contrast necessary for a certain level of visibility, for people of various ages. Note that the amount of contrast required increases significantly at light levels of less than 0.6 foot-candles (6.5 lux). By the same token, light levels above 0.6 foot-candles (6.5 lux) provide little additional benefit with respect to object detection. Depending on the configuration of the luminaries[1] and the uniformity of the lighting system, the average illuminance will be three to four times higher than the minimum illuminance. Therefore, in a concrete parking structure with a uniform lighting configuration, an illuminance of approximately 1 foot-candle (10 lux) at the pavement level could provide adequate visibility of curbs and wheel stops.

In general, light sources from metal halide lamps (MH), fluorescent lamps, or light-emitting diodes (LEDs) are recommended for the illumination of pedestrian destination areas. In pedestrian destination areas, the average horizontal illumination on the pavement and the average vertical illumination at 5 feet (1.5 meters) above the pavement should meet or exceed 10 foot-candles (108 lux). Finally, the industry standard is a minimum of 2 foot-candles (22 lux) on the floor or walking surface.

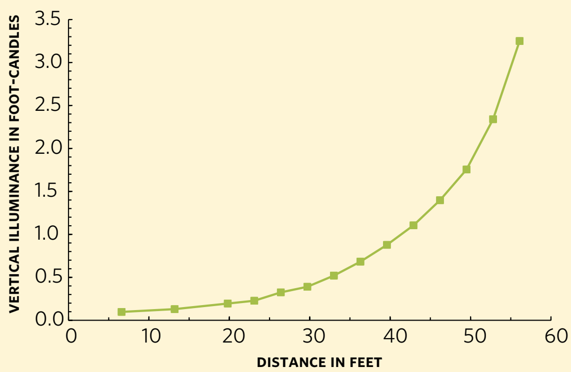
Crime Deterrence

How much lighting is necessary to deter criminal activity? Although many parking facilities that have increased light levels have experienced reductions in some types of accidents and criminal activity, there is no conclusive evidence that improved lighting reduces crime. However, surveys undertaken before and after lighting improvements indicate that patrons felt safer after the lighting improvements because of (1) greater distance visibility and (2) the ability to identify potential assailants and take evasive action.

P.R. Boyce and M.S. Rea studied the effects of perimeter security lighting on people's ability to (1) detect someone walking toward them along a lighted path and (2) later recognize the individuals from a selection of four photographs.[2] The results indicated that a vertical illuminance (see "Horizontal Illuminance at a Glance," page 132, for a definition) of about 0.1 foot-candles (1 lux) is sufficient to obtain a 90 percent probability of correct detection (that is, subjects were able to notice someone's presence, but not distinguish their facial features). At about 2 foot-candles (22 lux), the probability approaches 100 percent. A vertical illuminance of about 1.5 foot-candles (16 lux) is sufficient to obtain a 90 percent probability of correct recognition (that is, the ability to identify the person's features and expression). In other words, the vertical illuminance required for correct recognition is approximately 15 times greater than that required for correct detection.

P. Rombauts, H. Vandewyngaerde, and G. Maggeto studied facial recognition under street-lighting conditions.[3] Displaying some of their findings, Figure 14-2 illustrates the relationship between vertical illuminance and confident facial recognition at various distances. Approximately 0.1 foot-candles (1 lux) of vertical illuminance is required for confident facial recognition at a distance of 6.6 feet (2 meters); approximately 0.5 foot-candles (5.4 lux) at a distance of 33 feet (10 meters); and approximately 3 foot-candles (32 lux) at a distance of 56 feet (17 meters). The study concluded that confident facial recognition is not possible beyond 56 feet (17 meters).

FIGURE 14-2: Vertical Illuminance versus Distance for Confident Facial Recognition



Source: P. Rombauts, H. Vandewyngaerde, and G. Maggeto, "Minimum Semi-Cylindrical Illuminance and Modeling in Residential Area Lighting," *Lighting Research and Technology* 21 (1989).

On the basis of these two studies, it appears that to allow for confident facial recognition at a distance of 20 to 30 feet (6 to 9 meters), a minimum vertical illuminance of 0.5 to 1.0 foot-candles (5.4 to 10 lux), at a height of 5 feet (1.5 meters) above the floor, should be provided. In addition, security professionals suggest that a minimum distance of 20 feet (6 meters) is required for a person to take evasive action if another individual is perceived to be a threat. It follows that if lighting is adequate for confident facial recognition, potential criminals may avoid a parking facility because of the increased likelihood of being apprehended.

Other Visibility Issues

Ambient lighting of overhead signage is an important consideration in the selection of light fixtures. Overhead signs are typically mounted 7 to 8 feet (2.1 to 2.4 meters) above the floor. Readability requires both a minimum level of illuminance and a corresponding contrast between a message and its background. If the contrast is relatively low, the vertical illuminance at the sign face should be a minimum of 1 foot-candle (10 lux) for adequate visibility. Since an ambient illuminance of at least 1 foot-candle is difficult to achieve 7 to 8 feet (2.1 to 2.4 meters) above the floor, signage designers often require a minimum reflectance difference[4] of 75 percent, to ensure adequate visibility at low light levels. If the sign does not have adequate contrast, and/or if adequate ambient lighting for overhead signage cannot be achieved, then internally illuminated signs should be used.

Facilities outfitted with closed-circuit television systems require a minimum illuminance of 0.5 foot-candles (5.4 lux) for today's state-of-the-art colored cameras (the alternative is to pay a premium for cameras that have increased light sensitivity). Care should be taken in positioning the camera so that it is not aimed directly at a light fixture, and so that it does not scan directly across a light fixture. Because the camera adjusts to the brightness of the light source, exposing the camera to bright, direct light will cause the background detail to be lost.

FIGURE 14-3: Cutoff Luminaire

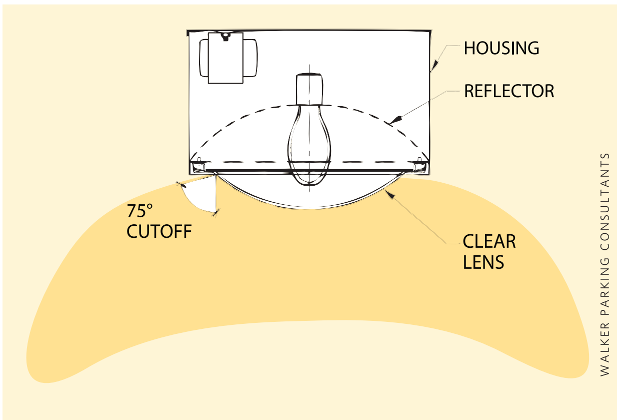
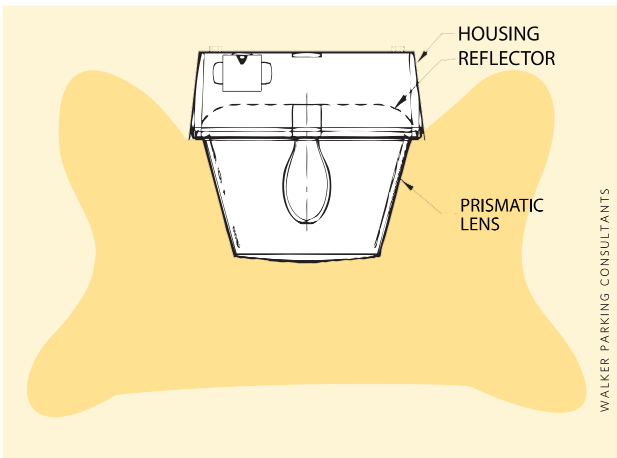


FIGURE 14-4: Noncutoff Luminaire



LIGHTING SYSTEM DESIGN

The design of the lighting system should take into account a number of factors, including luminaire design, glare, color rendition, and maintenance.

Luminaire Design

Luminaires are generally classified as cutoff or noncutoff (see Figures 14-3 and 14-4). IES defines a cutoff luminaire as a fixture that shields emitted light such that the light output is (1) less than 2 percent above the horizontal plane and (2) less than 10 percent above an 80-degree angle that is drawn from a vertical line through the light source. Cutoff fixtures reduce glare by minimizing high-angle light; however, the fixtures must be spaced close enough to provide (1) overlapping light distribution at the driver's line of sight (see figures 14-5 and 14-6) and (2) adequate light distribution over and between parked vehicles. For fixtures with an 8.5-foot (2.6-meter) mounting height and a 75-degree cutoff angle to provide adequate illumination at 5 feet (1.5 meters) above the pavement, the fixtures must be spaced approximately 15 feet (4.6 meters) apart. Lower mounting heights require even closer spacing. If overlap is insufficient, users will be unable to adjust to the rapid variations in light levels and will feel uncomfortable when passing through the light and dark areas at driver's eye level.

Noncutoff luminaires provide better light distribution and uniformity at high elevations above the floor, which is important for the visibility of pedestrians and for adequate ambient lighting of signage suspended from ceilings or overhead beams. The disadvantage of noncutoff fixtures is the potential glare produced by high-angle light.

To obtain adequate vertical illumination at 5 feet (1.5 meters) above the pavement, cutoff luminaires are often mounted at heights above 12 feet (3.7 meters); noncutoff luminaires are recommended for mounting heights of 10 feet

FIGURE 14-5: Visual Field for Precast Concrete Garage

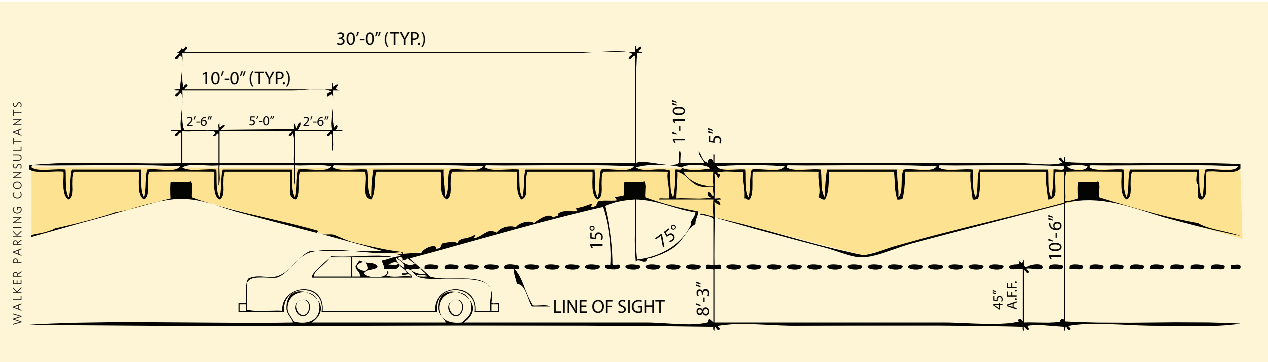
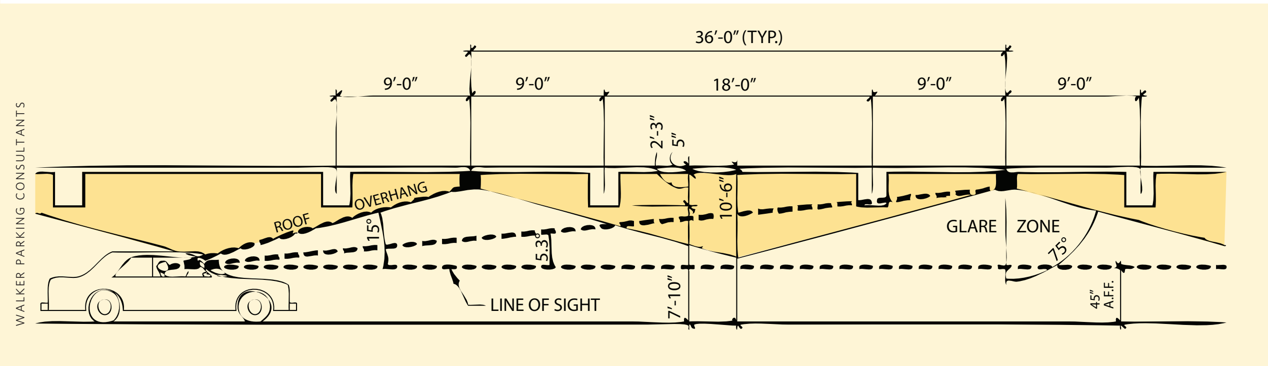


FIGURE 14-6: Visual Field for Cast-in-Place Concrete Garage



(3 meters) or less. Calculations must be used to determine which type of light fixture is appropriate at mounting heights between 10 and 12 feet (3 and 3.6 meters). Because the floor-to-floor height in most parking structures is on the order of 10 feet (3 meters), noncutoff luminaires should be used on the covered levels.

On the roof level of parking structures and in surface parking lots, cutoff luminaires are recommended to minimize light trespass and to hide the light source from the view of adjacent properties. For roof-mounted pole lights on interior column lines, the mounting height should be equal to approximately half the horizontal distance to be illuminated: for instance, a 30-foot (9.14-meter) mounting height would be needed to illuminate a 60-foot (18.28-meter) horizontal distance. A mounting height of less than 25 feet (7.6 meters) will likely require light fixtures at the perimeter of the roof or surface lot because the horizontal illuminance at the perimeter walls would otherwise be insufficient.

Glare

Lighting for Parking Facilities defines "discomfort glare" as "a sensation of annoyance or pain caused by a high or non-uniform distribution of brightness in the field of view."[5] Discomfort glare can be reduced by a number of measures:

▷ *Location of fixtures.* The offset at more than a 10-degree angle from the driver's direct forward line of sight is what is important here.

▷ *Lighting intensity and contrast.* Decreasing the intensity of the light source and/or the contrast between the light source and background surfaces.

▷ *Optical control of light sources.* Designing internal reflectors and/or lenses to redirect light away from the drivers' and pedestrians' direct line of sight (which occurs between 75 and 90 degrees from a vertical line through the light fixture).

▷ *Color rendition.* Using subdued, warm white or yellowish-white light sources, such as high-pressure sodium (HPS) lamps, because bright white light sources produce more glare.

Location of Fixtures

It is important to properly integrate the lighting system and the structural components of a parking facility. To minimize light blockage, light fixtures should be centered between structural beams or joints. However, the beams or joists also serve to shield the light fixture and minimize glare. At distances of more than 60 feet (18 meters), the beams or precast concrete tee stems shield the light fixtures. At distances of less than 15 feet (4.6 meters), the overhang of the vehicle roof shields the driver from the fixture. Therefore, the fixture can be seen only when the driver is 15 to 60 feet (4.6 to 18 meters) away from it.

Locating the light fixtures away from the driver's direct line of sight can also minimize the potential for discomfort glare. Research has shown that a lateral offset of 10 degrees or more from the direct line of sight greatly reduces the potential for glare. If the fixtures are located over the parking stalls on each side of the driving aisle, the lateral offset will be approximately 12 feet (3.7 meters) from the driver's direct line of sight. At a distance of 60 feet (18 meters), this lateral distance represents an angular offset of 11 degrees. Assuming a lateral offset of 12 feet (3.7 meters) from the driver's direct line of sight, the glare zone for the driver is between 9 and 15 degrees above the horizontal line of sight (or 75 to 81 degrees in relation to a vertical line drawn through the fixture). Using these figures as a guide, the designer can select a luminaire that is designed to reduce the light output in the glare zone. For pedestrians, the potential glare zone is reduced even less, because the pedestrian's line of sight is approximately 60 inches (152 centimeters) above the floor, versus 45 inches (114 centimeters) for the driver. However, additional shielding may be required at the crossover aisles that are perpendicular to the parking access aisles.

Lighting Intensity and Contrast

Discomfort glare is a function of the contrast between the light source and its background. For instance, vehicle headlights can cause visual discomfort at night, but are almost unnoticeable in bright sunlight. Thus, reducing the intensity of the light source and/or increasing the brightness of the background surfaces can minimize glare.

Lower-wattage lamps can be used to reduce the intensity of the lighting. A 100-watt HPS lamp, for example, is 59 percent as bright as a 150-watt HPS lamp. The background brightness can be increased by a factor of 2 to 2.5 by painting interior surfaces (including ceilings and beams) off-white or white, which will reduce the potential for discomfort glare by 50 to 60 percent.

Because painted ceilings increase reflectance, they also increase the illuminance by approximately 10 to 15 percent. The increased reflectance has a greater impact on the illuminance of the darker areas, increasing lighting uniformity. In addition, painted ceilings greatly increase the psychological perception of the brightness of the space. Since cutoff luminaires direct little or no light upward, painting ceilings and beams is of little benefit with that fixture type. Similarly, there is little benefit in painting precast double-tee soffits that do not contain a light fixture, since a direct source of uplight is necessary in the soffits. The soffits need a light source to illuminate the ceiling surface so that there is significant reflected light from the higher reflectance of the painted surface. A soffit without a light source has little or no direct light, and therefore very little reflected light.

Optical Control of Light Sources

To control glare, many fixture manufacturers use reflectors and lenses to redirect light output and minimize the lighting intensity in the zone that is within a 75- to 85-degree angle from a vertical line drawn through the fixture. Limiting the light output in the glare zone to less than 2,500 candelas will generally minimize the potential for glare.

For the roofs of parking facilities, cutoff fixtures are recommended that limit the light output above a 75-degree angle from a vertical line drawn through the fixture. In addition, the pole height and/or the shielding of the roof fixtures should be designed to prevent the light source from being viewed from a position that is within a 75-degree angle from a vertical line drawn through the fixture, or from a position that is greater than 15 degrees above the pedestrian observer's horizontal line of sight. According to research undertaken in Australia and Germany on obtrusive light, a maximum luminous intensity (brightness) of 2,500 candelas is recommended at the angle of view that would be experienced by an observer standing at the property line—which would generally limit

FIGURE 14-7: International Protection Ratings

First Digit	Protection against Foreign Objects	Second Digit	Protection against Moisture
0	Not protected	0	Not protected
1	Protected against objects larger than 50 millimeters	1	Protected against dripping water
2	Protected against objects larger than 12 millimeters	2	Protected against dripping water when tilted to 15N
3	Protected against objects larger than 2.5 millimeters	3	Protected against spraying water
4	Protected against objects larger than 1.0 millimeters	4	Protected against splashing water
5	Protected against dust	5	Protected against water jets
6	Dust tight	6	Protected against heavy seas
		7	Protected against the effects of immersion
		8	Protected against submersion

the light source to a 400-watt lamp. Moreover, the vertical illuminance should not exceed 0.5 foot-candles (5.4 lux) at a height of 5 feet (1.5 meters) at the property line.

Color Rendition

"White" light from MH lamps, fluorescent lamps, or LEDs renders colors most accurately. However, the color rendition of MH lamps varies significantly from lamp to lamp and deteriorates with age; fluorescent lamps provide more reliable and longer-lasting color rendition than MH lamps. HPS lamps produce a yellowish light that slightly distorts the hues of many colors; in particular, it can be difficult to distinguish some shades of blue from green under HPS lighting. For most people, however, the color distortion is not sufficient to interfere with recognition of their vehicle.

The fact is that color discrimination is not a high priority in a parking structure. First, although the accuracy with which colors can be named generally decreases at lower light levels and increases at higher light levels, the eye adapts to the lighted environment, adjusting the way that it recognizes different colors for that environment. Second, patrons occupy the parking facility only for a short period of time. Third, patrons' color-related tasks—identifying their vehicles or recognizing the color codes used to distinguish floors—can be performed even if hues are slightly distorted. Finally, since 5 percent of the population is color-blind, and 30 percent is color-impaired, the wayfinding system should not rely exclusively on color schemes.

Color rendition is most significant in elevator lobbies, or in other areas where the messages conveyed by colored graphics and signage are important. In addition, some designers feel that white light intensifies the starkness of concrete parking structures and that the yellowish-white light of HPS lamps adds some "warmth" to the concrete environment. One option is to use HPS lamps in parking areas and to use white light sources, such as MH or LED lamps, in pedestrian lobbies.

Recent research indicates that at an adapted luminance[6] of 1 candela per square meter (equivalent to approximately 1 foot-candle [10 lux] of illuminance in a concrete parking structure), viewers could accurately name 86 percent of colors under MH lighting and 65 percent of colors under HPS lighting. HPS lamps that allow more accurate rendering of colors are available; however, because both lamp life and light output are significantly lower with HPS lamps, the improvements in color rendition do not make economic sense.

Maintenance

A number of factors affect both the cost and effort involved in maintaining a lighting system, including the design of the fixtures, lamp life, lumen depreciation, and ballast factors.

Fixture Design

Luminaires should have an IP (international protection) rating, indicating that they have met the standards established by publication IEC 529 of the International Electrotechnical Commission for protection against dust and moisture infiltration.

FIGURE 14-8: Lamp Life for Selected Fixtures

Lamp Type	Lamp Life*
150-watt high-pressure sodium	28,500 hours
150- to 200-watt pulse-start metal halide	15,000 hours
4-foot (1.2-meter) T8 fluorescent	30,000 hours
4-foot (1.2-meter) T5 high-output fluorescent	24,000 hours
Light-emitting diode	100,000 hours
Induction	100,000 hours

*Assumes that the lamp is burning 24 hours a day.

FIGURE 14-9: Lamp Lumen Depreciation Factors for Selected Fixtures

Lamp Type	Lamp Lumen Depreciation Factor*
4-foot (1.2-meter) T5 high-output fluorescent	0.9
4-foot (1.2-meter) T8 fluorescent	0.9
150- to 200-watt pulse-start metal halide	0.70
100- to 150-watt high-pressure sodium	0.73
Light-emitting diode	0.70
Induction	0.70

*Assumes that the lamp is burning 24 hours a day.

This rating is indicated by the letters "IP," followed by two numerals (see Figure 14-7). The first numeral indicates the level of protection against foreign objects, and the second numeral indicates the level of protection against moisture. A minimum rating of IP51 is recommended. A rating of IP65 is required for luminaires that will be subject to power washing. IP standards may be more restrictive or have higher standards than the "damp location" or "wet location" listings provided by Underwriters Laboratories.

Fixtures must be vandal-resistant. Lenses should be impact-resistant, and tamper-proof hardware should be used to prevent unauthorized dismantling of the fixtures. Polycarbonate lenses are not recommended, as they become more brittle with age until they are no stronger than high-impact acrylic. Further, polycarbonate lenses are more prone to yellowing and degradation, particularly when exposed to ultraviolet (UV) radiation, and have lower light transmission than acrylic or glass.

Since MH lamps produce UV radiation, to protect lenses from UV damage these lamps require one of the following:

- ▷ the use of a coated lamp, to reduce the UV output;
- ▷ UV stabilizers, if plastic lenses are used; or
- ▷ tempered-glass lenses.

Lighting calculations should assume that the combination of discoloration and the accumulation of dirt and bugs in or on the lenses will reduce light output by at least 10 percent. Annual cleaning is recommended to ensure that output is reduced by no more than this amount.

Lamp Life

Maintenance of a lighting system consists primarily of replacing expired fixtures. Figure 14-8 lists the lamp life for light sources typically used in parking facilities.

The "T" designation used for fluorescent lamps indicates the diameter of the tube in eighths of an inch; thus, a T8 fluorescent lamp is 1 inch (2.5 centimeters) in diameter. Because they are more efficient, T8 fluorescent lamps have replaced T12 lamps for office lighting and parking structure lighting. Two T5HO (high-output) fluorescent lamps produce approximately the same light output as four T8 lamps at approximately the same amount of energy usage. Both lamp types have a lamp life of at least 30,000 hours, based on 12 hours per start.

Pulse-start MH lamps with specialized ballasts and igniters increase lamp life from 10,000 to 15,000 hours and provide higher maintained light output[7] than standard MH lamps. However, MH lamps that are left on continuously must be turned off for 15 minutes a week to prevent violent premature termination (i.e., they explode). (All subsequent references to MH lamps in this chapter refer to pulse-start MH lamps.)

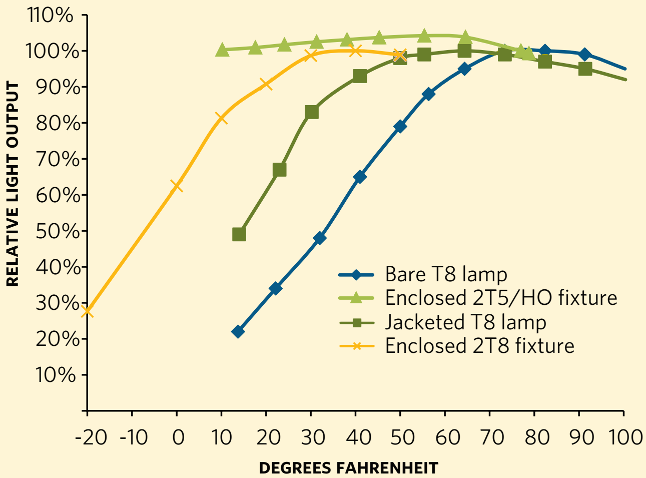
Lumen Depreciation

The light output of a lamp decreases with the amount of time that it is operated: this phenomenon is called *lamp lumen depreciation* (LLD). Lighting calculations should be based on the light output that will be available at the end of the rated life of the lamp (see Figure 14-9). Rated life is determined in

Temperature

As shown in the accompanying figure, the light output of fluorescent lamps is significantly affected by ambient temperature. Although fluorescent lamps are not typically recommended where the ambient temperature will fall below freezing during operating hours, recent test data indicate that a wraparound acrylic lens can capture the heat from the lamp, increasing the temperature of the bulb wall approximately 15 degrees Fahrenheit (9.4 degrees Celsius). This approach allows the use of fluorescent fixtures in temperatures as low as 0 degrees Fahrenheit (-18 degrees Celsius). In areas where the low temperature in the winter months is above 0 degrees Fahrenheit (-18 degrees Celsius), fluorescent lamps are the most cost-effective light source. In colder climates, LED fixtures are the most cost-effective light source. The light output of LED light sources and MH and HSP lamps is not affected by temperature.

Light Output versus Temperature for Various Types of Fluorescent Lamps



the laboratory as the number of operating hours at which 50 percent of the lamps have expired and 50 percent are still functioning. Because the light output of the lamps will continue to depreciate after they have exceeded their rated life, regularly scheduled relamping is important to maintain the minimum illuminance required for safety and security. Lamps should be replaced when the illuminance directly under the fixture is below a predetermined value. To ensure that the lamps are replaced with sufficient frequency, each fixture should be checked annually with a light meter.

Ballast Factors

A ballast is a device used with fluorescent, MH, and HPS lamps to obtain the necessary circuit conditions (voltage, current, and waveform) for starting and operating. The ballast supplied with the fixture may result in lower light output than the reference ballast (that is, the ballast that was used to determine the photometric characteristics of the luminaire in the testing laboratory). The ballast factor is the ratio of the light output of the installed ballast versus the light output of the reference ballast. The ballast factor for high-intensity discharge (HID) lamps is typically 0.9 to 1.0. As illustrated in Figure 14-10, the ballast factor for fluorescent lamps can vary significantly, ranging from 0.77 to 1.38. (Ballast factors are listed in manufacturers' catalogs.)

FIGURE 14-10: Ballast Factors for Fluorescent Lamps

Power Rating	Ballast Factor	Input watts: Four T8 fluorescent	Input watts: Two T8 fluorescent
Low	0.77	96	48
Normal	0.87	109	55
High	1.18	146	74
Very high	1.38	Not applicable	80

The advent of electronic ballasts for fluorescent lamps has made these lighting systems much more energy efficient. For example, a luminaire with four 32-watt T8 fluorescent lamps and one high-frequency electronic ballast with a ballast factor of 0.88 uses approximately 110 watts. A luminaire with two T5 54-watt (high-output) lamps and one full-light-output electronic ballast

FIGURE 14-11: Ballast Factors for Fluorescent Lamps

Type of Lamp	Initial Lumens	Lumen Depreciation	Design Lumens
150-watt high-pressure sodium (HPS)	16,000	0.72	11,520
175-watt metal halide (MH)	14,000	0.65	9,100
Four T8 fluorescent	11,800	0.90	10,620
Five-bar light-emitting diode	8,500	0.70	5,950
150-watt induction	12,000	0.70	8,400
100-watt HPS	9,500	0.72	6,840
100-watt MH	8,500	0.65	5,525
Two T8 fluorescent	5,900	0.90	5,310

(that is, with a ballast factor of 1.0) will use approximately 117 watts. These fixtures produce almost the same light output as 175-watt MH fixtures, while saving 40 percent in energy costs.

THE ECONOMICS OF LIGHTING SYSTEMS

The costs associated with lighting systems include

- ▷ construction costs (first cost);
- ▷ operating costs (that is, energy costs); and
- ▷ maintenance costs (for example, cleaning fixtures and replacing lamps).

Construction Costs

Construction costs depend largely on the cost of the individual fixtures and the number of fixtures. The number of fixtures, in turn, depends on the type of light source, the mounting height, the fixture design, and the spacing required to achieve the desired illumination and lighting uniformity. The higher the lumen output of the light source, the fewer fixtures will be required. For example, an 8-foot- (2.4-meter-) long fluorescent fixture with pairs of T8 lamps in tandem, or a fluorescent fixture with two 4-foot (1.2-meter) T5 high-output lamps will be approximately equivalent in light output to a 150-watt HPS fixture or a 175-watt MH fixture. Figure 14-11 compares lumen outputs for equivalent light sources typically used in parking structures.

The material cost for a 150-watt HPS or a 175-watt MH fixture is typically $200 to $250, including a lamp.[8] An 8-foot- (2.4-meter-) long fluorescent fixture with four T8 lamps and a wraparound high-impact acrylic lens will cost approximately $175 to $200. LED fixtures are approximately $800 to $1,000 each. LED fixtures consist of silicon chips that produce light when an electric current is applied. Each chip is smaller than the tip of a finger and consumes approximately 1 watt of energy at a light output of approximately 60 to 65 lumens per watt. An array of approximately 100 to 150 LED chips is required at the bottom of the fixture to produce equivalent light output to 150-watt HPS fixtures or 175-watt MH fixtures; however, LED fixtures have a lamp life of 100,000 to 150,000 hours at a lumen depreciation factor of 0.7. Induction fixtures are approximately $400 to $500 each. Induction lamps are electrodeless fluorescent lamps that have a lamp life of approximately 100,000 hours. However, the light output is approximately 50 percent lower than 150-watt HPS or 175-watt MH fixtures. (For all the fixtures discussed in this paragraph, the installed cost is approximately double the fixture cost.)

The most common lighting configuration in a parking structure is 30-foot by 30-foot (9.14-meter by 9.14-meter) spacing; thus, the installed fixture cost is approximately $0.40 to $0.55 per square foot ($4.20 to $5.80 per square meter). These figures were calculated by multiplying the fixture cost by two to determine the installed cost, then dividing the installed cost by the area (900 square feet [83 square meters] per fixture). Wiring, conduit, transformer, generator, switch gear, lighting panels, and lighting controls result in a total lighting cost of approximately $1.00 to $1.50 per square foot ($10.75 to $16.10 per square meter) for lighting in general parking areas. An additional $.50 to $1.00 per square foot ($5.40 to $10.75 per square meter) should be included for the lighting of stairs, elevator lobbies, storage rooms, offices, and the exterior. This brings the total lighting cost to $1.50 to $2.50 per square foot ($16.10 to $26.90 per square meter). The total cost of the electrical system also includes other elements, such as power for elevators, parking equipment, security equipment. However, the initial construction cost is typically less than 10 percent of the 25-year life-cycle cost of the lighting system.

Operating Costs

Evaluated over the life of the luminaire (approximately 25 years), operating costs are typically five times the initial cost,

FIGURE 14-12: Energy Consumption for Selected Fixtures

Type of Lamp	Lamp-Plus-Ballast Wattage*
150-watt high-pressure sodium	188
150-watt pulse-start metal halide (MH)	190
175-watt pulse-start MH	208
Four T8 fluorescent	±110
Two T5/HO fluorescent	117
Light-emitting diode	128
150-watt induction	161

*Assumes all lamps are producing the same amount of illumination.

FIGURE 14-13: Operating Costs for Selected Fixtures

Lamp Type	Annual Operating Cost
150-watt high-pressure sodium	$132
150-watt/pulse-start metal halide (MH)	$133
175-watt/pulse-start MH	$146
Four T8 fluorescent	$77
Two T5 high-output fluorescent	$82
5-bar light-emitting diode	$90
150-watt induction	$113

or approximately 85 percent of the total life-cycle cost. The following formula allows comparison of operating costs for different lighting options:

> Lamp wattage + ballast wattage for each fixture x the number of fixtures x the annual number of operating hours x the cost per watt of electricity in the project area = Annual operating cost.

If the number of fixtures is the same for each lighting option, then the lamp-plus-ballast wattage for each type of fixture will determine which lighting option will be the most economical to operate. Figure 14-12 lists the lamp-plus-ballast wattage for the seven light sources typically used in parking structures. As the figure illustrates, fluorescent fixtures with electronic ballasts save up to 42 percent in operating costs when compared with the 150-watt HPS or 150-watt pulse-start MH fixtures. Figure 14-13 shows the annual operating costs per fixture, assuming a national average cost of $0.08 per kilowatt and 24-hour-per-day operation.

Maintenance Cost

Maintenance cost is typically less than 10 percent of the 25-year life-cycle cost. Because their lamp life is approximately one-half that of either HPS or fluorescent lamps, twice as many MH lamps as HPS or fluorescent lamps will expire each year. However, the equivalent fluorescent system utilizes four T8 lamps per fixture; thus, each year, it will be necessary to replace four times as many fluorescent lamps as HPS lamps, and twice as many fluorescent lamps as MH lamps.

Since fluorescent lamps are 10 to 20 percent of the cost of MH lamps, the material cost for fluorescent lamp replacement is still much lower than for MH lamps. However, the labor cost for relamping fluorescents is much higher. Annual maintenance costs for a fluorescent lighting system are therefore similar to those for an MH lighting system. Maintenance costs for an HPS lighting system, however, are much lower than those for either a fluorescent or an MH system.

NOTES

1. Made up of a housing, ballast, lens, and lamp, a luminaire is simply the technical name for a light fixture.
2. P.R. Boyce and M.S. Rea, "Security Lighting: Effects of Illuminance and Light Source on the Capabilities of Guards and Intruders," *Lighting Research and Technology* 22 (1990): 57.
3. P. Rombauts, H. Vandewyngaerde, and G. Maggeto, "Minimum Semi-Cylindrical Illuminance and Modeling in Residential Area Lighting," *Lighting Research and Technology* 21 (1989).
4. The *reflectance difference* is the reflectance of the target minus the reflectance of the background, or vice versa. By comparison, the *reflectance contrast* is the reflectance of the target, minus the reflectance of the background, divided by the background reflectance.
5. Illuminating Engineering Society of North America (IESNA), *Lighting for Parking Facilities*, RP-20-98 (New York: IESNA, 1998).
6. The adapted luminance is the reflected light level of the predominant background in the field of view to which the eye has adjusted.
7. Maintained light output refers to the light output immediately before lamp burnout or lamp replacement, whichever occurs first.
8. All costs are in 2008 dollars.

REFERENCES

Adrian, Werner. "The Physiological Basis of the Visibility Concept." Paper presented at the Lighting Research Institute's Second Annual Symposium on Visibility and Illuminance in Roadway Lighting, Orlando, Florida, October 26-27, 1993.

Box, Paul C. "Parking Lot Accident Characteristics," *ITE Journal* (December 1981).

Boyce, P.R., and J.M. Gutkowski. *Street Lighting and Street Crime.* Troy, New York: Lighting Research Center, 1992.

———. "The If, Why and What of Street Lighting and Street Crime." Paper presented at the Chartered Institution of Building Services Engineers' National Lighting Conference, Cambridge, UK, 1990.

Boyce, P.R., and M.S. Rea. "Security Lighting: Effects of Illuminance and Light Source on the Capabilities of Guards and Intruders." *Lighting Research and Technology* 22 (1990).

———. "Avoiding Tort Claims in Parking Lots." *Public Works* (January 1994).

Cunnen, J.M.L. "Crime and Lighting." *Lighting Design and Application* (April 1990).

English, William. *Safety Engineering Guidelines for the Prevention of Slips, Trips, and Falls.* Del Mar, Calif.: Hanrow Press, 1989.

Illuminating Engineering Society of North America (IESNA). *Lighting for Parking Facilities.* RP-20-98. New York: IESNA, 1998.

———. *Lighting Handbook: Reference and Application*, 8th ed. New York: IESNA, 1998.

Monahan, Donald R. "Safety Considerations in Parking Facilities." *Parking Professional* (September 1995).

Nam, Sheela H., and Joseph B. Murdoch. "Lighting for Bus Stops." *Proceedings of the IESNA Annual Conference*. New York, July 30–August 2, 1995.

Painter, K. "Lighting and Crime Prevention: The Edmonton Project." Unpublished paper, Middlesex Polytechnic, 1988.

———. "Evaluation of Public Lighting as a Crime Prevention Strategy: The West Park Estate Surveys." *Lighting Journal* (December 1991).

Rombauts P., H. Vandewyngaerde, and G. Maggeto. "Minimum Semi-Cylindrical Illuminance and Modeling in Residential Area Lighting." *Lighting Research and Technology* 21 (1989).

CHAPTER 15

Sustainable DESIGN

JOHN PURINTON, STEPHEN REBORA,
FORREST HIBBARD, LARRY CHURCH, AND RICK CHOATE

THE BUILDING INDUSTRY HAS A SIGNIFICANT EFFECT on the natural environment. Using data from the Department of Energy, the U.S. Green Building Council (USGBC) states that each year, buildings use 68 percent of all electricity and 37 percent of all energy consumed in the United States. In addition, buildings collectively produce 46 percent of sulfur dioxide emissions (one of the most common causes of acid rain), 19 percent of nitrogen oxide emissions, and 36 percent of all human-generated carbon dioxide.[1] Everyone who is involved in the building industry—from planners to designers, contractors, and owners—shares responsibility for designing, constructing, and maintaining buildings in ways that ensure sustainability.

Sustainability is not so much a design practice as a way of looking at the world and its processes. Simply stated, the goal of sustainability is to bring three elements into equilibrium: community, economy, and the environment. Put another way, sustainability involves "meeting the needs of the present while not compromising the ability of the future to meet its own needs."[2]

The drive toward sustainability is affecting every facet of the built environment, including parking structures. Many sustainable practices are already being used in the design and construction of parking structures, but many more could be incorporated. The design and construction industry has numerous processes and tools to evaluate the economic impacts of parking facilities, but it is only starting to develop similar tools for evaluating the environmental and community impacts. Doing so will require changes at every stage of the development process. This chapter focuses on the sustainable design strategies articulated in the Leadership in Energy and Environmental Design (LEED) rating system of the USGBC.

Compact development and a mix of uses can be a major component of sustainability. A six-level, 448-space parking structure at Clayton Lane—a mixed-use retail project in Denver, Colorado—features street-level shops with the upper floors stepped back to maximize exposure to sunlight.

LEED STANDARDS

The USGBC is one of the leaders in efforts to integrate sustainable design into the building industry. The USGBC's major tool for promoting sustainable design is its LEED rating system, which establishes a common standard for evaluating green buildings. The LEED rating system is organized into six categories:

- ▷ Sustainable Sites;
- ▷ Water Efficiency;
- ▷ Energy and Atmosphere;
- ▷ Materials and Resources;
- ▷ Indoor Environmental Quality; and
- ▷ Innovation and Design Process.

A building is awarded credit points for meeting performance criteria associated with each of these categories. Depending on the total number of credit points awarded, a building can be LEED certified at one of four levels. In ascending order of rigor, the four levels are certified, silver, gold, and platinum.

Although parking structures that are part of mixed-use projects have received LEED certification, there are no free-standing parking structures that have been LEED certified. Current LEED criteria (versions 2.2 and 2009) include specific requirements for building occupants, and energy requirements that do not apply to parking structures. To an extent, parking structures can follow the USGBC's design philosophy (such as incorporating shared parking or encouraging public transit use), but the available reference guides for sustainable construction offer limited examples of technologies and strategies for parking structures.

Further, the LEED rating system's six categories all include prerequisites that must be met in order to obtain any level of LEED certification. Of the prerequisites that must be met before any level of LEED certification can be achieved, four of these only relate indirectly, at best, to parking structures. Of these four, two are in the Energy and Atmosphere category, and two are in the Indoor Environmental Quality category. Under the Energy and Atmosphere category, the prerequisite for minimum energy performance requires compliance with ASHRAE/IESNA (American Society of Heating, Refrigerating, and Air-Conditioning Engineers/Illuminating Engineering Society of North America) 90.1-2004. Garage lighting levels will need to be in compliance. However, heating and insulation

Elements of Sustainable Design

Sustainable Sites

▷ Develop on brownfield sites.

▷ Develop parking facilities that allow people to park their cars and choose public transportation.

▷ Minimize the development footprint by maximizing parking density (through underground or multistory structures) and by creating mixed-use facilities that integrate parking into their design. Consider the use of automated parking systems.

▷ To reduce light pollution, use cutoff fixtures on the top parking deck and along the building perimeter.

▷ Collect stormwater runoff in sedimentation basins to (1) water the landscaping on the site; (2) reduce runoff quantity; and (3) reduce suspended solids in stormwater.

▷ To reduce the heat island effect, provide planters and trellises on the top deck and install porous surfaces around the perimeter. Consider using open-grid paving systems such as Grasspave. (A parking structure may qualify for credits regarding the reduction of the heat island effect if the structure reduces the footprint of the hardscape area needed for parking.)

▷ Provide preferred parking for alternative-fuel vehicles and carpools.

▷ Install alternative-fuel refueling stations.

▷ Provide secure bicycle storage and shower facilities.

Water Efficiency

▷ Provide rainwater collection on parking roofs to replace or reduce the amount of potable water used for irrigation of landscaping.

▷ Provide on-site treatment of water used in the garage. (Garages typically consume water during biannual cleanings of floor spaces.)

Energy and Atmosphere

▷ Use green power.

▷ Use chlorofluorocarbon-free and hydrochlorofluorocarbon-free refrigerants in heating, ventilating, and air-conditioning systems for occupied spaces.

▷ Consider using renewable energy sources such as wind and geothermal.

▷ Install lights with timers.

▷ If the layout permits, construct light wells to reduce the amount of lighting required during daylight hours.

▷ To increase reflectivity and reduce daytime lighting requirements, paint the interior of the parking structure white.

Materials and Resources

▷ Use construction materials that are durable enough to resist the unique exposure conditions that parking facilities are subjected to.

▷ Provide recycling bins for patrons and staff to use.

▷ Ensure that construction waste is recycled.

▷ Specify the use of locally sourced building materials.

▷ Specify the use of “greener” building materials (for example, structural steel and reinforcing steel with high-recycled content, and concrete that includes supplementary cementing materials).

requirements will apply only to garage areas that are heated and/or cooled (typically, office spaces and stair/elevator lobbies). The second prerequisite that may not be applicable to parking structures in the Energy and Atmosphere category is the chlorofluorocarbon (CFC) reduction in heating, ventilating, air-conditioning, and refrigerating equipment. Parking structures rarely use equipment that requires refrigerants, so although they would technically meet this prerequisite, it does not really apply to them. The prerequisites in the Indoor Environmental Quality category are requirements for indoor spaces, and since open parking structures are not usually considered indoor spaces, the prerequisites do not apply.

Nevertheless, those who are involved in the design, construction, and operation of parking garages should not be discouraged from incorporating as many sustainable design elements as possible. Parking structures can contribute to some of the USGBC’s broad goals, such as the promotion of density and of vertical, rather than horizontal, development. Moreover, some institu-

▷ Consider using framing systems that will reduce the quantity of construction waste. For example, cast-in-place structures require formwork, but precast structures do not.
▷ Implement a parking maintenance program. Proper maintenance and repair help ensure that structures will achieve their anticipated service life.

Indoor Environmental Quality

▷ Specify low-VOC (volatile organic compounds) content for sealants, adhesives, paint, and coatings.
▷ Ensure that the chemicals used for cleaning are environmentally responsible.

Innovation and Design

▷ Plan for shared parking among adjacent community and business organizations.
▷ Optimize entry/exit lanes and parking-access and revenue-control systems to minimize vehicle delays and thereby reduce engine emissions.
▷ Use the results of parking and demand studies to create structures with an appropriate number of spaces. Garages without enough spaces can increase the amount of time drivers spend searching for an available stall. This, in turn, can increase congestion and engine emissions. However, garages with too many spaces can be a waste of construction materials and land.
▷ To promote the use of public transportation systems, create intermodal parking facilities.

tional clients, such as universities, local governments, and health care organizations, have LEED equivalency requirements for the design and construction of their buildings, and these requirements can also be applied to parking structures.

Many sustainable design elements are inherent to parking structures; others can be successfully incorporated with little or no additional cost. "Elements of Sustainable Design," on page 146, lists sustainable design strategies and classifies them according to the LEED categories.

DESIGNING WITH SUSTAINABILITY IN MIND

Although a thorough discussion of sustainable construction techniques and design features is beyond the scope of this chapter (for more information on this topic, see the USGBC's *LEED for New Construction Reference Guide Version 2.2*),[3] the three sections that follow describe how parking structures can earn points in the Sustainable Sites category. This information is presented to illustrate the possibilities for including sustainable design and construction practices in the development process and operation of parking facilities. In the Sustainable Sites category, credit points are awarded to projects that "avoid development of inappropriate sites and reduce the environmental impact of the location of a building on a site."[4] The points that parking structures could earn under this category would be based on site selection, alternative transportation, and the heat island effect.

Site Selection

The site selection credit is awarded to projects that avoid locations such as the following:
▷ Land that is defined by the U.S. Department of Agriculture as prime farmland.
▷ Land whose elevation is less than five feet (1.5 meters) above the elevation of the 100-year flood zone, as defined by the Federal Emergency Management Agency.
▷ Land that is located within 100 feet (30 meters) of any wetlands, as defined by federal regulations. (If distances required by local or state laws are more stringent, those will prevail.)
▷ Land that was previously public parkland, unless the public landowner accepts in trade, as parkland, land that is of equal or greater value. Many projects that are in downtown locations, or that are part of office parks or universities, would likely receive this credit point.

Alternative Transportation

The alternative transportation credit is intended to "reduce pollution and land development impacts from single occupancy vehicle use."[5] The alternative transportation credit includes a subcredit for parking capacity, which is required "to meet, but not exceed, minimum local zoning requirements and provide preferred parking for carpools and vanpools for 5 percent of the building occupants."[6] For a stand-alone parking structure, the

WATRY DESIGN, INC./MATTHEW MILLMAN PHOTOGRAPHY

With a rooftop photovoltaic system that powers lights and elevators, the City of Mountain View Parking Structure comprises four stories of parking above 16,200 square feet (1,505 square meters) of streetfront retail space.

parking capacity would be based on the building or buildings the parking structure serves, provide the minimum number of spaces required to meet local zoning requirements, and include spaces for carpools and/or vanpools.

Reducing the Heat Island Effect

The intent of the credit for the heat island effect is to "reduce heat islands (thermal gradient differences between developed and undeveloped areas) to minimize impact on microclimate and human and wildlife habitat."[7] Heat island effects can increase temperatures in urban areas by as much as 10 degrees Fahrenheit (12 degrees Celsius), which increases cooling loads for buildings. Decreasing the amount of dark roofs and paving and incorporating shading vegetation into sites can reduce peak summer cooling loads by over 20 percent.

The credit for the heat island effect has two parts: nonroof and roof. The nonroof portion requires that for at least 30 percent of the site's nonroof impervious surfaces, including parking lots, walkways, and plazas, (1) shade will be provided within five years, and/or (2) light-colored/high-reflectance materials and/or open-grid pavement will be used. Other options for obtaining the nonroof point require (1) placing a minimum of 50 percent of parking spaces underground, or covering them by building structured parking or (2) using an open-grid pavement system (less than 50 percent impervious) for a minimum of 50 percent of the parking lot area.

The roof portion of the credit for the heat island effect requires the use of Energy Star–compliant (highly reflective) and high-emissivity roofing for at least 75 percent of the roof surface,[8] or the installation of a green (vegetated) roof for at least 50 percent of the roof area. The credit also allows a combination of high-albedo and vegetated roof areas, as long as they collectively cover 75 percent of the entire roof.

Because structured parking extends vertically above or below ground and therefore minimizes impervious cover on a site, parking structures automatically meet the requirements for a nonroof credit. However, to decrease the total heat island effect of a project, any hardscape on the property (other than parking) should also be enhanced. The nonroof

WATRY DESIGN, INC./MATTHEW MILLMAN PHOTOGRAPHY

Landscaping on top of the 1,033-stall underground Stanford University Medical Center Parking Structure 4 reduces the heat island effect and helps to manage stormwater.

credit point could be achieved through the use of pervious concrete (which meets the requirement for being less than 50 percent impervious) for on-grade parking lots, walkways, and sidewalks. Pervious concrete is also significantly more reflective than asphalt. Other paving technologies that could be used for this credit include concrete with white or blended cement, pavement with reflective coatings and integral colorants, and open-grid paving systems. Pervious and open-grid pavements have the added advantage of helping to mitigate stormwater runoff.

The site design should also include vegetation to provide cooling effects through shade and evapotranspiration. Although most site designs for parking structures already incorporate trees and shrubs outside the structure, designers should strive not only to meet but to exceed the requirement that 30 percent of the site be shaded within five years.

Strategies similar to those used in the nonroof portion could be used to achieve the roof portion of the credit for the heat island effect. White cement could be used in the concrete mix for the uppermost deck; another option is to apply a white coating to the concrete deck. Either approach would help to reduce the heat island effect, and both options would likely qualify for the credit point, depending on the reflectance and emissivity of the deck surface. Vegetation could also be used on the top deck, either alone or in combination with white concrete or a white coating. Depending on the form and function of the top level of the parking structure, vegetation could be added in the form of planters scattered throughout the parking layout, or as part of a parklike setting that would include trees, plants, and grasses. Several underground parking structures have street-level decks that are completely covered with vegetation.

CONCLUSION

The parking industry must take responsibility for planning, designing, constructing, and maintaining buildings to minimize their impact on the environment and support sustainable development. The LEED point system provides basic design intents that can be used for improving the sustainability—and the image—of parking projects. The creation of greener parking structures is a matter of corporate responsibility; at the same time, the promotion and construction of such structures offers significant business opportunities for designers, owners, and operators.

NOTES

1. U.S. Department of Energy, Energy Efficiency and Renewable Energy Network, Center of Excellence for Sustainable Development, 2003. Cited in U.S. Green Building Council, "Building Momentum: National Trends and Prospects for High-Performance Green Buildings," U.S. Green Building Council, 2003; available at http://www.usgbc.org/Docs/Resources/043003_hpgb_whitepaper.pdf.
2. United Nations, United Nations Resolution A/42/187, "Report of the World Commission on Environment and Development," December 11, 1987; available at http://www.un.org/documents/ga/res/42/ares42-187.htm.
3. U.S. Green Building Council (USGBC), *New Construction Reference Guide Version 2.2*, 2nd Ed. (Washington, D.C.: USGBC, 2006).
4. Ibid.
5. Ibid.
6. Ibid.
7. Ibid.
8. LEED defines high emissivity as emissivity of at least 0.9 when tested in accordance with ASTM 408.

CHAPTER 16

Budgeting and FINANCIAL ANALYSIS

LARRY D. CHURCH, VICTOR M. IRAHETA,
JOHN PURINTON, AND MICHAEL P. SHAEFER

OWNERS, DEVELOPERS, AND OPERATORS of parking projects need to know how much to budget for construction. Construction decisions and budgets directly impact the long-term budgets for operations, maintenance, and repairs. Although design and construction professionals can refine the budget as the project develops from concept to completion, it is helpful for owners and/or developers to have a standardized method for generating budget or cost estimates at project inception. In this book, a *budget estimate* is defined as the estimate of probable cost developed by the design professional, and a *cost estimate* is defined as the estimate of cost developed by the contractor or construction manager.

This chapter describes two metrics—cost per space and cost per square foot—for generating budget estimates. These two metrics are related by parking efficiency, which is defined as the floor area per space. Using these standardized metrics allows owners and/or developers to easily compare various project alternatives. The chapter also provides a checklist that can be used to prepare a project budget, and addresses the costs associated with long-term facility operations such as maintenance and repair.

The building industry continues to show support for sustainable design and construction practices. High-performance, sustainable facilities typically require budgeting for the estimated life-cycle costs that include the initial construction and long-term operations or maintenance cost. Understanding the relationship between initial budgets and long-term budgets allows informed decisions for ownership and sustainable practices. If the initial design and construction requires premium costs or increased budgets, some or all of these costs can often be recovered through a combination of long-term savings on operations and higher sales values. Although long-term operations, maintenance, and repair are mentioned, this chapter focuses primarily on the initial construction budget.

The parking garage at Aurora St. Luke's Medical Center West, in Milwaukee, Wisconsin, has 1,336 spaces.

CONSTRUCTION BUDGET SEQUENCE

The level of detail in a budget typically increases as the project moves from concept to reality. The budgeting method outlined here provides the basis for reasonable estimates, but includes enough flexibility to address the changes that occur as the project advances. The sequential approach to budgeting used in this chapter is based on typical planning, design, and operations phases described in this book. Many projects follow the project planning and design phases described in the American Institute of Architects' Standard Form of Agreement between Owner and Architect (Document B101):[1]

▷ the programming and conceptual design phase;
▷ the schematic design phase;
▷ the design development phase;
▷ the construction documents phase;
▷ the bidding and negotiation phase; and
▷ the construction phase.

The first two phases (programming and conceptual design, and schematic design) can include various combinations of planning studies (chapters 1 through 5) and preliminary design studies (chapters 6 through 19).

During the initial three phases, the project is mainly conceptual, and the budget depends mostly on the information available from the design professional. As the designer prepares drawings and specifications to define the owner's requirements, contractors can use these documents for quantity takeoffs, and can use supplier proposals as a basis for construction cost estimates. Once the design documents are completed, contractors' bids or negotiations with contractors typically provide the owner with enough detail to proceed with construction and arrange for financing. (Financial institutions often require construction contracts to be executed simultaneously with financing documents.)

The best budgets rely on the strengths of various members of the project team during each of the design phases, as follows:

▷ *Programming, conceptual, and schematic design phases.* Design consultants clarify the owner's requirements, define project scope, evaluate options or special items with contractors or suppliers, and provide preliminary budgets and estimates.
▷ *Design development and construction documents phases.* On the basis of drawings and specifications and preliminary pricing from contractors or suppliers, design consultants provide more detailed budgets.
▷ *Bidding or negotiating phase.* On the basis of drawings and specifications, the contractor, construction manager, or construction estimator estimates overall costs.
▷ *Construction phase.* The contractor or construction manager estimates costs on the basis of the clarifications or change

WATRY DESIGN, INC./MATTHEW MILLMAN PHOTOGRAPHY

The 496,100-square-foot (46,089-square-meter) West Entry Parking Structure, at the University of California at Davis, has 1,519 spaces on six levels.

orders, and design consultants or construction estimators provide independent cost verifications.

BUDGET CONTINGENCIES

The actual cost of construction is generally not known until the work is complete. Accordingly, owners need to maintain contingency accounts to accommodate changes that can affect the initial cost—specifically,

▷ bidding contingency amounts to account for normal fluctuations in prices and bids not caused by inflation;
▷ design contingency amounts to account for clarifications made to the drawings during construction;
▷ contingency amounts for normal inflation, for increases that may occur during the design and construction process; particularly when it extends over several construction seasons; and
▷ contingency amounts for unforeseen conditions or other changes.

To ensure that cost estimates remain current as the design progresses, budgets must be kept in tune with fluctuations in the prices of materials and labor. During periods of rapid market change, contractors' bids remain valid for as little as 30 days—evidence of the delicacy that is required to keep calculations up to date.

BUDGET INDEXES

Construction budget ranges depend on many variable factors, including type of construction (cast-in-place concrete, precast concrete, or structural steel); architectural finishes; facade treatments; site conditions; region or location factors; financing method; and form of ownership. Because owners cannot define many of these variables until the construction is completed, many budget estimates are developed on the basis of the related indexes: cost per space and cost per square foot.

Cost per Space

The cost per parking space is the index most commonly used to budget new parking facility construction. As of 2009, the cost per space in "open" parking structures (as classified by code) is generally between $12,000 and $22,000.

Because cost per space is a blended average, it is important to understand the primary factors that determine it. These factors include building code classification, structural systems, regional location, accessibility (for example, downtown versus suburban), interior and exterior architectural finishes, landscaping, sustainable design elements, fire-protection systems, and access-control or revenue-control systems. Because the length and width of a site have a direct impact on parking efficiency (square feet per space), site dimensions also affect the cost per space. Below-grade construction and special uses at the top level, such as a plaza or landscaped areas, involve special construction requirements and costs. The costs of underground structures increase rapidly with the depth below grade: for example, if an above-ground parking structure costs $10,000 per space, the first below-grade level would cost $20,000 per space, the second $30,000, and the third $40,000.

Although cost per space allows for a direct comparison of total costs, it provides little insight into how or why a facility's costs might vary from the average. For a more detailed understanding, it helps to look at the cost per square foot (basic unit cost) and the parking efficiency to relate the basic unit cost to the cost per space.

It is easy to understand that a significant difference in cost per space results when a parking structure requires more square feet of floor area per parking space than an otherwise identical structure in the same locality. If both cost the same per square foot to construct, the less efficient design will cost more per space than the more efficient design. Likewise, if one structure costs more per square foot, the cost per space will differ. The aggregate cost difference becomes substantial when the costs are calculated for all the spaces in the facility. Assuming a 1,000-space facility, an increase of $1,000 per space will drive up the total construction cost by $1 million. Because parking geometrics (Chapter 7) and functional design (Chapter 8) determine parking efficiency, most financial analyses include at least a schematic level of functional design.

Area per Space

Parking efficiency depends on the efficiency of the use of the site, and on parking geometrics. New approaches to geometrics implemented since the 1970s have accounted for increases in efficiency of between 10 and 100 percent.

Among the factors that can affect parking efficiency are the length of the spans between columns, the use of single-loaded parking bays (that is, a drive aisle with parking stalls on only one side), and the design of the ramps for vertical vehicular circulation.

Several factors influence the area per space, including the following:

- ▷ user types (for example, employees, short-term shoppers, medical patients, event patrons);
- ▷ length, width, and shape of the building footprint;
- ▷ whether the facility serves a single use or a mix of uses;
- ▷ zoning requirements for parking space size, or supplemental requirements such as landscaping within parking areas; and
- ▷ local codes, including structural, ventilation, lighting, and fire-protection requirements.

Although there are a number of ways of defining floor area (including gross floor area, gross leasable area, and net floor area), this chapter relies on gross parking area (GPA), which is defined as the sum of the floor area on each tier, calculated as follows: "out-to-out" measurements of exterior walls, less any enclosed areas devoted to auxiliary uses such as stair towers, elevator shafts, lobbies, storage and equipment rooms, and any other uses such as retail or office space. This definition of GPA provides the measure that reflects the efficiency of the parking layout, while excluding areas (such as stair and elevator lobbies, and storage and mechanical space) that respond to specific project requirements.[2] This approach also allows for tracking unit costs for parking areas and associated areas (such as stairs, elevators, and mechanical spaces). Thus, this chapter defines parking efficiency as GPA divided by total parking capacity.

Parking efficiencies in new, self-park facilities with sloping parking ramps and long-span construction range from about 300 to 350 square feet (28 to 33 square meters) per space; the average is about 325 square feet (31 square meters) per space. The lower end of the range may indicate special

Life-Cycle Costs

When it comes to budgeting, initial costs are only a part of the equation. Life-cycle costs must also be taken into account. For example, the decision to use sustainable design practices may generate higher upfront costs, but those may be captured later, through lower maintenance or operating expenses, or longer service life. Similarly, the use of waterproofing and of corrosion-resistant materials may increase initial construction costs but reduce long-term operating, maintenance, and repair costs. Because the choice of structural system can affect the expected useful life of the facility, any evaluation of the relative cost-benefits of structural alternatives must address variations in service life.

The evaluation of life-cycle costs for buildings in general is defined in *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems.*[1] The American Concrete Institute (ACI) has also developed industry standards for the life-cycle analysis of concrete structural options and the prediction of service life. The ACI's *Service Life Prediction: State of the Art Report* summarizes industry-accepted criteria that can be applied to concrete parking facilities.[2] Independent industry groups have also developed computer models that can be used to evaluate concrete construction alternatives. The best models (1) calculate cost differences attributable to the use of various materials, (2) predict service life, and (3) use life-cycle costing methods to provide an understandable basis for the comparison of alternatives.

Notes

1. ASTM International, *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems*, ASTM E917-05 (West Conshohocken, Pa., 2005).
2. American Concrete Institute (ACI), *Service Life Prediction: State of the Art Report*, ACI 365.1R-00 (Farmington Hills, Mich., 2000).

designs, like small-car-only stalls; the higher end may indicate small, irregularly shaped sites, or mixed-use facilities with parking interferences from commercial, residential, or office space that is constructed above the garage.

When express ramps (that is, ramps that do not include space for parking) are used for some or all of the vertical circulation, the efficiency of the parking areas, excluding ramps, remains at about 300 to 350 square feet (28 to 33 square meters); however, when the ramp area is figured into the GPA calculation, as it is in most cases, efficiency can range from 375 to 450 square feet (35 to 42 square meters) per space, depending on facility size and the extent of the express ramping.[3]

Short-span construction, which is generally required in mixed-use facilities, adds 15 to 25 percent to the square footage of each space, increasing the average size to between 345 and 435 square feet (32 to 40.4 square meters) per space for structures with parking ramps, and to between 430 and 550 square feet (40 to 51 square meters) per space for structures with express ramps.

Users also have a significant impact on the area per space, because they determine the level of service (LOS) to which the facility should be designed. For example, because of lower turnover, employee or other long-term parking spaces can be designed with less generous parking-stall widths (that is, a lower LOS) than higher-turnover spaces, such as those designed for retail customers. A narrow site may dictate a shallow parking angle and preclude 90-degree parking, which is generally more economical in terms of space per stall. An irregular footprint creates wasted areas, and mixed-use facilities are less efficient because of the need for infrastructure to support the other uses. Finally, local zoning and code requirements can decrease parking efficiency by, for example, requiring wider spaces or aisles.

Cost per Square Foot

The second index for understanding cost efficiency is cost per square foot, which is defined as construction cost divided by GPA. The construction cost is the total sum paid to the contractor, including the cost of change orders issued during construction but excluding design fees and fees for testing services.

Cost per square foot is affected by a number of factors, including the following:

- geographic location (for example, snowy and coastal states must protect against salt damage, whereas desert states need not);
- the number of levels in the facility;
- the topography and shape of the site;
- soil and site conditions (for example, some above-ground sites may require expensive retaining walls or extensive excavation and dewatering);
- the need for supporting infrastructure; and
- local construction costs and practices.

A simple, above-ground, open parking structure generally costs between \$35 and \$65 per square foot (between \$323 and $538 per square meter) depending on the locality; amenities and architecture can easily add $5 to $25 per square foot ($54 to $269 per square meter).

Cost per square foot can vary dramatically if parking is underground, if the structure has only one supported level, or is high rise (eight or more levels). The rule of thumb for underground parking is that the cost of each level below grade is a constant plus the cost of the level immediately above it. Thus, as in the example used earlier, if the first below-grade level costs $60 per square foot ($646 per square meter), the second will cost $90 per square foot ($969 per square meter) and the third $120 per square foot ($1,292 per square meter). However, because subsurface conditions have a major impact on cost, experience with other, similar underground facilities and with the site-specific geotechnical information can greatly increase the reliability of cost-per-space estimates for underground parking.

High-rise structures generally require standpipes, sprinkler systems, ventilation, and sometimes other life-safety features that can add $5 to $10 per square foot ($54 to $108 per square meter).

Supplemental costs for exterior facade requirements, architectural finishes or treatments, stairs, and elevators (elevator height, speed, number of stops) are typically evaluated independently of the parking floor areas.

Cost per square foot does not include land, development, design, financing costs, or required reserves. An initial budget should include an additional 20 percent or more for soft costs. Additional reserves should be included for land and development.

A BUDGETING CHECKLIST

The detail of any cost estimates must be greatly refined by the time the owner begins to seek financing. The budgeting checklist shown in Figure 16-1 is designed to help ensure that no significant costs are overlooked. The checklist divides project costs into ten broad categories:

- ▷ land costs;
- ▷ development costs;
- ▷ design costs;
- ▷ construction costs;
- ▷ other owner costs;
- ▷ financing costs;
- ▷ grant program costs;
- ▷ development and construction period interest;
- ▷ reserves; and
- ▷ contingencies.

The discussion that follows focuses on a few selected items included in the checklist.

Land Costs

Of the four components of land costs listed in Figure 16-1, the two that can significantly increase the budget for land costs are special assessments and environmental remediation.

Development Costs

While private developers are usually aware of development costs, government entities often overlook them. Development costs range anywhere from 5 to 15 percent of total project costs. Particularly if the project includes a mix of uses, such as residential, commercial, and office space, the marketing expense can be significant.

Design Costs

Of the design costs associated with a new parking structure, the design fees listed in Section C of Figure 16-1 are usually included as part of a single design contract. Funds for geotechnical investigation, environmental assessment, and zoning variances are often left out of budgets, but they can be significant and should be included.

Construction Costs

The construction portion of the checklist is typical of most building construction; however, a few of the items are unique to parking, including access-control equipment and ventilation equipment, which is required for underground facilities. Parking also generally requires special security and signage.

Other Owner Costs

Because of changes in construction methods for parking facilities, more and more owner/developers now retain the services of a construction manager to contain costs and ensure timely completion. At the same time, increasingly stringent regulations require extensive testing and inspections during construction, which can be the province of an owner's representative or construction manager.

A construction manager, a designated owner's representative, and inspection agencies can assist the owner in

FIGURE 16-1: Budgeting Checklist: Development and Construction

A. Land Costs
Acquisition
Special assessments
Closing costs
Environmental remediation

B. Development Costs
Site feasibility analysis
Title and recording fees
Real estate taxes during construction
Utilities during construction
Insurance during construction
Interim financing during construction
Legal fees
Audit/cost certification
Financial feasibility study
Predevelopment fees
Development consultants' fees
Relocation expenses
Historic preservation
Governmental oversight
Special-district formation
Marketing
Startup expenses
Initial equipment
Real estate taxes
Insurance
Working capital
Initial operating deficit

C. Design Costs
Design fees
- Architectural design
- Civil engineering
- Structural engineering
- Mechanical engineering
- Electrical engineering
- Landscape design
- Interior special materials
- Traffic/parking consultant

Surveys
Geotechnical investigation
Environmental assessment
Additional site representation during construction
Allowance for redesign during construction
Testing services during construction
Zoning variances

D. Construction Costs
General conditions
- Builder's overhead
- Builder's profit
- Permits, fees, and plan checks
- Municipal service charges
- Builder's risk
- Bond premium

Site improvements and demolition
Off-site improvements
Earthwork and foundations
Structural system
Architectural treatments
Masonry
Miscellaneous metals, wood, and plastics
Roofing and waterproofing
Doors, windows, and glass
Stairs
Finishes
Access-control equipment
Revenue-control equipment
Furnishings
Special construction
Elevators/escalators
Heating, ventilating, and air conditioning
Mechanical systems, plumbing, and fire protection
Electrical, lighting, and security systems
Signage and markings

E. Other Owner Costs
Owner's representative
Construction manager
Tests during construction
Quality-control reviews
Owner-furnished equipment and fixtures

F. Financing Costs
Public and/or private financing
Financial adviser
Bond counsel
Issuer's counsel
Special tax counsel
Underwriters' fee and origination fee
Underwriters' counsel
Bank counsel
Rating-agency fees
Credit-enhancement fee
Credit-enhancement counsel
Bond-issuance fees (local government only)
Appraisal
Trustee fees
Counsel fees
Accountant verification
Escrow agent
Paying agent
Registration
Printing
Inspection engineer
Miscellaneous fees

G. Grant Program Costs
Grant program–specific fees
Grant writer fees

H. Development and Construction Period Interest
Capitalized gross or net interest (net interest is gross interest minus interest earnings)

I. Reserves
Capital-replacement reserve
Operating-deficit reserve
Debt-service reserve

J. Contingencies
Land acquisition
Design
Construction
Other owner costs
Development
Financing

WATRY DESIGN, INC./MATTHEW MILLMAN PHOTOGRAPHY

Parking Structure Number 6, in the Mission Inn Historic District of Riverside, California, provides 208,210 square feet (19,343 square meters) of parking for 556 vehicles, above 35,000 square feet (3,250 square meters) of street-level office and retail space.

ensuring that furnished equipment and fixtures are in place and that the project (1) is constructed according to plans and specifications and (2) meets quality-control criteria. Another function of the construction manager is to identify fixtures or equipment that may have been overlooked.

Contingencies

The amount of funds set aside for six of the budget categories—land costs, development costs, design costs, construction costs, other owner costs, and contingencies—depends on the original budget estimates and how far along the project is.[4] Contingency amounts for land acquisition, for example, are usually set aside for potential environmental remediation costs. During the schematic design phase, the owner/developer might set aside 10 percent of design and construction costs for such contingencies; once the construction documents are completed, however, the owner/developer might reduce that amount to 5 percent.

The stringency of the owner's cost accounting can also affect contingency amounts: an owner who tracks costs carefully and can therefore better estimate these costs has less need for the protection afforded by larger contingency amounts. Regardless of cost-accounting procedures, however, it is often prudent to set aside a certain percentage of the total project cost as undesignated funds.

FIGURE 16-2: Budgeting Checklist: Maintenance and Repair

Preventive maintenance
- Sealants
- Expansion joints
- Penetrating sealers
- Traffic-bearing membranes

Routine maintenance
- Sealants
- Sealers
- Concrete patching
- Plumbing and drainage system
- Lighting
- Access-control system
- Revenue-control system
- Inspections
- Condition appraisals
- Elevators
- Fire-protection systems

Replacement and repairs
- Structural
- Architectural
- Electrical
- Mechanical and plumbing
- Fire protection
- Access-control system
- Revenue-control system

BUDGETING FOR MAINTENANCE AND REPAIR

The operations and maintenance budget is the total of anticipated expenditures over the building's expected useful life (service life). The *Parking Garage Maintenance Manual* identifies three primary types of maintenance cost:

▷ Preventive maintenance: actions to protect the useful life of the structure or equipment.

▷ Routine maintenance: periodic repairs and corrective actions necessary to maintain operations.

▷ Repair and replacement maintenance: repair of damaged or worn out structural components or equipment.[5]

Regular maintenance is required to realize the originally anticipated useful life of a structure. Maintenance does not, however, prolong useful life; nor does it add to the value of a parking facility. Nevertheless, lack of maintenance can reduce the value of a facility and shorten its useful life. Thanks to enhanced features, materials, and procedures, the expected life of special facilities—such as garages that support other buildings or uses—can extend beyond 50 years.

Maintenance and repair requirements and procedures are typically defined in the operations plan for a parking facility. Ideally, the operations plan is developed during the preliminary design phase. At this point, the owner/developer selects the construction materials, sustainable design criteria, preventive maintenance measures, and other elements that will best meet the initial and the long-term goals for the facility.

A maintenance and repair budget for a parking facility will depend on the original construction materials and details, exposure conditions, operations, the current condition of the facility, and expected performance. To ensure that adequate funds will be available for maintenance, the owner/developer typically commissions (1) a condition appraisal, to evaluate the current condition of the facility, and (2) a parking asset management plan, which is used as the basis for a five- to ten-year maintenance budget. Budgeting for repairs often requires more detailed evaluations. To choose between various repair and maintenance alternatives, each of which will yield a different service life, the owner/developer will need to commission a life-cycle cost analysis.

Figure 16-2 lists items typically included in maintenance budgets. For parking facilities, the factors that have the greatest impact on maintenance and repair costs are the condition of the structural system, the details of structural elements and connections, the level of corrosion protection for the structural system, waterproofing and sealant systems, the level of chloride-ion contamination (which indicates the depth of corrosion in the concrete), and the amount of concrete that has been removed during previous repairs.

Operating a parking facility requires other procedures and expenditures aside from those identified in the maintenance checklist, such as management, housekeeping, security, and utilities. Such expenditures are discussed in greater detail in the last three chapters of this book.

NOTES

1. American Institute of Architects (AIA), *Standard Form of Agreement between Owner and Architect*, Document B101 (Washington, D.C.: AIA, 1997).

2. Most building codes and industry groups, such as the Institute of Transportation Engineers, use the gross area measure—as opposed to the net area measure, which is calculated "in to in"—to define floor area.
3. The circular helix is virtually the only type of express ramp that is not included in efficiency calculations. Because circular helixes represent high costs undertaken within a relatively small area, they can significantly skew the calculation of both parking efficiency and cost per square foot. Therefore, the estimated cost for the helixes is typically calculated separately from cost per space.
4. Financing costs are generally estimated fairly closely, so large contingency reserves for financing are rarely needed.
5. John G. Burgan et al., *Parking Garage Maintenance Manual*, 4th ed. (Washington, D.C.: National Parking Association, 2004).

CHAPTER 17

Project DELIVERY

VICTOR M. IRAHETA AND LARRY D. CHURCH

AN OWNER/DEVELOPER EMBARKING ON A NEW PROJECT needs to know how, when, and by whom the project will be designed, built, and operated. In other words, what approach to project delivery will be used? Project delivery matters because it can affect feasibility. In selecting a project-delivery method, owners need to find a good match between the project's specific needs and requirements (including cost, schedule, financing, location, and aesthetics) and the experience and qualifications of the project-delivery team.

The process of selecting design, construction, and construction-management firms is known as the *procurement process*. Broadly, the procurement process involves the submission of proposals or bids in response to terms and conditions specified by the owner or the owner's agents. The three principal project-delivery methods are design-bid-build (also known as *conventional bidding*), construction management, and design-build. The sections that follow consider each of these approaches, as well as some variations on these approaches.

DESIGN-BID-BUILD

Design-bid-build is the most common method of construction procurement. The first step in design-bid-build is the selection of a design professional. The selection is based on two factors: (1) the designer's qualifications and experience, and (2) the price. Ideally, the design professional should be a parking consultant (PC) with demonstrated experience in the design of parking structures. The design professional helps the owner/developer define the project scope, prepares detailed plans and specifications, and assists in soliciting bid proposals from contractors. The project is then constructed in accordance with the design professional's plans and specifications. In many cases, the owner will also retain a PC before selecting the design professional. The PC will then be asked to undertake a series of studies and analyses (such as supply/demand

Bordering two sides of a running track and athletic field, the Calhoun Street Parking Garage in Cincinnati, Ohio, is a four-level, cast-in-place building with space for 1,000 vehicles.

studies, financial analyses, and shared-parking studies) to determine or to more clearly define the owner's needs, and/or to investigate the financial aspects of the proposed endeavor. Clearly defining the owner's needs allows design professionals to provide refined proposals that can more easily be compared.

In its purest form, design-bid-build requires all drawings and specifications to be complete before they are made available to contractors to submit construction bids. Although the theory is that the owner will select the contractor who offers the lowest responsive price, private owners are not required to do so; government regulations, however, may require public owners to accept the lowest bid. To protect their interests, public owner/developers should prequalify contractors to eliminate firms that are undesirable on the basis of experience, size, or financial stability.

With the help of the design professional, the owner evaluates the bids and then selects and contracts directly with a contractor for construction of the project. The design professional remains involved in the project to review shop drawings and observe construction on behalf of the owner.

Design-bid-build generally works well, especially for public projects; its advantage is that it almost entirely eliminates the possibility of subjective evaluations during the selection process. This is because the owner/developer reviews and approves the final design before committing construction dollars and can choose a contractor on the basis of bids that are founded on completed construction documents, which have the lowest probability of changes. During construction, the design professional is contracted directly to the owner/developer and acts as his adviser.

Nonetheless, the several potential disadvantages of design-bid-build have led to variations and alternative project-delivery methods. Concerns about time frames—from the selection of a design professional to project completion—have led to the fast-track method, issue for pricing, and the design-build arrangement. In addition, concerns about the lack of contractor input on issues such as constructability, cost savings, and schedule impacts are common during the design phase and have led to negotiated contracts, construction management, and design-build contracts. Further, concerns about the inconvenience and financial risk associated with separate design and construction contracts—which are standard in design-bid-build—have led to the design-build arrangement, in which the owner has only one contract with the design-builder. The following three sections address variations to design-bid-build contracts and explain how they differ from design-bid-build.

Negotiated Contracts

One variation of design-bid-build is a negotiated contract. In this method, as with design-bid-build, the design professional and the contractor each have separate contracts with the owner. However, with a negotiated contract, the contractor is selected during the design process based on reputation, relationship with the owner, and experience. In some cases, the selection is also based on the estimated construction cost, which is derived from preliminary documents in lieu of completed design documents. The owner may issue a request for proposals (RFP) and preliminary drawings, which describe the scope and quality of construction in general terms, to select a contractor. A contractor selected during the schematic design or design development phases can have input into design decisions to help control costs.

In some negotiated contracts, when the construction documents are completed, the contractor confirms the earlier estimated construction cost. If all terms are acceptable to both the owner and the contractor, the two parties execute a formal construction contract. In other negotiated contracts, the owner and contractor may share construction-cost savings below an agreed-on price. Even with prequalification, the low-bid contractor may not offer the best quality or value. The contractor may try to cut corners, or to secure unjustified extras to compensate for the low bid. In some cases, negotiated contracts for construction have proven more successful, at least for private owners.

Fast-Track Method

Compressed project schedules mean that it is not always possible to wait until all drawings are complete to award a construction contract. The fast-track method responds to the need for accelerated scheduling of design and construction.

In this approach, as portions of the design are completed, they go out separately for bid and are awarded to specialty contractors (foundation, superstructure, mechanical, electrical, plumbing, and so forth), thus speeding the start of construction. Fast tracking can cause problems, however, if the final design of later project components affects components that have already been awarded and may even be under construction. Moreover, if a large project involves several contracts with specialty contractors, the owner may face additional responsibilities for administration and coordination. These responsibilities are usually handled by a general contractor, and thus the fast-track method may create a need for a construction manager.

Issue for Pricing

Another variation on design-bid-build, called *issue for pricing,* involves bringing the design drawings to between 50 and 90 percent of completion before releasing them for bid. The drawings are then completed during the bidding and award phases and sometimes early in the construction phase, while shop-drawing production is still underway. Like the fast-track approach, issue for pricing allows the schedule to be accelerated, but it also creates a risk that changes occurring after the award of the construction contract may cause the contractor to make a significant claim for additional compensation or construction time.

Issue for pricing may work well on routine projects with contractors, design professionals, PCs, and owners who are familiar with each other and with the type of project to be designed. However, it can lead to misinterpretation in the case of unique or complex projects, or when the design professional, contractor, or owner is unfamiliar with the type of structure under construction.

CONSTRUCTION MANAGEMENT

Every project includes a wide range of tasks, such as cost estimation and control; the selection of products, systems, and contractors; the assessment of market conditions; and the review of constructability concerns. Traditionally, these tasks have been performed by the design professional, the general contractor (GC), or both. But certain factors, such as new technologies, the development of fast tracking, and the general trend toward specialization, have led to the need for independent construction managers (CMs) to coordinate design, construction, and administration.

Construction management involves managing the entire building process, including planning and design, and should more appropriately be called *project management*. To ensure the best results, the CM must be brought on board early in the project. The CM is selected on the basis of qualifications, experience with similar projects, overhead costs, fee structure, and a preliminary estimate of the probable construction cost. The CM participates in the design process, providing the owner with updated construction-cost estimates and suggesting cost-saving revisions.

Advantages and Disadvantages

Construction management is particularly helpful in the case of large or complex projects. When used correctly, construction management offers a number of advantages:

▷ avoiding duplication of responsibilities;
▷ minimizing the risk of cost overruns;
▷ accelerating the schedule through the use of fast tracking, multiple prime contracts, and budget estimates (budget pricing typically relies on cost per square foot or cost per space, as opposed to detailed, quantity-based cost estimates); and
▷ reducing the owner's management burden.

FIGURE 17-1: Construction Manager as Adviser

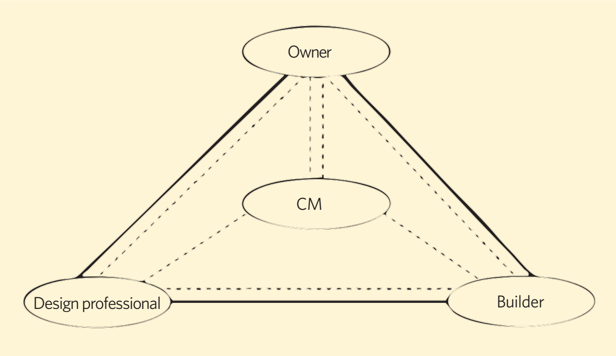
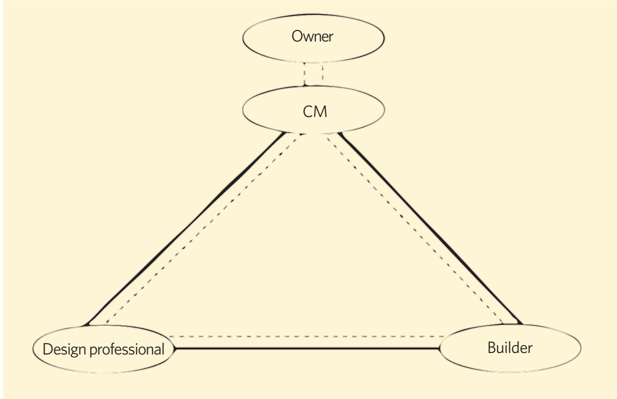


FIGURE 17-2: Construction Manager as Agent



The CM also brings specialized knowledge of market conditions, and of new technologies that may influence the selection of systems. Finally, in several types of construction-management arrangements, the CM acts as a liaison and resolves differences between the designer and the contractors.

However, unprofessional or poorly trained CMs can become communication bottlenecks, and drive up costs by causing design professionals to undertake unnecessary rework. At worst, CMs can supplant owners' interests with their own.

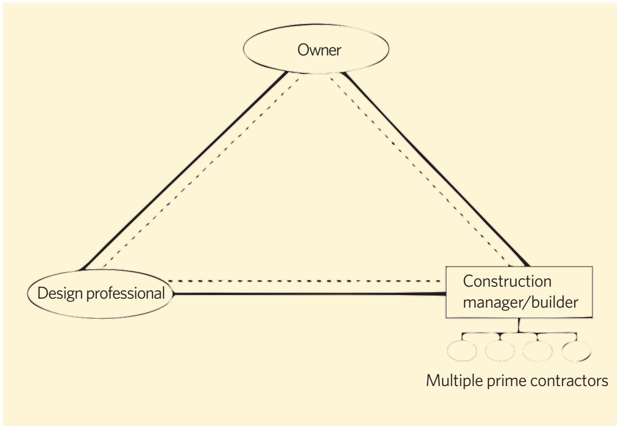
Construction-Management Models

The three basic construction-management relationships are CM as adviser, CM as agent, and CM as constructor (see figures 17-1, 17-2, and 17-3).

In the first approach, the CM enters into an independent consulting contract with the owner to perform certain functions, some of which would otherwise have been handled by the PC, the design professional, or the contractors. The CM is not, however, at financial risk for the overall cost of the project.

The CM-as-agent approach is similar to the CM-as-adviser approach, except that the CM (1) holds the contracts with the design professional and with the contractors, (2) makes decisions on the owner's behalf, or (3) does both. Thus, in the CM-as-agent approach, the CM may have a contractual relationship with, and responsibility for, the designer and builder—as in a design-build arrangement. A CM acting as the owner's agent assumes some legal risk—and possibly some financial risk—related to the various pass-through contracts, but the risk is not related to the final cost of construction.

FIGURE 17-3: Construction Manager as Constructor



The CM as constructor is, in effect, the GC—and may therefore subcontract out all or part of the usual GC services. Because the CM as constructor does bear financial risk related to the final construction cost, this approach is sometimes known as *CM at risk.* Among the possible financial arrangements are cost plus fee, guaranteed maximum price (GMP), partial GMP with exclusions, and a cost-plus-fee target price with incentives and penalties.

In the CM-as-adviser and CM-as-agent approaches, the CM is contractually obligated to act in the owner's best interest. Under the contractual arrangements that define the CM-as-

Additional Design-Build Resources

Additional information on design-build is available through a variety of sources, including the following:

- ▷ American Consulting Engineers Council (www.acec.org)
- ▷ Design-Build Institute of America (www.dbia.org)
- ▷ XL Design Professionals Insurance (www.xldp.com)
- ▷ Federal Acquisition Regulation (www.acquisition.gov/far).

constructor approach, however, the CM acts solely or partly in his own interest; the CM does not have a contractual relationship with the design professional, as is the norm in a design-build arrangement. This delivery method increases the risk to the CM, but also proportionately increases the financial reward.

Traditionally, the CM as agent and CM as constructor have been the most common construction-management arrangements for parking facilities, with a GC generally performing this role. One reason for the predominance of GCs, as opposed to design professionals, performing the role of CM is that the dollar value of construction services is much greater than that for design services. Therefore, GCs have a detailed familiarity with a much greater percentage of the overall project. In addition, some professional liability policies held by design professionals exclude coverage when a design professional has an ownership interest in a project.

DESIGN-BUILD

The design-build project-delivery method can take two forms: *competitive* and *negotiated*. In the competitive approach, the owner/developer, often with the assistance of an independent designer, assembles information that describes the scope and requirements of the project, and then solicits competitive construction proposals from design-build teams. In a well-structured selection process, price will be only one of the factors considered. Other factors will include qualifications such as relevant experience, proximity to the owner and/or the project site, the statement of interest, the project approach, and the quality-control plan. To ensure that the selection is not based on price alone, each of the relevant factors should be ranked. The selected design-build team prepares the final plans and specifications, and constructs the project for a fixed price that includes the design fees for the project.

In the negotiated design-build approach, the owner/developer begins by selecting the designer and the builder, generally on the basis of the same factors used in the competitive approach. From the outset, the designer and contractor work together to produce the project design, which will reflect value-engineering suggestions from the contractor.

Benefits of the Design-Build Approach

Design-build offers a number of potential benefits. First, the owner negotiates and administers a single contract, and responsibility for completion lies with a single entity. This arrangement can protect the owner from involvement in contract disputes between the designer and the builder, which is advantageous because such disputes often lead to delays and additional costs. However, design-build does not necessarily eliminate the possibility of disputes between the owner and the designer-builder.

Second, design-build can yield substantial time savings because design and construction can overlap. However, the amount of savings will depend on a number of factors, including the level of owner involvement, the time of year, and the submission requirements for building permits. Other bidding methods, such as fast tracking, may provide similar time savings.

Third, design-build can yield still more cost savings if both the designer and the contractor, each with specialized knowledge that the other may not have, collaborate on innovative and cost-effective solutions to issues that arise during project development. Collaboration also eliminates some duplication of effort in areas such as administration and cost estimation.

Risks of the Design-Build Approach

For all its advantages, design-build poses some potential risks. For example, because the design is not complete at the time the designer-builder is selected and the contract and price are negotiated, the owner relinquishes some control over the design. Specifically, the owner can request changes but risks additional charges for modifying portions of the project that have already been constructed.

Nonetheless, the owner can minimize the risk of additional construction costs. First, a thorough RFP should be prepared, including preliminary design drawings and specifications. The RFP should clearly establish the minimum quality standards and goals of the project. For example, is it preferable to have

Using a Consultant

Depending on the owner's knowledge and available time, it may be advisable to retain a consultant experienced in the design of parking facilities, particularly with respect to the following:
▷ evaluating initial needs, and conducting feasibility and site-selection studies;
▷ obtaining project approvals and funding;
▷ preparation of request-for-proposal documents, including instructions to bidders, design criteria, selection criteria, preliminary specifications, and (possibly) schematic design;
▷ evaluation of proposals; and
▷ advising owners during design and construction.

500 spaces arranged as efficiently as possible, or should there be as many spaces as possible on the site? Second, the selected proposal should be thoroughly evaluated, particularly for conformance with the criteria. Changes and clarifications can be requested at this time. Third, the owner can authorize the selected designer-builder not to proceed with construction until the affected parties have agreed on the design. If changes to the proposal are necessary, price adjustments can be made without reworking any of the completed construction.

Another potential risk of the design-build approach is that the design professional does not play the traditional role of owner's adviser. Instead, as part of the design-build team, the design professional is obliged to advance the interests of the designer-builder. Legally, the designer is a vendor, not an agent, and therefore has different rights and responsibilities. Thus, the owner should make a point of selecting a designer-builder on the basis of qualifications and reputation, as well as price.

If necessary, the owner should hire an independent consultant to undertake the preliminary design, to evaluate proposals, and to monitor the work of the designer-builder. Finally, the owner might consider contracting for construction-inspection services, either with an independent consultant or with a construction-inspection firm.

Selecting a Designer-Builder

The negotiated method of selecting a designer-builder involves making a selection solely on the basis of qualifications, then


©BLAKE MARVIN/HKS INC.

The Terminal D parking structure at the Dallas/Fort Worth International Airport.

(1) negotiating a price and schedule or (2) refining the price and schedule as the design evolves. The owner may negotiate with a design-build firm with which he is already familiar, or with a firm recommended by a reliable source. Alternatively, the owner may find a qualified designer-builder by issuing a request for qualifications (RFQ). The RFQ should ask interested firms to submit qualifications including name; background information; corporate and financial data; details of previous experience; references; and resumes of the designer-builder, the professional designers, and other key staff.

In an approach that combines two primary selection methods, the owner preselects a limited number of design-build teams (through an RFQ or other means) and then issues an

In Colorado Springs, Colorado, T. Rowe Price has space for 591 vehicles in Parking Structure Number 2.

RFP to those teams. The proposals are then evaluated on the basis of qualifications, price, schedule, and other factors. Even if all proposers have been prequalified, some may reveal a fuller understanding of specific issues, demonstrate a greater commitment to the project, offer a desirable schedule, provide more value, or simply present a better design.

The more complete the RFP, the more complete and directly comparable the responses will be. A good RFP has the following characteristics:

▷ A clear statement of the design criteria—including, if necessary, schematic design drawings and preliminary specifications.

▷ As much background information as possible. Site-specific information might include surveys, topographical surveys, a geotechnical soil report, aerial photographs, and hazardous-materials reports.

▷ A clear statement of the requirements for the RFP submittal. It is customary to ask for price, schedule, schematic plans and elevations, descriptions of major systems or components not shown on plans (structural, mechanical, and so forth), a staffing plan, an organizational chart, a bid bond, and a certificate of insurance.

▷ A clear statement of the selection criteria. If price is the only criterion, the RFP requirements should say so, although selection on the basis of price alone is not recommended.

▷ A statement of the relative weights allocated to the various evaluation categories, so that each proposer knows what is most important to the owner.

Sufficient time must be allotted for proposal preparation; typically, turnaround time ranges from two to eight weeks, depending on the size and complexity of the project and the detail requested. Compressing this phase of the project will only cause problems later. A schematic design can be expected from each team as part of the proposal, especially for the purpose of establishing that the teams understand the goals of the project. If design is the predominant criterion, with less emphasis on price or schedule, the selection process will resemble a design competition. To defray the high cost of proposal preparation for complex projects, the owner may offer an honorarium to each prequalified design team.

Design-build project delivery has been common in the private sector for years, and many government laws and procedures have been amended to allow design-build. For example, the General Services Administration (GSA) has established procedures for a two-phase design-build procurement method. In phase one of the GSA's procurement process, an independent design professional is retained to prepare a scope-of-work statement and provide technical

WALKER PARKING CONSULTANTS

The Historic Downtown Parking Facility at the Visitor Information Center in St. Augustine, Florida, has space for 1,164 vehicles.

advice throughout the project. Phase two begins with the selection of the design-build team.

Since this procedure has been established, public sector agencies now use design-build more often. Public agencies also frequently use the two-envelope method, in which the technical and non-price-related items are reviewed before the price is known. This is done in order to avoid distorting the separate parts of the evaluation. The teams are ranked based on qualifications, and the highest-ranked team within an agreed-to percentage of the lowest responsive bid is selected. This approach makes it possible to select the most qualified team at a competitive price.

Whereas design-build combines design and construction into a single contract, design-build-finance and design-build-operate combine financing or operations, respectively, into the same contract. Such arrangements are often referred to as *turnkey construction*.

EQUITY PARTNERSHIPS

In the event that an owner cannot or chooses not to raise the money for a parking facility by conventional means, an equity partner can be secured. In most cases, the equity partner serves as the temporary or permanent owner and contracts with the original owner to furnish all or part of the facility under a variety of agreements, including free rental, lease, and lease-purchase. In some cases, the original owner may retain ownership of the land; in others, the original owner may lease the land to the equity partner as part of the agreement.

Equity partners often require a greater return on investment than conventional lending sources because of their “risk capital” funding status. The demand for a higher return, in turn, requires a higher-than-usual revenue stream from parking fees, or requires other aspects of the project to provide the necessary funding levels. In many cases, the original owner would be well-advised to consider some form of design-build-finance as an alternative to bringing in an equity partner.

OPERATIONS SERVICES

An owner may wish to contract with a parking-management firm for operation of the facility. In fact, it is becoming more common to package the operations function with design, construction, and financing, thereby creating one package for all the services required by the owner.

Several major parking management firms are willing to consider any feasible project as a total development package. These firms use their own resources to fund the project, or acquire funds from a financing partner with whom they collaborate regularly. Similarly, operators can secure project design and construction services from firms that they engage regularly. The operations-services approach yields a single development package with a single source of responsibility for the project that can extend 30 years or longer. The drawback to this approach is that the owner relinquishes the right to modify any conditions whatsoever without the consent of the operator.

CHAPTER 18

Automated Parking FACILITIES

DONALD R. MONAHAN AND RICHARD BEEBE

HENRY FORD HAS GENERALLY BEEN CREDITED with the development of the mass-produced motor car as we know it. He may also be credited with creating the parking space shortage. Major parking problems began to emerge even before World War I, and grew rapidly thereafter. During the prosperous post–World War II years, the increasing number of automobiles created a demand for parking that spread from the streets to vacant lots and parking structures of many types. One popular approach to dealing with the problem was to retrofit large buildings with freight-elevator systems that were designed to accommodate parking. Even in newly constructed multilevel garages, elevators predated ramp-access garages, which required larger footprints and more ingenious structural systems.

Early elevator systems—that is, mechanical-access garages—employed an attendant who drove the automobile onto an elevator, operated the elevator from the driver's seat, and drove the car into a parking space on an upper-level floor. In the United States after World War II, there was a surge in the construction of these mechanical parking systems. Richard Bowser constructed a mechanical garage in Des Moines in 1951, and went on to build dozens of others, including three in Chicago: one on LaSalle Street, which had 375 spaces and was erected in 1954; one on Wacker Drive, which had 718 spaces and was erected in 1955; and one on Rush Street, which had 420 spaces and was erected in 1955. Among the other notable mechanical systems were the Park-O-Mat, in Washington, D.C. (72 spaces, erected in 1951); the Pigeon-Hole, in Toronto (396 spaces, erected in 1957), and the Speed-Park, in New York City (270 spaces, erected in 1961). Most of these facilities have since been demolished to make way for more modern and higher-use buildings.

Generally, mechanical garages have been more popular overseas, where land is particularly scarce in major urban areas. A self-park, ramp-access garage requires a minimum land area of approximately 150 feet by 125 feet (46 by 38 meters)—a parcel size that is rarely available in the downtowns of major cities, particularly in Europe

The first step in using an automated garage is for the driver to park on a steel pallet. Once the driver has left the car, he or she uses an electronic key card or coded ticket to activate the storage process.

and Asia. Mechanical systems, in contrast, can be constructed on parcels as small as the size of two parking spaces: 20 feet by 20 feet (six meters by six meters). Moreover, technological advances now allow computers to control the lifts and horizontal transport devices—allowing greater reliability than was possible with the older mechanical (hydraulic) parking systems. Because it is much easier to incorporate redundant components—including backup power and backup computers—into computer-controlled facilities, such systems are up to 99.9 percent reliable.

CONTEMPORARY AUTOMATED FACILITIES

Whereas the older mechanical parking systems required an attendant, today's automated facilities require no human assistance. Automated parking facilities consist of a large vault with steel racks for storing cars on either side of a transport aisle. The racks are often four to ten levels high, and sometimes higher. The vehicle is often transported on a steel pallet, which has rollers that slide into guide rails located in the storage space. Because the storage vault is unoccupied, neither fire-exit stairs nor elevators are required. In addition, the parking facility is more secure because the public is not allowed inside the storage vault. And since the vehicles are not operated during transport, ventilation of vehicle emissions is not required. Lighting requirements and heating, ventilating, and air-conditioning requirements are greatly reduced or nonexistent.

The Garden Street Parking Facility, in Hoboken, New Jersey, is a typical automated parking system. The following is a description of the facility: Drivers access the parking facility by driving onto the steel pallet, which is housed inside a compartment the size of a single garage stall. The driver turns off the ignition, sets the parking brake, gathers his or her belongings,

STEPHEN J. SHANNON

The steel pallet on which a vehicle sits is transported through the automated garage by a system of horizontal and vertical lifts.

and exits the compartment. Sensors measure the vehicle to ensure that it is not too large for the system and has no protruding mirrors, racks, or other attachments that could be damaged. Meanwhile, the driver approaches the activation station just outside the entry compartment and uses an electronic key card or an electronically coded ticket to close the doors to the entry compartment and activate the storage process.

A computer records the patron's identity, identifies an empty storage location, and maintains that record (which is linked to the encoded ticket or key card) for later retrieval. The door to the storage vault opens, and a motorized transport device slides under the pallet in the entry compartment, lifts the pallet, and removes the pallet with the vehicle on top. The transport device moves horizontally to a vertical lift, and the car is then transferred onto the lift and moved vertically to the storage level. Another horizontal transport device removes the pallet, with the vehicle, from the lift and transports the car horizontally to the storage space. The pallet is then pushed into the storage space. Because there are separate horizontal shuttles and lifts, many vehicles can be retrieved and stored simultaneously, which speeds the system's storage and retrieval rate. Upon returning to the parking facility, the patron presents a key card, punches in a code or presents an electronically encoded ticket at the parking activation station, and pays the fee; the vehicle is automatically retrieved within two minutes.

In the automated system used at the Summit Grand Parc Condominiums, in Washington, D.C., a crane moves horizontally on rails that are fixed to the ground floor in the transport aisle of the storage vault. A vertical lift is built into this single transport device. This system is generally suited for smaller-capacity garages (150 spaces or less), although a second crane could be provided for larger facilities. Another example of this system can be found at the two ten-story warehouses of Quad Graphics, in Milwaukee, where automated cranes are used to move pallets of magazines that are stored between printing and shipping.

STEPHEN J. SHANNON

After traveling through the garage, vehicle and pallet are pushed into a storage space, where they are stored until the driver retrieves the vehicle.

STEPHEN J. SHANNON

An automated parking facility can accommodate twice the number of cars as a self-park, ramp-access garage.

RAMP-ACCESS VERSUS MECHANICAL-ACCESS GARAGES

As noted earlier, the older mechanical systems required a parking attendant. Ramp-access garages gained popularity because they allowed patrons to park their own vehicles, without the expense of an attendant and with more reliable retrieval times. Another advantage of self-park, ramp-access garages is that they are less expensive to construct and operate. However, in the same volume of space, an automated parking facility can accommodate two times the number of cars as a self-park, ramp-access garage. There are two reasons for this: first, each storage rack in an automated facility is approximately seven feet (two meters) high; a ramp-access garage, in contrast, typically has a floor-to-floor height of ten feet (three meters). Thus, three automated levels can fit into the same space as two ramp levels. Moreover, in an automated facility, selected floors can have a higher clearance to accommodate vans and sport utility vehicles, while the remaining floors can be designed for the height of the majority of automobiles.

Second, in an automated parking facility, the movements of the vehicles into and out of the parking spaces are precisely controlled, so the width of the stall need only clear the side-view mirrors. Because an automated stall requires approximately 7 feet (2.1 meters) of width, versus 8.5 to 9 feet (2.6 to 2.7 meters) for a self-park garage, a mechanical garage can accommodate four cars in the same width that would yield only three spaces in a self-park garage. Automated parking systems can also accommodate tandem parking stalls, further increasing the parking efficiency.

CAPACITY AND SERVICE RATES

One of the potential disadvantages of automated garages is speed. The service rate of an automated garage depends on the number of transport devices and the number of entry/exit compartments. The industry standard is a maximum retrieval time of two minutes, or 30 vehicles per hour; manufacturers must provide enough lifts and transport devices to meet this standard. Compared to the service rate for a single lane of a self-park garage with a ticket dispenser or card reader (which is 400 vehicles per hour) automated parking can be very slow. Many more entry/exit compartments and transport devices would be needed to achieve the same service rate as a self-park garage.

The service rate of the entry operation is a function of the time it takes for the following events to occur:

▷ The parking patron clears the entry compartment.

STEPHEN J. SHANNON

To retrieve a vehicle, a patron uses a key card or ticket, pays a fee, and waits for the vehicle. The industry standard maximum retrieval time for an automated facility is two minutes.

▷ The vehicle is removed from the entry compartment.
▷ The system delivers another pallet to the entry compartment so that the next vehicle can be received. (The previous vehicle may still be in transit inside the storage vault when another vehicle is able to access the entry compartment.)

The time it takes for the patron to exit the compartment and activate the storage process, which is called the *dwell time*, averages approximately 45 seconds, although it will be higher for infrequent users than for repeat users. The average service rate for the entry operation is thus on the order of 30 to 50 vehicles per hour.

The service rate of the exit operation depends on the following:
▷ the vehicle retrieval time;
▷ the time required to rotate the vehicle on a turntable so that it can exit; and
▷ the dwell time before the vehicle exits the compartment.

If the average retrieval time is 60 seconds, the time to rotate the vehicle is 20 seconds, and the dwell time is 45 seconds, then the average outbound service rate is 29 vehicles per hour. Accessing tandem stalls—that is, vehicles parked behind another vehicle—requires moving the front vehicle before accessing the rear vehicle, adding time to the retrieval process and further slowing the service rate.

If the number of patrons who wish to retrieve their vehicles is greater than the number of available transport devices or exit compartments, retrieval time will be longer; delays of up to ten minutes may occur. However, if the patrons had to wait for an elevator, walk to their parked vehicles, and drive to the exit, the elapsed time would not be any greater than the average retrieval time for an automated parking facility. Nevertheless, the delay is more noticeable when patrons are not occupied by some other activity.

If the traffic volume at peak arrival and departure times is known or can be accurately projected, and assuming the service rates cited earlier, the designer can determine the number of entry and exit compartments and transport devices that are needed to serve that volume without excessive congestion or delay. However, automated parking facilities are not well-suited for high-volume arrivals and departures—such as those associated with special-event uses, cinemas, and offices—because the number of entry/exit compartments becomes excessive and the access design becomes very complex. Automated parking facilities are better suited to hotels, condominiums, vehicle sales storage, rental car storage, airports, and other uses with relatively low arrival and departure rates.

CONSTRUCTION COST

Three modern automated parking facilities have been constructed in the United States in recent years: the aforementioned facility in Hoboken, New Jersey; the Summit Grand Parc facility, in Washington, D.C.; and a third in New York City's Chinatown. The seven-story, 324-space Hoboken facility was constructed in 2000 and cost approximately $6.7 million, including the building and the automated parking equipment, for a cost per space of approximately $20,680. The building has four entry/exit compartments, two vertical lifts, and 14 horizontal shuttles (two per level).

The Washington, D.C., facility, constructed in 2002, consists of a luxury residential tower with 98 rental units and 24,000 square feet (2,230 square meters) of commercial/retail space in an adjacent five-story historic building. The four-level parking structure, situated under the residential tower, has a footprint that is 60 feet wide and 106 feet long (18 by 32 meters) within a total depth of 32 feet (ten meters). The cost of the automated parking system only (excluding the building shell) was approximately $1.5 million, or $20,000 per stall.

The optimum size of an automated parking facility is approximately 150 spaces per lift. The per-space cost for smaller facilities is high because the cost of the machinery is spread over a limited number of spaces. In contrast, an above-ground standalone open parking structure currently averages approximately $15,000 per stall, although this cost can easily double for an enclosed underground garage.

It is difficult to compare the cost of an automated parking facility to that of a ramp-access garage because an automated facility may be the only choice on a small site. Nevertheless, even after the higher land costs associated with ramp-access garages are taken into account, as long as the development parcel is large enough to accommodate a ramp-access garage, that is likely the more economical choice.

OPERATING COSTS

Automated parking facilities use automatic pay stations for revenue collection, so the operating costs should be compared to those of ramp-access garages that also use automatic pay stations. The largest expenses for either type of garage will be for utilities and maintenance.

According to Rob Bailey, of SpaceSaver Parking Systems, the electric utility cost for an automated parking facility is approximately $0.05 per storage or retrieval operation. According to the Robotic Parking Web site (www.robopark.com), the Hoboken garage handled over half a million transactions in 29,880 hours of operation, which amounts to approximately 150,000 transactions per year and an electric utility cost of approximately $15,000 per year, or approximately $46 per year per space. The cost of the other electrical systems in the facility may double the electric utility cost.

Maintenance of automated parking machinery is similar to elevator maintenance. The maintenance contract for the automated parking system in Washington, D.C., is approximately $3,600 per month, or $584 per space per year. A 2004 survey of 156 ramp-access garages by Walker Parking Consultants indicated a median utility cost of $52 per space per year and a median maintenance cost of $74 per space per year. Other operations costs—for management, insurance, office supplies, and miscellaneous—are likely to be similar for automated and ramp-access parking facilities: approximately $200 per space per year. The annual operating cost for an automated parking facility is therefore about $730 per space per year, versus $326 per space per year for a ramp-access garage.

In sum, per-space construction costs for an automated parking facility are approximately twice as high as the costs for an above-grade, stand-alone, ramp-access open parking garage. The difference in construction costs may not be as large for an underground parking garage. Operating costs for an automated parking garage, excluding cashier labor, are approximately double the costs for a self-park, ramp-access garage. However, if an automated garage is thought of as automated valet parking, then operating costs for an automated garage are likely to be much lower than those for a valet-parking garage.

On small sites in dense urban areas, automated parking facilities may be the only viable option. For high-end condominium or hotel projects, the higher cost may be justified.

REFERENCES

American Society of Mechanical Engineers (ASME). *Storage/Retrieval (S/R) Machines and Associated Equipment*. ASME B30.13-2003. New York: ASME, 2003.

Automated & Mechanical Parking Association (AMPA) and National Parking Association (NPA). *Guide to the Design & Operation of Automated Parking Facilities.* Washington, D.C.: AMPA and NPA, February 2003.

Bailey, Rob. "Double Your Capacity with Technology." Presentation by SpaceSaver Parking Company at Parking Industry Exhibit, Chicago, August 2006.

Chrest, Anthony P., Mary S. Smith, Sam Bhuyan, Mohammad Labal, and Donald R. Monahan. *Parking Structures: Planning, Design, Construction, Maintenance & Repair,* 3rd ed. New York: Springer Science + Business Media, 2001.

European Committee for Standardization, Technical Committee. *Safety of Machinery Equipment for Power-Driven Parking of Motor Vehicles.* DIN EN 14010. Brussels: European Committee for Standardization, Technical Committee, October 2003.

Haag, Gerhard, and Larry Byrnes. "Automated Parking: Two-Year Report Card." *Parking* (September 2004).

CHAPTER 19

Building CODES

DONALD R. MONAHAN

BUILDING CODES PROTECT THE HEALTH, SAFETY, and welfare of users by establishing minimum standards for the design and construction of the built environment. Until 1994, there were three code organizations in the United States—Building Officials and Code Administrators (BOCA), the International Conference of Building Officials (ICBO), and the Southern Building Code Congress International (SBCCI)—each of which had its own model building code. Typically, state and local governments would create legislation based on one of these model codes. However, differences between the model codes created difficulties for designers working in different regions of the country.

In 1994, the three code organizations founded the International Code Council (ICC), a nonprofit organization dedicated to developing a single set of comprehensive and coordinated model construction codes. Although the primary purpose was to develop a coordinated national code, it was decided that this code would also be marketed internationally and be adopted by countries throughout the world. The first model code developed by the ICC was the International Building Code 2000 (IBC 2000). By July 2008, all 50 states and the District of Columbia had adopted IBC 2000, IBC 2003, or IBC 2006.[1]

The IBC is part of a family of international codes created by the ICC. Other codes in the family include the International Fire Code, the International Plumbing Code, the International Mechanical Code, the International Energy Conservation Code, the International Fuel Gas Code, the International Residential Code, the National Electrical Code, the International Existing Building Code, the International Residential Code, the International Proprietary Maintenance Code, the International Private Sewage Code, and the International Zoning Code. Every international code, including the IBC, is updated every 18 months—first with a supplement, then with a full new version every three years. Any interested individual or group may propose a code change and participate in the proceedings. Eligible members of the model

WALKER PARKING CONSULTANTS/VINCE STREANO

With uniformly distributed openings on some of its sides, the 1,182-space parking structure at the Clemson University International Center for Automotive Research, in Clemson, South Carolina, is considered an open structure.

code groups review the recommendations of the ICC code-development committee at their annual conference and vote on the final action.

For parking facilities, building codes specify gravity loads, wind loads, seismic loads, number of fire exits, travel distances to fire exits, fire-protection systems, wall openings required for a facility to be classified as an open parking structure, and fire ratings for structural components. Ventilation and fire-protection requirements vary, depending on whether a structure is classified as open or enclosed.

OPEN PARKING STRUCTURES

Open parking structures are those that have sufficient openings around the exterior to provide for natural ventilation. The international codes do not require mechanical ventilation or sprinkler systems for open parking structures. However, some jurisdictions may add special amendments that alter the international code, such as requiring fire-sprinkler systems in open parking garages. IBC 2006 establishes the following criteria for open parking structures:

> For natural ventilation purposes, the exterior sides of the structure shall have uniformly distributed openings on two or more sides. The area of such openings in exterior walls on a tier must be at least 20 percent of the total perimeter wall area of each tier. The aggregate length of the openings considered to be providing natural ventilation shall constitute a minimum of 40 percent of the perimeter of the tier. Interior walls shall be at least 20 percent open with uniformly distributed openings.
>
> Exception: Openings are not required to be distributed over 40 percent of the building perimeter where the required openings are uniformly distributed over two opposing sides of the building.[2]

Light wells are sometimes used to provide natural ventilation and light for tiers that are partially or entirely below grade. There are no code requirements for the width of light wells; however, if the aggregate width of the wells around the perimeter is equal to the aggregate height of the vertical openings required for the below-grade levels, many jurisdictions allow basement levels to be classified as open parking structures.

ENCLOSED PARKING STRUCTURES

Parking structures that do not meet the criteria for open parking garages are classified as enclosed ("open parking garages" and "enclosed parking garages" are the technical terms used in the IBC), which means that they require mechanical ventilation, sprinklers, and enclosed stairwells. Lower portions of parking structures that are partially or entirely below grade may be classified as enclosed, while the upper portions may be classified as open.

In enclosed parking structures with less than four stories, enclosed stairwells with a one-hour fire rating are required; in enclosed structures with four stories or more, enclosed stairwells with a two-hour fire rating are required. At least one accessible means of egress is required in all parking facilities. For parking structures with four or more stories above or below the level of exit discharge, at least one of the required accessible means of egress must be an elevator; buildings with three stories or less are not required to have an elevator. Enclosed parking structures must provide an area of refuge at an accessible staircase for wheelchair patrons. This area must be separated from the rest of the structure by a smoke barrier. Accessible stairwells must have a clear width of 48 inches (122 centimeters) between handrails.

BUILDING SEPARATION

Parking structures within 5 feet (1.5 meters) of a common property line must have an enclosed fire wall between the exterior of the structure and the property line, and the wall must (1) have at least a one-hour fire-resistance rating and (2) no openings.[3] A fire wall is not required if the garage is ten feet or more from the property line.

Contrary to previous codes, the IBC allows a mix of uses in open parking garages, as long as they meet the fire-separation provisions. Generally, such provisions require a two-hour

CARL WALKER, INC.

Seven feet (2.1 meters) is the minimum clear height for each floor level in vehicular and pedestrian traffic areas.

horizontal and vertical fire separation between the parking garage and other uses.[4]

CLEARANCE

The clear height of each floor level in vehicular and pedestrian traffic areas must not be less than 7 feet (2.1 meters). A minimum clearance of 8 feet, 2 inches (2.5 meters) is required along the travel route to and from van-accessible parking. In order to meet the requirements of the Americans with Disabilities Act, valet parking areas and porte cocheres must have a 9-foot, 6-inch (2.9-meter) clearance for entering and exiting vehicles. For design purposes, 2 inches (5 centimeters) are often added to these clearances to allow for an acceptable margin of error during the construction of the structure.

The clear height along the travel path to a fire exit must be 7 feet, 6 inches (2.3 meters). Isolated projections below this height are allowed on up to 50 percent of the ceiling area, provided a minimum clearance of 6 feet, 8 inches (2 meters) is maintained.

RAMPS

According to the IBC 2004 supplement, the slope of vehicle ramps used for parking and vertical circulation must not exceed one unit vertical to 15 units horizontal (a 6.67 percent slope).[5] Ramps used as part of a means of pedestrian egress must not have a running slope steeper than one unit vertical to 12 units horizontal (an 8 percent slope).[6] Pedestrian ramps that are not part of a means of egress may have a slope of one unit vertical to eight units horizontal (a 12.5 percent slope).

Although there is no code requirement for the maximum slope of ramps that are used for vertical vehicular circulation but not for parking, a maximum slope of 16 percent is recommended (one unit vertical to six units horizontal) in the Parking Consultants Council's *Recommended Zoning Ordinance Provisions*.[7] Ramps whose slopes exceed 10 percent should have a 10-foot- (3-meter-) long transition at the top and bottom to minimize the break-over angle to less than 10 percent.

BUILDING HEIGHTS AND FLOOR AREAS

A parking structure's fire rating determines its maximum floor area and number of tiers. Floor areas may be increased if the facades are open on more than two sides.

ROSS BARNEY ARCHITECTS/DESMAN ASSOCIATES

The number of exit stairwells in a parking facility is determined in part by an occupant load ratio that calls for one person for every 200 square feet (19 square meters).

MECHANICAL VENTILATION

As mentioned earlier, parking garages that do not meet the criteria for open parking structures require mechanical ventilation. The ICC's International Mechanical Code specifies the requirements for such ventilation systems. A system's ventilating fans are allowed to operate intermittently if carbon monoxide monitoring is provided and if the system automatically turns on in response to the presence of vehicle operation or people in the garage. The mechanical code also calls for a minimum ventilation rate when an automated system is being used. In addition, if the garage has connecting offices, waiting rooms, ticket booths, or other similar uses, these spaces must be maintained under positive pressure (i.e., the air pressure inside the occupied space must be higher than it is outside the space).[8]

National Fire Protection Association Codes

The National Fire Protection Association (NFPA) has produced a series of code documents, including a model building code called NFPA 5000.[1] An alternative to the International Code Council's International Fire Code, the NFPA 5000 bases its recommendations for parking facilities on the NFPA's *Standard for Parking Structures*.[2]

There are a number of significant differences between this code and the International Building Code. Under NFPA 5000, open stairwells are permitted in an open parking structure; however, the exit travel distance must then include the length of travel down the stairs to the exit discharge. If an enclosed stairwell is provided, then the exit travel distance is to the door of the enclosed stair on that tier.

Open parking structures are defined as having perimeter wall openings of not less than 1.4 square feet (0.13 square meters) per linear foot (0.3 meters). Such openings must be distributed over 40 percent of the building perimeter, or uniformly over two opposing sides. Interior walls between parking rows must be at least 20 percent open, with openings distributed in such a way as to provide natural ventilation.

NFPA codes are often used to specify the installation of sprinkler systems (NFPA 13), the installation of fire alarms (NFPA 72), the installation of standpipes (NFPA 14), and the installation of portable fire extinguishers (NFPA 10).

Notes

1. National Fire Protection Association, *NFPA 5000: Building Construction and Safety Code* (2009).
2. National Fire Protection Association, *NFPA 88A: Standard for Parking Structures* (2007).

HANDRAILS AND BUMPER WALLS

Where the difference in the elevation of the adjacent floor is greater than 1 foot (0.3 meters), the IBC 2004 supplement, as well as later editions of the IBC, requires vehicle barriers at least 2 feet (0.6 meters) high at the ends of drive lanes.[9] The vehicle barriers must be designed for a 6,000-pound (2,722-kilogram) horizontal load acting at a height of 18 inches (46 centimeters).

IBC 2003 and later editions require guardrails at all exterior and interior vertical openings in all floor and roof areas where the vertical distance to the ground or surface directly below exceeds 30 inches (76 centimeters).[10] Handrails must extend to a height of 42 inches (107 centimeters) above the floor line. Open handrails must have the following characteristics:

- ▷ balusters or ornamental patterns such that a sphere 4 inches (10 centimeters) in diameter cannot pass through any opening, up to a height of 34 inches (86 centimeters);
- ▷ triangular openings formed by the riser, tread, and bottom rail of a size such that a sphere 6 inches (15 centimeters) in diameter cannot pass through; and
- ▷ a design such that from a height of 34 inches (86 centimeters) to 42 inches (107 centimeters) above the walking surface, a sphere 8 inches (20 centimeters) in diameter cannot pass through.

DESIGN LIVE LOADS

Under IBC 2003 and later editions, design uniform live loads for parking structures are 40 pounds per square foot. In addition, parking structures must be able to withstand a 3,000-pound (1,361-kilogram) concentrated load acting on an area of 20 square inches (129 square centimeters); this requirement addresses the structural demands of passenger cars that hold up to nine passengers.

All codes require parking facilities to withstand earthquake-induced loads for the seismic zone in which they are located. Either rigid frames or shear walls are normally used in parking structures to resist seismic loads. The design of structures for seismic resistance is a specialized field, and owner/developers will likely have to hire consultants with the necessary training to address these issues.

Code-specified wind loads are applied to the gross area of a parking structure facade. No additions or reductions are made to the wind load to reflect the relative openness of the structure's facade, or the impact of the wind as it comes through openings in the exterior facade and acts on interior elements.

FIRE EXITS AND STAIRS

Stairs serving fire exits in open parking structures must be located so that the travel distance to the exit door or to the closest riser of an open stair along the unobstructed path of travel is not greater than 300 feet (91 meters) in a garage without sprinklers, or greater than 400 feet (122 meters) in a garage with sprinklers.

At least two exit stairwells are required in a parking garage, and more may be required, depending on the maximum travel distance or occupant load. The occupant load ratio in a parking garage is one person per 200 square feet (19 square meters).[11] If the total occupant load of a floor is between 501 and 1,000 persons, or the floor area is between 100,000 and 200,000 square feet (between 948 and 18,581 square meters) per tier, then a third exit is required.[12] If the total occupant load of a floor is more than 1,000 persons, or there are more than 200,000 square feet (18,581 square meters) per tier, then four exits are required.

Vertical openings or stairwells that serve only the open parking garage are not required to be enclosed.[13] As noted earlier, stairs in enclosed parking garages must be enclosed.

FIRE PROTECTION

Parking structures must be constructed of noncombustible material. Open parking structures that are less than 150 feet (46 meters) above the lowest level of fire department access must have a Class I manual standpipe system with a ground-level fire department connection for attaching a water supply. Standpipes are not required where the highest story is located 30 feet (9 meters) or less above the lowest level of fire department access.[14] Class I manual dry standpipes are allowed in open parking garages subject to freezing, provided that they are located so that all portions of the building are within 30 feet of a nozzle attached to 100 feet (30 meters) of hose. Where more than one standpipe riser is provided, standpipes must be interconnected.

Under the ICC's International Fire Code, 4A:80BC-rated, dry-chemical fire extinguishers are required for parking structures, which are classified as ordinary hazards.[15] Fire extinguishers must be located no more than 75 feet (23 meters) from any location on a floor, and the maximum floor area per extinguisher is 11,250 square feet (1,045 square meters).

Enclosed parking structures must have fire alarms and (1) automatic sprinkler systems activated by heat, or (2) smoke detectors placed throughout the structure.

NOTES

1. Another code that is often adopted is *Accessible and Usable Buildings and Facilities*, by the International Code Council and American National Standards Institute (ICC/ANSI A117.1-2003). This document is prepared by the ICC and is intended to meet the requirements of the Americans with Disabilities Act (ADA). The provisions of the ADA are discussed in Chapter 8. To obtain the latest information as to the jurisdictions that have adopted the IBC, see www.iccsafe.org/government/adoption.html.
2. *International Building Code* (IBC) (2003), sec. 406.3.3.1.
3. See IBC, table 602, table 704.8, note c (2003, 2006, and 2009).
4. *IBC*, sec. 302.3.
5. *IBC* 2004 supplement, sec. 406.2.5.
6. *IBC* 2004 supplement, sec. 1010.2.
7. Parking Consultants Council, *Recommended Zoning Ordinance Provisions* (Washington, D.C.: National Parking Association, 2006).
8. *International Mechanical Code* (2003), sec. 404.
9. *IBC* 2004 supplement, sec. 406.2.4.
10. *IBC*, sec. 406.2.3.
11. *IBC*, table 1004.1.2.
12. *IBC*, table 1018.1.
13. *IBC*, secs. 406.3.11 and 1019.
14. *IBC*, sec. 905.3.1.
15. *International Fire Code* (2000), sec. 906.

CHAPTER 20

Operations and MANAGEMENT

STEPHEN J. SHANNON AND LARRY DONOGHUE

NO MATTER HOW BIG OR SMALL THE PARKING FACILITY, operations must be carefully planned long before the first patron pulls into the entry lane. Once the facility opens, its operations must be monitored continuously over the life of the facility. Although parking-facility operations may seem simple at first glance, facilities vary widely, and operations must be tailored to the particular needs and characteristics of each facility. This chapter is designed to familiarize the reader with the primary issues associated with parking-facility operations: method of operation, cost of operation, personnel management, the facility-management system, governmental influences, financing influences, safety and security, maintenance and repair, and management options.

METHOD OF OPERATION

The method of operation—whether the facility will feature valet parking or self-parking, and whether it will have staffed exit lanes or automated pay-on-foot machines—should be fully examined early in the development process to determine its impact on facility design and operating costs. Two factors, labor and liability insurance, make the cost of operating a self-park facility considerably lower than the cost of operating a valet-parking facility. Labor costs are lower because there is no need for valets, and insurance costs are lower because the operator never takes possession of the vehicles. Pay-on-foot operations, which eliminate cashiers, can reduce costs even further.

COST OF OPERATION

Although the owner makes certain assumptions about operating costs during the planning process, as the opening of the facility approaches, costs must be reevaluated in light of current market conditions. Beyond local parking taxes, which can be as high as 50 percent in some major cities, there are a number of costs to be considered. Generally, costs vary with size, age, method of operation, user type, facility location, and other factors. Expenses for a typical facility include the following:

- ▷ wages, salaries, and benefits;
- ▷ payroll taxes;
- ▷ maintenance and repair;
- ▷ professional fees (legal, accounting, etc.);
- ▷ insurance;
- ▷ accident claims;
- ▷ supplies;
- ▷ licenses and permits;
- ▷ utilities and telephone service;
- ▷ taxes (sales, parking, income, use, property, etc.);
- ▷ uniforms;
- ▷ rent or management fees;
- ▷ corporate overhead;
- ▷ equipment (including service and replacement costs); and
- ▷ miscellaneous expenses.

Parking facilities require many types of insurance, including comprehensive and garagekeepers' liability, workers' compensation, and business interruption. Because of increased litigation, workers' compensation insurance is rapidly becoming a major cost. Parking operators must therefore make every effort to encourage and maintain a safe working environment for their employees.

The nature of the parking business and the volume of patrons served create considerable likelihood of damage to vehicles (particularly at attended facilities) and injury to patrons. While the various types of insurance provide liability coverage, the owner/operator should consider an annual allowance to cover the cost of deductibles. More important, it is critical that the owner/operator maintain an ongoing risk-assessment program and regularly monitor claims in an effort to contain costs. Particularly since other unexpected costs could arise, the owner/operator should consider a contingency fund for unforeseen occurrences such as equipment failure and emergency repairs. In fact, maintenance costs can become extremely high if the owner/operator fails to undertake preventive maintenance. This is especially true of concrete deterioration, which can increase exponentially if not repaired in a timely manner.

SKIDATA, A MEMBER OF THE KUDELSKI GROUP

One of the first decisions needed in the development of a parking facility is how the facility will be staffed. Shown here is a valet with a wireless handheld ticketing device.

PERSONNEL MANAGEMENT

Staffing the facility is by far the single most costly aspect of operations, representing 40 to 60 percent of total expenses. Because of the expense represented by labor costs, it is important for employees' duties and responsibilities to be clearly defined in a personnel handbook. Handbooks typically cover the following topics:

- ▷ job descriptions;
- ▷ employee benefits;
- ▷ operational procedures;
- ▷ cash handling;
- ▷ revenue-control procedures;
- ▷ daily housekeeping responsibilities;
- ▷ customer service procedures;
- ▷ safety and security; and
- ▷ emergency procedures.

CHOATE PARKING CONSULTANTS, INC.

While valet parking adds a dimension of customer service, the labor costs can take up a large part of a structure's operating budget.

Regardless of how much planning and careful thought go into developing a new parking facility, all facilities go through a shakedown period, during which the management and staff adjust to the facility's unique operational requirements. For any facility to succeed, the owner must hire an experienced manager who fully understands the local market. The manager must then undergo thorough training in operations and management procedures specific to the facility.

The manager's primary duty is to strike a balance between the cost of operations and the level of service. On a day-to-day basis, the manager is responsible for the following:

▷ planning the schedule to ensure that an acceptable level of service is maintained;

▷ training and supervising line employees;

▷ monitoring occupancy and market rates and recommending rate changes accordingly; and

▷ interacting with the public on critical issues such as complaints and accidents.

The manager also ensures that the image of the facility is a favorable one: public perception of a parking facility can make or break it.

THE FACILITY-MANAGEMENT SYSTEM

The facility-management system (FMS), which is often furnished as part of the parking access- and revenue-control system (PARCS), is an important tool for tying all the equipment together and allowing the manager to monitor the overall parking operation from a central computer. It can also have the capability of monitoring multiple parking facilities from one online location. An FMS can generate a wide variety of reports and provide real-time information on occupancy, revenues, etc. It can also aid managers in day-to-day operational duties by catching any problems (such as discrepancies in the cash-handling process or misuse of monthly access cards). The checks and balances built into the facility-management system should be reviewed periodically and revised as necessary to respond to changing circumstances.

GOVERNMENTAL INFLUENCES

Local government regulations affect parking-facility operations in a number of ways:

▷ Local building and zoning codes influence the ultimate design and layout of a facility.

▷ Most local governments require various licenses for the operation of a parking facility.
▷ Facilities may be subject to periodic inspections for conformance with local ordinances.
▷ Local governments may require audits to confirm that the taxes collected are appropriate to the revenues received.

In terms of federal regulations, the manager must monitor compliance with the Americans with Disabilities Act (ADA). Specifically, the manager must ensure that the facility maintains (1) the required number and type of ADA-prescribed parking spaces and (2) access to unobstructed pathways into and out of the facility. The manager must also ensure that employees with disabilities are accommodated by doing such things as providing barrier-free access to the facility office and to at least one of the cashiers' booths.

FINANCING INFLUENCES

Funding sources may impose limitations and restrictions on facility operations, including minimum debt-coverage ratios, minimum levels of insurance coverage, requirements for a reserve fund for maintenance and repair, and limits on reserved parking (especially in the case of tax-free financing).

SAFETY AND SECURITY

To minimize the possibility of injury to a patron or employee, safety must be addressed during the early planning stages. Before opening for business, each facility should be carefully evaluated to identify potential safety or security concerns that might have been overlooked during planning. In addition, periodic safety and security inspections must be made throughout the life of the facility, to ensure that management remains responsive to changing conditions. For example, if a facility opens in a relatively safe neighborhood, it may initially require minimal safety and security measures, but if the incidence of crime increases, surveillance cameras, grade-level security screens, upgraded lighting, and increased security patrols may be necessary. In some instances, security concerns may be so great that a facility must reduce its hours of operation in order to minimize liability.

Safety inspections are also required to monitor normal wear and tear. Settlement of grade-level surfaces and the deterioration of structural slabs can result in spalled surfaces and potholes, both of which can create tripping hazards and potentially expose the owner/operator to injury claims.

MAINTENANCE AND REPAIR

Design, construction, and maintenance are the three critical factors that determine the performance of a parking structure. If just one of these factors is given inadequate attention, the facility will incur unnecessary maintenance and repair costs. A comprehensive maintenance program, based on a checklist of tasks to be undertaken periodically, is critical to achieving anticipated service life. (Chapter 22 addresses maintenance in further detail.)

MANAGEMENT OPTIONS

The major types of parking-facility management are
▷ self-operation;
▷ lease agreement;
▷ contract agreement;
▷ concession agreement;
▷ fixed-fee management agreement; and
▷ percentage management agreement.

Self-Operation

When a parking facility owner is also the operator, the arrangement is referred to as *self-operation*. The owner receives all the gross receipts from the parking operation and pays all the expenses. Staff may be employees of the owner, contract workers from a temporary employment agency, or a mix of the two, in which case the permanent employees are managers and supervisors, and the contract employees are cashiers.

Lease Agreement

Under a lease agreement, the owner leases a parking facility to a private or public parking operator for a fixed annual fee, or for a sliding percentage of gross revenues less any taxes, if applicable. (In a sliding percentage arrangement, as gross receipts increase, the percentage paid to the owner decreases.) If the lease term is greater than one year, the contract may include an escalation clause that approximates the rate of inflation, and is usually tied to some widely accepted index such as the consumer price index. The operator receives all the gross receipts,

Parking Garage Four, at the Raleigh-Durham International Airport, in North Carolina, has space for 6,150 vehicles.

and the compensation to the owner is usually paid on the first day of each month.

The lease may or may not require the lessee to cover operating expenses such as property taxes, utilities, or routine maintenance (minor repairs, coatings and sealers, striping, etc.). Major repairs, including structural repairs, are usually the responsibility of the owner, unless they are determined to have been caused by lack of proper maintenance.

Contract Agreement

Under a contract agreement, a parking operator provides the cashiering and revenue-control function in return for a fixed annual fee. The operator also provides all the necessary operating and supervisory staff and covers all parking-related expenses such as uniforms, parking tickets, and telephone service. The owner pays the property taxes, utilities, and all maintenance and repair costs.

The operator is usually required to deposit the gross receipts daily into a bank account in the name of the owner, and is usually paid at the end of the month for the services rendered during that month.

Concession Agreement

Under a concession agreement, the concessionaire covers most operating expenses, including labor, bookkeeping, operating supplies, restriping, housekeeping, and snow removal, in return for an agreed-upon fee. The fee arrangements may vary, although compensation is usually based on a sliding percentage of gross receipts, less any local taxes.

The owner usually pays the property taxes and covers utilities, major repairs, new revenue-control equipment, lighting, and other significant expenses. The concessionaire collects the gross receipts, subtracts the agreed-upon percentage, and remits payment to the owner ten to 15 days after the end of each month.

Fixed-Fee Management Agreement

Under a fixed-fee management agreement, a parking operator manages and operates a parking facility on the owner's behalf, providing supervisory, cashiering, accounting and auditing, maintenance, and housekeeping services. The operator's fee covers

- the assumption of risk associated with the management agreement;
- interest on borrowed funds for the operator's working capital;
- annual audits by a certified public accountant;
- internal audit expenses;
- depreciation of furniture and fixtures;
- premiums for performance bonds;
- the operator's profit; and
- a portion of the staffing and overhead costs of the company's home office.

All out-of-pocket facility-related expenses are reimbursed by the owner.

Under most management agreements, the operator deposits the gross receipts daily in a bank account held in the owner's name. At the end of each month, the operator submits an invoice covering both the fixed fee and reimbursement for expenses.

Percentage Management Agreement

A percentage management agreement is similar to a fixed-fee agreement, but instead of a fixed fee, the operator receives a percentage of the gross receipts, which creates an incentive to generate more revenue for the facility. From the operator's standpoint, it is preferable to receive a smaller percentage of gross revenue and a higher percentage of net revenue; this arrangement rewards the operator for increasing both gross and net revenue but provides additional compensation for reducing expenses, and thereby increasing net revenue. Some agreements stipulate that achieving a certain revenue threshold will trigger a bonus or an increase in the percentage of revenue awarded to the operator. Some agreements also include incentives for achieving a low level of customer complaints.

CONCLUSION

By the time a parking facility is completed and opens to traffic, most aspects of its operation should have been addressed, including the method of operation, internal traffic flow, vehicular and pedestrian safety, security, and anticipated operating expenses. Most important, procedures should have been established to ensure that revenues will be sufficient to cover debt service and operations, and yield an adequate return on investment.

The operation of any parking facility can be extremely complicated and is best left to an experienced manager or parking-management company. To the average person, the nuances of facility management may seem insignificant; to the skilled practitioner of parking management, however, those nuances can make the difference between a successful and an unsuccessful operation.

CHAPTER 21

Parking Access and REVENUE CONTROL

DAVID MOORE

PARKING-ACCESS AND REVENUE-CONTROL SYSTEMS are vital to the success of any parking facility. The use of appropriate technologies can increase the efficiency of operations and maximize revenue collection. They can also enhance customer service and create a more pleasant parking experience—which in turn, yields repeat customers. However, these control systems must be reliable, modest in cost, and capable of accurately calculating parking fees.

While some parking operations still employ attendants who issue tickets by hand and use a time clock to record entry and exit times, most facilities use some form of revenue-control equipment. The larger the parking operation, the more sophisticated its access- and revenue-control systems are likely to be. And the higher the annual gross revenue, the greater the level of expenditure that is warranted for revenue-control equipment.

Different types of parking naturally call for different approaches to revenue control. Although the main focus of this chapter is on off-street parking, the chapter also includes a brief discussion of on-street parking-control techniques.

To determine the best technology for a given parking facility, it is essential to take into account the facility's unique functional and operational characteristics. The following are among the factors that must be considered:

▷ size, type, and location of the facility;
▷ mix of user groups;
▷ volume of revenue and business;
▷ rate structure;
▷ function and layout;
▷ user acceptance of parking technology; and
▷ cost of technology.

KIMLEY-HORN AND ASSOCIATES, INC.

Pay-on-foot systems, which are becoming more common in the United States, can increase vehicle throughputs and reduce operating costs and emissions from queued vehicles.

OFF-STREET PARKING

There are two basic types of off-street parking: attendant parking and self-parking.

Attendant parking is probably the oldest form of control seen in parking operation. Upon entering a facility, the driver surrenders his vehicle to a parking attendant, who parks the vehicle. In valet parking, one form of attendant parking, the vehicle may be stored remotely from the driver's destination. Valet parking is becoming more popular at facilities such as hospitals and airports because of the convenience and time savings it offers.

Parking operators have moved away from attendant parking for two reasons: first, customers generally prefer to park their own vehicles; second, labor and insurance costs are lower with self-parking. Thus, self-parking has become the most common method of operation for off-street parking facilities.

Self-parking calls for an array of tools, including ticket dispensers, card readers, barrier gates, fee computers, and pay-in-lane devices.

Lane Technologies

In self-park facilities, it is necessary to control access into and out of the facility, and entry and exit points are the logical places to collect revenue. The various methods used to control access and collect revenue are known as *lane technologies*. In the early days of off-street parking, lane technology consisted of attendants who collected flat-rate fees from drivers as they exited, and placed the money in cigar boxes or apron pockets. A similar approach is still used at event-parking facilities: operators simply open the entry gates, staff the lanes, and collect a flat fee, providing each patron with a ticket to display on the car's dashboard. Exit lanes are left unobstructed so that patrons can leave without having to stop.

A wide range of lane technologies are available today; the following sections describe some of the most common.

Pay on Exit

Also referred to as traditional cashiering, pay on exit is the system most commonly used in U.S. parking facilities. The basic method consists of a ticket dispenser at the entry to the facility and a staffed cashier's booth at the exit. The cashier's booth is equipped with a manual or automatic fee-computing device, which relies on the time stamp on the ticket to determine the fee. Manual systems require the cashier to enter in the entry time and date; more advanced systems automatically read the time, which is encoded on the ticket in bar-code or magnetic-stripe form.

Pay on Foot

Pay-on-foot systems, which are becoming more and more common in the United States, consist of a ticket dispenser at the entry to a facility; kiosks for paying the parking fee via cash or credit card; and a ticket-accepting device at the exit. As with the pay-on-exit approach, fees are based on the entry time and date, which are encoded on the ticket issued at entry. Once patrons pay the parking fee, they are given a grace period—typically about 15 minutes—to exit the facility. Patrons who exceed the grace period are required to pay an additional fee upon exiting. A properly implemented pay-on-foot operation can offer increased throughput at the exit plaza, reduced emissions from queued vehicles, and the potential for reduced operating costs.

Ticket in/Credit Card out

Paying by credit card is convenient and is becoming increasingly common. Ticket-in/credit-card-out systems consist of a ticket dispenser at the entry to a facility and an unmanned credit card payment device at the exit. As with other methods, parking fees are computed on the basis of the time and date encoded on the ticket issued at entry. Ticket-in/credit-card-out systems offer reduced capital costs as well as reduced operational costs when compared to a traditional pay-on-exit operation.

Credit Card in/Credit Card out

The recently developed credit-card-in/credit-card-out approach is growing in popularity in the United States. The basic system consists of a credit card acceptance device at the entry to a facility and an unmanned credit card payment device at the exit. Parking fees are based on the entry time and date, which are stored as data associated with the credit card number that was used at entry. Advantages of a credit-card-in/credit-card-out system are similar to those offered by ticket in/credit card out, but also include slightly faster processing times upon exit.

Automatic Vehicle Identification

Automatic vehicle identification (AVI) is another state-of-the-art technology that is designed to integrate with the software systems of most parking-equipment manufacturers. In the basic system, which relies on radio-frequency identification (commonly referred to by its acronym, RFID) technology, readers in the entry and exit lanes receive a signal from an identification transponder located in the patron's vehicle. The system is used for monthly or employee parking, in VIP parking programs, and by toll-road authorities.

License-Plate Recognition

License-plate recognition, which is typically seen in airport-parking operations, is a state-of-the-art technology designed to integrate with the existing lane devices and software systems of most parking-equipment manufacturers. Significant capital and operational costs limit the number of applications where it can be justified. The basic system consists of a high-resolution camera that captures an image of the patron's license plate at entry and links the number to the ticket that was issued to the vehicle. When the patron exits the facility, the system takes another photo of the license plate and matches it to the one that was already stored in the system. The patron uses one of the payment options described earlier to pay the fee. License-plate recognition provides an automated way for operators to catch fraudulent activities, and gives revenue-control systems the capability to automatically calculate accurate parking fees for transactions. It can be especially useful in dealing with lost tickets.

Monthly and Employee Parking

For the most part, lane technologies for monthly parking have changed little over the years. Some owner/operators still use hangtags; others, however, have advanced to proximity cards and AVI.

Most card-access systems are based on the same principles; what differentiates them is the way that the card is presented.

In older systems, the card had to be swiped or inserted into a reader. Newer systems use a "prox card," which only needs to be within a few inches of the reader. In addition to saving time and increasing lane throughput, the new technology makes it possible to use a single card for multiple purposes: identification, building access, and parking access.

For monthly access control, AVI offers ease of use for the driver, system flexibility for the owner/operator, and increased lane throughput. Moreover, the same AVI tag used for toll-road access can be used to pay parking fees.

Event Parking

In most cases, attendants at event-parking facilities still collect the parking fees and store the money on their persons. A few manufacturers, however, have developed equipment to improve on revenue collection and auditing capabilities for event parking. Wireless handheld ticket scanners, made specifically for managing parking at events, allow attendants to scan tickets that were printed earlier and to print new tickets on the fly, among other things. All transactions can be linked to a central server so that the owner/operator can pull reports, issue receipts, count vehicles, and accept credit cards—all of which allow for better revenue management.

Space-Availability Systems and Smart Parking

Space-availability systems, also known as *count systems*, make use of various technologies to count vehicles as they enter and leave both parking facilities and individual spaces. The most commonly used technology is the in-ground detector loop, which is also used in the transportation industry (to count vehicles on roads or highways) and in the traffic industry (to determine when traffic signals change). Newer technologies, which include ultrasonic sensing devices, infrared sensing devices, closed-circuit television analytics, and wireless detector loops, allow owner/operators to count vehicles in several different ways:

▷ Lot counting simply counts vehicles as they enter and exit a facility. The number of available spaces within a particular facility is tracked. This number can help the operator determine whether to direct cars to a particular facility or perhaps to close a facility that is reaching capacity. In its simplest form, lot counting is a basic feature in most revenue-control systems, and counts are collected from valid entry and exit events.

▷ In a multilevel parking structure, count stations can be installed at the entry and exit points for each level. The number of spaces available on each level can be posted on strategically located dynamic message signs (DMSs). Multilevel counting accuracy varies greatly, depending on geometric layout, count locations, and the operational procedures of the facility. Moderate capital costs are typically associated with multilevel counting, due to infrastructure requirements on each level.

▷ Area or row counting can accurately track vehicle entries and exits in a specific area or row of spaces. As with multilevel counting, the results can be displayed on DMSs. This method can substantially reduce search time when compared with lot counting, and thereby allow a facility to remain open until a very high percentage of the parking spaces are occupied. An added benefit of reduced search times is decreased vehicular emissions. Area or row counting accuracy varies greatly, depending on geometric layout, count locations, and the operational procedures of the facility. Substantial capital

KIMLEY-HORN AND ASSOCIATES, INC.

The parking structure at Fort Lauderdale–Hollywood International Airport, in Fort Lauderdale, Florida, employs a counting system that lets patrons know how many spaces are available on each level.

SKIDATA, A MEMBER OF THE KUDELSKI GROUP

Paying for parking using a mobile phone is one possible innovation on the horizon for parking access and revenue control.

costs are typically associated with area or row counting, due to significant infrastructure requirements.

▷ Individual space-counting systems, which use ultrasonic sensors over each space in a facility, keep track of the occupancy of every space in a facility and offer patrons the greatest savings in search time. Again, a DMS can be used to display information about available spaces. While decreasing emissions, this also allows a facility to remain open until all of the parking spaces are occupied. Accuracy for individual space-counting systems is higher than any of the other space-counting methods discussed, and so are the costs. Substantial capital costs are typically associated with individual space counting, due to significant infrastructure requirements to install a sensor above each space.

ON-STREET PARKING

Typically found within central business districts, on-street parking is usually intended for short-term, high-turnover use. The following are some of the most common ways to control on-street parking.

Time Limits

Time limits, the oldest and probably the most basic form of parking control, usually range from 15 minutes to two hours, and are enforced by municipal staff. The enforcement agent places a chalk mark on the tires of parked vehicles, and then returns after the time limit on a space has expired. If the vehicle remains parked beyond the time limit, the driver may receive a parking-violation ticket and be required to pay a fine. With this type of parking control, fines are the only revenue collected.

Single-Space Parking Meters

The single-space parking meter is the most common form of on-street parking control in U.S. cities. As its name implies, the device controls only one parking space. Technological advances allow parking meters to accept credit cards and/or value cards as well as coins. (Value cards are similar to debit cards; the appropriate amount—based on the length of stay and the rate schedule—is simply deducted from the card.) A technology that is in its early stages of development, but that has already been installed in a few U.S. cities, allows patrons to use their cell phones to pay parking fees.

Multispace Parking Meters

A multispace parking meter controls more than one space—usually all the spaces on an entire block (approximately eight to 12 spaces). With this type of system, the driver parks in a marked space, walks to the multispace meter, and pays for the desired amount of parking time. The meters can accept several forms of payment. Since the spaces must be numbered, this technology may not be practical in climates subject to heavy snowfalls.

Pay and Display

Like a multispace meter, a pay-and-display device typically controls eight to 12 spaces, but the spaces are not numbered. After parking the vehicle, the driver walks to the pay-and-display device and pays for the desired amount of parking time. A receipt is issued that displays the valid amount of time that the vehicle can be parked in the spot. The driver must then walk back to the vehicle and place the receipt on the dashboard, so that it is visible to an enforcement agent. Pay-and-display devices accept bills, coins, credit cards, and value cards. One advantage of pay and display over multispace meters is that the spaces are not numbered, so it is possible to park more vehicles along the curb, thereby increasing revenues.

Parking Time Clock

A parking time clock is a battery-operated device that counts down from a set amount of time; the amount depends on how much the patron pays for. The device is displayed in the vehicle so that it is visible to an enforcement agent.

Parking Hang Card

A parking hang card is typically a thin piece of cardboard coated with scratch-off paint. By removing the paint in the appropriate places, a driver can reveal the time, day, and month; the driver then displays the card so that it will be visible to an enforcement agent.

LOOKING AHEAD

Huge advances have been made in parking-access and revenue-control technologies, and the future is sure to hold many new technologies that are unimaginable at this time. The Internet and wireless technology offer many opportunities for innovations; among the most likely are the following:

▷ paying for parking via mobile phone;
▷ new technologies that can track vehicles through unique identification numbers placed on the vehicles at the time of manufacture;
▷ the use of photo imaging to track vehicles and drivers as they enter and leave facilities; and
▷ a single AVI tag that would allow a user to park anywhere in a city and have fees charged to a single account.

CHAPTER 22

MAINTENANCE

MARK HOFFMAN, LARRY CHURCH, AND SYLVIE MERCIER

PROPER PLANNING AND ORGANIZING FOR PARKING-FACILITY maintenance provide great potential for improving an owner's return on investment. Because it typically establishes priorities—or creates a working model that can be used to help plan and predict future costs and performance—a well-planned maintenance program can help an owner make the best decisions, given the financial goals and constraints of the facility. Today, computer software can assist with maintenance planning, service-life evaluation, and the analysis of repair alternatives and maintenance choices.

A maintenance program identifies and prioritizes capital and operational maintenance requirements. It also includes a budget to guide implementation. This chapter outlines key aspects of parking-facility maintenance and repair: the maintenance program, maintenance of structural elements, and operational maintenance.

THE MAINTENANCE PROGRAM

A parking-facility maintenance program has two principal purposes: to protect the owner's investment and to minimize disruptions in operations. It may also help to ensure that the facility remains attractive and easy to use. The maintenance program for any given garage will depend upon many factors, including design details, the quality of materials and construction, and exposure conditions. Some facilities, for example, are subject to humidity, rain, snow, ice, de-icer salts, temperature change, or salt spray. Other facilities may face special conditions, such as heavy moving loads from buses or equipment.

Scheduling and prioritizing are crucial to a comprehensive maintenance program. Because of variations in design, construction, operations, environmental exposure, and other factors, a maintenance program must reflect the unique characteristics of the facility. To ensure that the facility functions at the desired performance level, maintenance work that affects operations should be carefully planned to avoid interruptions to service. For example, maintenance on the structural, architectural, mechanical, electrical, plumbing, fire protection, and security systems can be very disruptive to service, if poorly scheduled.

A comprehensive maintenance program includes the following elements:

▷ a schedule of maintenance actions (what needs to be done, and how often);

▷ a budget to cover the costs of the program; and

▷ an implementation plan to manage, control, follow up, and make any adjustments necessary to keep the facility functioning at the desired performance level.


THP LIMITED

Water is a major causative agent in damage caused by corrosion and freezing and thawing.

Developing a maintenance program before a facility even opens allows the owner to optimize the service life of the garage. Developing a program for an existing garage typically requires an assessment of current conditions, and an inventory of the systems and maintenance schedules. The *Parking Garage Maintenance Manual*, published by the National Parking Association, (1) provides information on condition appraisals and other tools used to evaluate current conditions and plan for maintenance or repairs, and (2) outlines typical maintenance schedules and budgeting information for parking facilities. The following summary of the key elements of a comprehensive maintenance program is based in part on that volume:

▷ Routine maintenance: Tasks performed regularly as interim corrective actions, housekeeping tasks, and safety checks required for effective day-to-day operation.

▷ Preventive maintenance: Tasks performed as needed to avoid future repairs and protect the owner's capital investment.

▷ Replacement maintenance or repairs: Actions taken to repair elements when it is possible and economical to do so, or to replace them when they have reached the end of their service life.

▷ Condition appraisal: An assessment of the operational and physical elements of a parking garage to (1) assess current conditions and (2) outline repairs or maintenance measures that may be necessary to help the facility achieve its anticipated service life.

▷ Rehabilitation and restoration: Repairs made to an existing garage; such repairs are often required before a comprehensive maintenance program can begin. Decisions made during the restoration process will directly affect maintenance requirements for the rest of the facility's service life.

▷ Maintenance budget: Financial plan for implementing a maintenance program.

The initial maintenance budget identifies the costs for maintenance or repair of existing conditions. More detailed planning is typically required to separate the budget into operational and capital budgets, construction phases, or work that may span multiple budgeting periods. It is often desirable to build a reserve fund for items that need maintenance at long intervals, as well as for unanticipated needs.

Budgets for maintenance vary. For example, older facilities usually have higher repair and maintenance costs than newer facilities. Some costs, such as those for cleaning and maintaining certain equipment, are incurred every month, or at other regular intervals. Other maintenance tasks, such as repainting or applying protective coatings to concrete surfaces, are performed only periodically. (Chapter 16 includes more detailed information on budgeting for maintenance.)

Maintenance budgets include three primary classifications: structural, operational, and aesthetic. The remaining sections of the chapter describe effective maintenance practices for structural and operational maintenance. It is important to note, however, that the recommendations are not applicable in every situation, and must therefore be tailored for each facility. The development of a maintenance program requires the combined efforts of the garage owner, the operator, and a professional engineer experienced with parking-garage design, repair, and maintenance.

MAINTENANCE OF STRUCTURAL SYSTEMS

Structural maintenance generally warrants the highest priority and makes up the greatest part of maintenance costs. The most significant structural maintenance is associated with the parking-deck floor slabs, which are subject to impact and abrasion from car traffic as well as harsh environmental conditions.

Despite its critical importance, structural system maintenance is frequently neglected. Although the results of neglect may not show up for many years, they can be serious. Catch-up maintenance expenditures can be costly, and can result in lost parking capacity and lost revenue while repairs are underway. Serious neglect can lead to safety concerns and structural repairs that can interrupt or stop normal parking operations. In the extreme, severely deteriorated parking structures can be condemned, and partial collapses can occur.

The most common causes of deterioration in a parking structure are

- salt-induced corrosion of steel reinforcement in the concrete;
- freezing and thawing damage to the concrete;
- corrosion of exposed metals; and
- cracking or distress to the structure (caused by movement, or changes in temperature and other factors).

These causes can also interact, compounding the rate of deterioration. In the cases of damage from freezing and thawing and corrosion, water is a causative agent. In addition, cracks in the structure often result in water leaks, which further damage the structure, annoy patrons, and damage vehicle finishes.

From the time a parking facility first opens, it requires regular inspection, preventive maintenance, and repair. Structural maintenance should start with an annual inspection of the entire facility, documenting areas of deterioration, water leakage, and corrosion of exposed metals. The following elements require special attention:

- upper surfaces of all floors, and the undersides of parking floors;
- columns and beams;
- expansion-joint seals;

Examples: Restoration and Repair

The following descriptions of actual parking garages highlight the severe consequences of salt-induced deterioration caused by the use of chloride-based de-icers.

Parking Garage for Hospital Visitors and Employees
The five-story, 1,200-car parking garage was constructed in the Midwest in 1963. The garage structure consisted of cast-in-place (CIP) concrete. The beams spanned 56 feet (17 meters), and the slabs spanned 18 feet (5.5 meters). The concrete generally had a relatively high ratio of water to cement. By the early 1980s, the slabs had become heavily contaminated with chloride, and corrosion of the steel in the top of the slabs, along the beams, had delaminated the concrete over most of the beams. Ongoing corrosion of the steel in the bottom of the slabs was also causing concrete spalling of the bottom surfaces of the slabs.

A number of trial repair and rehabilitation methods were implemented and evaluated, including several cathodic protection systems, but none were considered able to supply the long-term, maintenance-free solution the owner desired. In 1987, the slabs were removed and replaced (the beams and columns were retained and reused), at a cost that was near the garage's original total construction cost. Since then, the garage has performed well and appears capable of continuing to do so in the future.

Parking Garage Attached to a Major-League Stadium
Constructed in 1970 in the Midwest, the facility was a four-story, 1.5 million-square-foot (139,500-square-meter) parking garage, composed of CIP concrete with pan-joist framing. The parking decks were nearly flat and drained poorly. The original construction lacked any systems for mitigating chloride contamination from de-icer salts, or the resulting corrosion of internal steel reinforcing. By the mid-1980s, the decks had become heavily contaminated with chloride, and the top steel was severely corroded. Because of leaks through cracks and construction joints above, the bottom steel in the joists and beams was also corroding.

Delamination and spalling were widespread. A number of trial repair and rehabilitation methods—including sealer systems, membrane systems, cathodic protection systems, and patching techniques—were implemented and monitored. The only approach considered to provide sufficient benefit (life extension versus cost) for full-scale implementation involved nominal patching, followed by the application of a membrane. This technique was shown to slow the acceleration of reinforcing corrosion and was implemented at a cost of about $3.50 per square foot ($37.70 per square meter). The garage structure reached the end of its life in 2000 and was demolished when the stadium was replaced.

Corporate Headquarters Garage

The facility was a 750-car garage constructed in two phases below a 22-story corporate headquarters tower in the Midwest. Phase I, which had five levels and was built in 1969, was constructed of CIP concrete; beams and slabs were reinforced with paper-wrapped mono-strand post-tensioning tendons. Built in 1978, the two-level Phase II had a structural steel frame with composite steel decking and concrete slabs.

The first repairs began in 1995, when a corroded post-tensioning tendon failed, which caused the tendon to burst up through the slab. As of 1996, 23 additional tendons out of a total of 820 had failed. At the time that Phase I was constructed, tendons were not required to be fully encapsulated and protected from salt exposure, as they have been since the late 1980s. The paper-wrapping of tendons provides little, if any, protection from salt exposure.

Repairs have included sealer applications, crack sealing, the application of membranes over tendon anchorage zones, the replacement of the 23 failed tendons, and the installation of permanent shoring below isolated areas. The cost of replacing the tendons was $2,800 per tendon (in 1996 dollars). Since 2000, a proprietary electronic system that detects tendon and wire breaks has been used to monitor tendon performance throughout the garage. Using sensors, the system "hears" the noise emitted when a tendon wire breaks, and through computerized triangulation provides the location of the break. Minimal tendon breakage has been detected since 2000. The composite steel decking on the upper levels is moderately corroded in small, isolated areas, but did not show widespread corrosion as of 2005.

Parking Deck at a Regional Mall

The facility, built in 1975 in the Midwest, has one supported level of 200,000 square feet (18,580 square meters). The garage is constructed of precast, prestressed double tees with a three-inch (7.5 centimeters) field cast and bonded topping, jointed above double-tee joints. Column centers are typically 60 feet by 32 feet (18.3 meters by 9.8 meters).

About half of the deck was flat, without adequate drainage slopes. The first significant repairs to the deck were undertaken in 2000, and consisted of the following:

▷ Removal and replacement of 25 percent of the bonded topping in areas that had failed because of freeze/thaw action and corrosion of the topping's mesh reinforcement.

▷ Removal and replacement of all of deck joint sealants, which amounted to more than 10 miles (16 kilometers) of linear joints.

▷ Replacement of over 250 tee-flange-to-tee-flange shear connectors, which had failed because of (1) vehicular loading and (2) corrosion caused by leakage through failed joint sealants.

▷ Installation of supplemental drains and a traffic-bearing membrane in the portion of the deck without adequate drainage slopes.

Garage at a Retail and Entertainment Complex

The facility is a seven-level, 6,000-car garage constructed in the Midwest in 1992. The construction method was precast prestressed double tees without a field-cast bonded topping. Tees span 60 feet (18.3 meters), and their "pretopped" flanges were furnished four inches (10 centimeters) thick. As of 2005, deterioration had consisted of (1) leakage through tee-joint sealants and (2) corrosion and breakage of the tee-flange-to-tee-flange shear connectors. Repairs in 2005 included the removal and replacement of nearly 60 miles (97 kilometers) of tee joint sealant and the replacement of 950 tee-flange-to-tee-flange shear connectors.


THP LIMITED

The worst-case scenario for a severely deteriorated garage is a collapse.

▷ control and construction-joint sealants;
▷ guardrails and handrails (to verify that they are rigid and safe);
▷ stairways;
▷ barrier walls and other structural elements that restrain vehicles;
▷ in a precast concrete system, connections, sealants, and bearing pads; and
▷ wheel stops.

A qualified engineer experienced in parking should perform the inspection—and, if the inspection uncovers damage to structural elements, corrective measures often must be taken immediately. The specific methods will vary with the situation, but the following general guidelines apply:

▷ Concrete normally develops cracks, but many small cracks are of no consequence and need not be repaired. Cracks that require attention are usually structural cracks, or those that allow water to leak into the interior of the concrete through the floor: such leaks can corrode the reinforcing steel and cause other damage.

▷ When exposed metal corrodes, it needs to be thoroughly cleaned and painted with a protective coating or other appropriate compound. The painting can take place as part of touch-up work or in the course of general repainting.

▷ Water leaks in the concrete structural system normally require sealers, sealants, or water proofing. The assistance of a qualified engineer is recommended to ensure that the solution fits the problem. For example, a crack that will continue to be subject to movement should be filled with a flexible rather than rigid material.

▷ If concrete has deteriorated, it is essential to make appropriate repairs and undertake preventive maintenance to prevent further damage. For example, it is not enough to simply patch potholes or spalled areas in concrete floors with asphalt. Because asphalt is porous, water will collect in the bottom of the patched hole, further accelerating deterioration of that area. Many repair materials are on the market, most of which work reasonably well for some, but not all, types of repairs. Again, it is best to consult with a qualified engineer before undertaking concrete repair work.

Concrete structural elements are best maintained by preventing moisture from penetrating the concrete, particularly the top surface of floor slabs. The parking industry has a range of specialty products, from water repellants to long-life membranes. Three types of material can help prevent moisture penetration: a protective concrete sealer, a thin (traffic-bearing) membrane, and a protected membrane (a membrane with a protective wear course for vehicle traffic). These products vary considerably in cost, service life, maintenance, and effective applications. With this range, it is important to match the product and performance to the owner's needs and expectations.

In a concrete garage that is subject to salt-induced corrosion of its internal reinforcing steel, preventive maintenance can take many forms, including cathodic protection, realkalization, chloride-ion extraction, corrosion-inhibitor absorption, and oxygen starvation.

Although they do not contain structural elements, parking lots require many of the same maintenance procedures as garages. Given that most parking lots are surfaced with an asphalt mix, maintenance should include regular repair of potholes and periodic applications of sealing coats.

OPERATIONAL MAINTENANCE

Generally easier and less costly than structural maintenance, operational maintenance includes routine cleaning and maintenance of the facility and its equipment. Operational maintenance is important because any malfunction or breakdown of an operational element can take part or all of a facility out of service or compromise user security and safety.


THP LIMITED

Patching a damaged floor slab can be expensive and cause lost revenue. Pictured here is a slab suffering from delaminations and spalls.

THP LIMITED

A failed tee-flange shear connector.

Equipment

To ensure safe, smooth operation of the facility, the maintenance program should require inspection of all equipment to verify that it is functioning properly. Equipment with moving parts usually needs to be inspected and lubricated at regular intervals. When an inspection indicates that a piece of equipment is not functioning properly, the equipment should be repaired or replaced immediately.

For each piece of equipment, the operator should maintain (1) a file containing the operating and maintenance manual and (2) a log of the maintenance and repair work performed on that equipment. The manufacturer's recommendations for operation and preventive maintenance should be followed.

Equipment that requires regular inspection, lubrication, or other preventive maintenance includes, but is not limited to, the following:

▷ parking- and revenue-control equipment;
▷ elevators, escalators, and man-lifts;
▷ electrical equipment, including lighting and emergency lighting;
▷ doors, including hinges, closers, and latch sets;
▷ mechanically operated doors;
▷ security systems;
▷ heating, ventilating, and air-conditioning equipment;
▷ carbon monoxide monitors;
▷ restrooms;
▷ sump pumps;
▷ fire-protection system; and
▷ floor- and roof-drainage systems.


THP LIMITED

Replacement of broken tendons in a post-tensioned slab.

Some of these elements, such as carbon monoxide monitors, should be checked daily; other equipment may need less frequent inspection or attention. Some equipment, such as elevators and parking-control equipment, should probably be maintained under a service contract that provides routine services, such as inspection and lubrication, as well as emergency repairs.

Because nearly all equipment used in parking facilities is subject to corrosion, which can shorten service life, all inspections should include observations for corrosion. If corrosion is found, the equipment should be cleaned and properly painted to maintain its appearance and integrity.

Housekeeping

Housekeeping maintains the facility's appearance and helps protect the structural elements from damage. Aesthetic maintenance is important because poor aesthetic conditions are immediately obvious to patrons, but housekeeping also serves an operational function. For example, if dirt and debris are not removed from the parking floors, they can clog floor drains and result in water ponding—which creates a hazard if the water freezes, and can also damage the structural system over time.

Patrons prefer a bright, clean facility; they also tend to litter less in a well-kept facility. Housekeeping tasks include, but are not limited to, the following:

▷ sweeping and washing floors in the pedestrian and vehicular areas;
▷ washing windows;
▷ cleaning stairs, including handrails;
▷ cleaning elevator cabs;
▷ emptying trash cans;
▷ removing trash and other debris;
▷ cleaning floor drains and expansion-joint seals;
▷ cleaning signs;
▷ removing grease drippings;
▷ removing snow and ice;
▷ replacing burned-out light bulbs;
▷ removing graffiti; and
▷ repainting stall stripes and other pavement markings.

The frequency of these tasks varies with the situation. Heavily used public areas require more frequent attention than little-used areas. Picking up trash on floors, without sweeping, also has some benefit. Floors should be washed at least once a year. In areas where salt is used to melt snow and ice or is present in the air, all floors should be washed down in early spring.

SUMMARY

Every parking garage and lot requires a comprehensive maintenance program that is tailored to its needs. This program should consider design details, quality of construction and materials, and exposure conditions. A condition appraisal undertaken by a qualified engineer, combined with a capital-asset management plan, will provide the framework to address the multifaceted issues associated with the maintenance of a parking facility, and will help the owner/operator understand the maintenance requirements and make wise choices.

Implementation of a maintenance program requires an ongoing budget and management commitment. The cleanliness, appearance, and condition of a parking facility generally reflect management's attitude toward maintenance. A large part of every maintenance program consists of regular observations to verify that the facility's structural elements, systems, and equipment are clean and in proper working order. Any problems should receive immediate attention. Preventive maintenance is generally more cost-effective than repair. Where parking facilities are operated by a different party from the owner, it is in the interest of both the owner and the operator to clearly define the maintenance responsibilities of each party and to assign appropriate amounts in the operating and capital budgets.

NOTE

1. National Parking Association (NPA), *Parking Garage Maintenance Manual*, 4th ed. (Washington, D.C.: NPA, 2004).

GLOSSARY

Albedo—a measure of reflectivity. Dark rooftops have a lower albedo, which can make buildings more costly to cool in the summer and contribute to the heat-island effect.

Attendant parking—a system in which attendants (sometimes called valets), rather than customers, park and retrieve vehicles.

Automated parking facility—a facility in which vehicles are stored and retrieved by mechanical action rather than by patrons or attendants.

Automatic vehicle identification system—electronic sensors, antennae, and transponders that detect a vehicle's presence for identification, which results in some subsequent action, such as access control and/or revenue collection.

Ballast—a device used to provide the starting voltage or to stabilize the flow of current in a light fixture.

Ballast factor—the ratio of the luminous output of a lamp (bulb) operating on a ballast to its output, when the bulb is being operated under standard rating conditions.

Beam—the major horizontal support for the floor of a parking structure; beams rest on vertical columns and are the supports to which floor slabs are attached.

Bond counsel—an attorney who specializes in municipal security law.

Bond insurance—a service whereby issuers of a bond pay a premium to a third party who will provide interest and capital repayments, as specified in the bond, in the event that the issuer fails to do so.

Break-over angle—The measure of a vehicle's ability to drive over a sharp ridge or ramp without touching its underside. If the angle is too large, some vehicles may scrape their bumpers, or their undercarriage may "bottom out" on the transition.

Budget pricing—an approximation of the cost of an activity, job, program, or project, prepared for budgeting and planning purposes only. Budget pricing is not accurate enough to provide a basis for a firm commitment; it represents only the budget maker's understanding of the scope and expense of what needs to be done.

Building code—local ordinances that protect public health, safety, and welfare by establishing minimum standards for the design and construction of the built environment.

Bumper wall—a wall on the interior and the perimeter of a parking facility that is designed to resist a lateral force from automobile impact.

Capacity—the number of vehicles that can be accommodated in a parking facility.

Captive market—markets in which potential consumers face a severely limited amount of competitive suppliers; their only choices are to purchase what is available or to make no purchase at all.

Cast-in-place concrete—a construction method in which concrete is poured into a form fabricated on site; also called poured-in-place concrete (compare precast concrete).

Central cashiering—a centrally located cashiering function; may be staffed or automated.

Chloride-ion contamination—an electrochemical process that leads to the deterioration of concrete and metal.

Circulation system—the overall horizontal and vertical vehicular and pedestrian paths within a facility.

Clear-span facility—a parking facility that has columns only at the perimeter of the structural bays, and no columns between parking stalls. The structural bays usually have spans ranging from 55 to 60 feet (16.8 to 18.3 meters).

Cognitive map—an overall mental representation of a setting that cannot be grasped from a single viewpoint; a term used in the study of wayfinding.

Column line—a linear set of columns that is part of a larger structural grid.

Composite construction—a generic term used to describe any construction method that involves multiple dissimilar materials.

Conflict point—the point at which vehicles run a higher risk of collision, such as where aisles intersect.

Construction management—a delivery method in which construction is supervised by a qualified construction manager.

Contingency account—an amount set aside to address potential unknowns when estimating the cost for a project.

Continuous-ramp parking structure—a type of parking structure in which vehicles park on a continuous sloped parking deck that normally does not exceed a 5.5 percent gradient.

Cross aisle—an area in a parking facility or lot where two parking bays intersect, usually perpendicularly. Cross aisles are usually differentiated from parking aisles because they do not have parking along them.

Crossover—an area in a parking structure where motorists can change direction or proceed to another parking circuit and/or exit.

Cross slope—a parking surface whose slope is perpendicular to the drive aisle.

Curb ramp—a depressed curb at a sidewalk that allows patrons using strollers, wheelchairs, walkers, or other devices to move more easily up to or down from the sidewalk.

Cutoff fixture—a type of light fixture that concentrates the light downward, where it is needed, thus limiting the light directed upward.

Dead load—the permanent weight of the structural components of a building.

Debt-service coverage ratio—a comparison of the amount of revenue available to pay debt service with the debt service itself.

Deflection—the degree to which a structural element is displaced under a load.

Demand—the number of potential customers for a parking facility or system.

Depreciation—a percentage of the value of an asset that is deducted each year for wear and tear.

Design-build—a project-delivery system in which a single entity is responsible for both design and construction.

Design day—the level of parking activity that recurs frequently enough to justify providing parking spaces; used to determine what capacity a facility will be expected to provide.

Design hour—a percentage (usually 85 percent) of the highest one-hour volume of parking demand experienced in a particular location; used to determine what capacity a facility will be expected to provide.

Design live load—the amount of weight (load) that a structure will support, including the weight of the structure itself (dead load), as well as people, cars, equipment, etc., all of which need to be taken into account in the design.

Detector loop—a device embedded in the pavement that is used to count incoming and exiting vehicles.

Directional signage—signs that direct motorists and pedestrians to entrances, available parking, exits, stairs, elevators, or destinations.

Double-helix parking structure—a parking structure that has two interlocking ramp systems.

Double tee—a precast concrete structural element used as a beam; the name derives from the shape, which is similar to a pair of Ts.

Drive aisle—the traveled path through a parking facility that provides access to the parking spaces.

Dump time—the estimated amount of time required for the entire capacity of a parking facility to exit.

Dwell time—in an automated facility, the time that a transit vehicle is stopped for the purpose of serving passengers, and to open and close its doors.

Dynamic message sign—a sign that can change its message in response to changing conditions; also called a variable message sign.

Effective supply—a downward adjustment, usually between 10 and 15 percent, of the actual parking inventory, to reflect the fact that the facility will rarely be functioning at 100 percent of capacity. When a parking facility is designed, it ordinarily incorporates an effective supply cushion, which is the difference between the actual number of spaces and the effective supply.

Electro-discharge lamp—a high-powered light source produced by an arcing electrical discharge between two electrodes suspended in a glass tube filled with gas (usually sodium, xenon, mercury vapor, or metal halide).

Enclosed parking structure—a structure that lacks natural ventilation, and is often below grade.

Expansion joint—a construction joint positioned between the sections of large concrete slabs, which safely absorbs temperature-induced expansion and contraction of the slabs.

Feasibility study—an analysis of the viability, design, and financial performance of a parking facility.

Financial analysis—a projection of the operating expenses, revenues, and sometimes the debt service associated with an existing or proposed facility, or with the expansion of an existing facility; includes an assessment of the owner's ability to fund the improvements through parking income.

Flat-floor parking structure—a facility that has flat, rather than sloped or ramped, parking floors.

Foot-candle—a measure of illumination; equivalent to the amount of light delivered by a one-candela light source to a one-square-foot (0.093-square-meter) surface one foot (0.3 meter) away.

Functional design—the arrangement of vehicular and pedestrian flows in a parking facility.

General-obligation bonds—bonds that are sold by a public agency to finance public improvements, and that are backed by the full faith and credit of the issuing agency.

Generator—a use that creates parking demand, such as a store, office building, hospital, or recreational facility.

Geotechnical investigation—a process by which geotechnical engineers or engineering geologists obtain information on the physical properties of soil and rock on and around a site; used to design earthworks and foundations for proposed structures, and to repair distress to earthworks and structures that is caused by subsurface conditions.

Gross revenue—the amount of revenue generated prior to deductions such as payroll, operations, and maintenance.

Hard costs—the costs of construction, including land, materials, and labor, but not including soft costs such as fees, permits, insurance, and financing costs.

Hollow-core precast concrete—a slab that has a hollow center, to reduce weight.

Honor box—steel boxes used in unattended parking facilities, where customers are on their honor to pay the fee.

Horizontal illuminance—the amount of light falling on a horizontal surface (compare vertical illuminance).

Hydraulic elevator—a type of elevator that employs plungers that push up from below the platform; the plungers, in turn, are powered by pressurized oil in a hydraulic cylinder. Hydraulic elevators are typically used for low- or medium-rise passenger travel, and for heavy-duty freight elevators.

Illuminance—the amount of direct light falling on a surface; it can be measured with a light meter and quantified in luxes.

Interlock—a herringbone pattern created by the alignment of adjacent stalls when parking spaces are angled.

Interlock dimension—the overlap between one stall and the module of another stall.

International symbol of accessibility—symbol used to guide patrons to areas such as parking spaces, elevators, and curb ramps that are compliant with the Americans with Disabilities Act.

Joint—in concrete construction, a means of connecting sections of a floor or slab to permit expansion and contraction caused by thermal conditions or movement of the structure; also called an expansion joint.

Joist—an element in a floor system that rests on the beams and supports the floor surface.

Land banking—purchasing land and holding it in reserve so that it can be used to provide additional parking at a later date.

Lane technology—technology developed specifically to manage parking access and revenue control at the entrance and exit lanes of a parking facility.

Lateral load—the pressure exerted against a building coming from the horizontal plane. Such pressures can be generated by static earth, wind, and earthquakes, among other things.

Letter of credit—a document, most likely issued by a financial institution, in which the institution agrees, for a specific period of time, to pay the letter holder a specified amount on demand.

Life-cycle cost—an analysis that determines the number of years in the service life of a facility. It takes many considerations into account, including first costs, maintenance, and repair.

Light level—light intensity, usually measured in foot-candles in parking facilities.

Light trespass—light that encroaches upon or spills over onto neighboring properties.

Live load—the weight of vehicles and people in a structure (compare dead load).

Loading—the forces to which a structure is subject because of superposed weight.

Lumen—a unit used to measure the amount of light output a bulb or fixture produces.

Lumen depreciation—the phenomenon in which light output decreases with the amount of time a lamp is operated.

Lux—a unit of measurement for illuminance and luminous emittance; equal to one lumen per square meter.

Management fee—a fixed fee or a percentage of revenue paid to the professional manager of a facility.

Market study—a projection of the number of users who may be captured by a facility on a particular site, given demand, competition, and prevailing parking rates.

Modal split—a percentage breakdown of users employing particular types of transportation.

Module width—the width of a module, measured from the front of a parking stall to the front of the parking stall directly across from it, including the drive aisle.

Net revenue—the remaining revenue after all expenses are deducted.

Noncutoff fixture—a light fixture that directs light both above and below the fixture.

Open parking structure—a parking structure with one or more levels and partial or parapet walls (compare enclosed parking structure).

Operator—an individual or firm that is responsible for operating a parking facility; the responsibility may be based on ownership, a lease, a contract, or another arrangement.

Outline specifications—a preliminary set of specifications on which later, more detailed specifications are based; outline specifications are generated during the early phases of the design process.

Panic hardware—an approved device installed on an exit doorway to allow for fast emergency egress.

Pan-joist system—a structural system that uses a combination of joists and form pairs; also known as flat-soffit construction or waffle-slab construction.

Parking-access and revenue-control system (PARCS)—A collective term for the devices used in parking facilities, including gates, ticket dispensers, counters, fee computers, and detectors.

Parking angle—the angle formed by a parking stall and the wall or centerline of a facility.

Parking bay—a section of a parking facility that contains a drive aisle and one or two rows of parking spaces.

Parking geometrics—the design criteria (including dimensions, flow patterns, and layout) that are applied to the design of a parking facility.

Parking load—the weight imposed on a structure by parked and maneuvering cars.

Pay-and-display system—a payment system in which a patron pays for the desired amount of parking time and is issued a receipt that must be displayed on the vehicle's dashboard.

Pay-by-space system—a payment system in which a patron pays at a centrally located machine that serves multiple numbered spaces rather than at an individual parking meter.

Pay-on-foot system—a payment system in which a patron pays for parking at a central cashiering station or at an unmanned kiosk before returning to his or her car.

Peak period—period of maximum parking activity; can be determined by the hour, by the day of the week, or by the season.

Person-trips—the number of trips a development generates, as measured by the number of people traveling to and from the development during a given period.

Positive drainage—a slope (generally no less than 1.5 percent) built into the floor surface of a parking facility to allow water to flow effectively to floor drains.

Post-tensioned concrete—concrete that is strengthened by tightened cables that run through the slab and beam.

Poured-in-place concrete—concrete poured into forms that are erected at the project site; also called cast-in-place concrete (compare precast concrete).

Precast concrete—concrete building components fabricated at a plant and shipped to the construction site.

Proximity card—a card that needs only to be within a few inches of a reader for verification; no swiping or insertion is required.

Quantity takeoff—an activity performed by general contractors, subcontractors, cost consultants, and quantity surveyors as part of the construction process. Quantity takeoff involves (1) counting the number of items associated with a particular construction project; (2) determining the associated materials and labor costs; and (3) formulating a bid, or estimate, as part of the bidding process.

Queue area—holding space within a parking facility for vehicles entering or exiting (also called reservoir space).

Ramp—an inclined area in a parking structure; depending on the design of the structure, a ramp may accommodate parking, or may be used only for vehicular circulation (in which case it is called an express ramp).

Recirculation—the reentry of drivers into the interior circulation pattern of a parking facility to search for vacant spaces.

Reflectance—the fraction of light reflected from an object, as compared to the direct light on an object.

Reflectance contrast—the contrast between the reflectance of a hazard and that of its background.

Retrieval time—the amount of time that elapses from the moment a patron requests a vehicle from the valet service or automated parking system and the moment the vehicle is delivered.

Revenue-control equipment—Devices, including gates, ticket dispensers, counters, fee computers, and detectors, that support the revenue-control system.

Revenue-control system—system for handling money and recording transactions in such a way as to ensure control of revenue.

Scissor-ramp structure—a design in which ramped floors are situated opposite one another like the blades of scissors; also called a double-helix structure.

Search pattern—the circulation pattern followed by motorists in search of available parking spaces.

Self-park garage—a facility in which cars are parked by the driver rather than by attendants or by means of mechanical systems.

Sensitivity analysis—a technique used to determine how different values of an independent variable will affect a particular dependent variable under a given set of assumptions; used within specific boundaries that will depend on one or more input variables.

Service rate—the number of vehicles per hour that a parking facility can serve. The service rate depends on the configuration of the entrance and exit controls, such as ticket dispensers, control arms, and card readers.

Shared-parking analysis—a projection of parking demand in mixed-use areas that takes into account (1) variations in demand by season, day of the week, time of day, and user type; and (2) the relationship between parking needs and planned land uses.

Short span—the span of a beam that is less than the total length of the parking bay or module; usually involves columns between the outer walls of the structure.

Shrinkage cracking—stress points and cracks that are created as concrete cures and shrinks over time.

Single-helix structure—a parking structure that has one ramp system with two-way traffic flow.

Single tee—a precast concrete structural element used as a beam; the name derives from the shape, which is similar to a letter T.

Soffit—the underside of any overhead component of a building, such as a beam, cornice, or vault.

Special taxing district—an area defined by ordinance in which unique taxes can be imposed to fund improvements such as parking.

Stall—the area, usually marked with distinguishing lines, in which one vehicle is to be parked; a parking space.

Steel-framed parking structure—a facility with a framework composed of steel columns and beams.

Structural system—the type of construction used to construct a parking facility, such as cast-in-place concrete, precast concrete, or steel.

Super-elevation—the banking of a curved roadway or ramp.

Supported level—the portion of a parking structure that is not slab-on-grade and is supported by columns, walls, and beams.

Topographical survey—the science and art of making essential measurements to determine the relative position of points and/or physical and cultural details above, on, or beneath the surface of the earth.

Transponder—a wireless communications, monitoring, or control device that picks up and automatically responds to an incoming signal. The term is a contraction of transmitter and responder.

Turning radius—the pavement or ramp width necessary to permit a vehicle to complete a turn.

Turnkey construction—a type of construction contract under which the construction firm is obligated to complete a project from start to finish, according to specified criteria, for a price that is fixed at the time the contract is signed.

Turn-out lane—a lane in which patrons can repark their cars without having to back out of the equipment lanes; usually used in a pay-on-foot system, in case a patron forgets to pay before attempting to exit.

Turnover—the number of vehicles expected to use one space on a given day.

Uniformity ratios—part of a complete set of lighting criteria intended to achieve uniform lighting coverage.

Valet parking—a form of attendant parking; usually provided as a service to patrons of commercial establishments.

Vehicle restraint—any means of restraining an occupied or unoccupied vehicle, ranging from horizontally strung steel cable assemblies to concrete or steel walls, barriers, or railings.

Vehicle-trips—the total number of daily trips by a vehicle generated by a specific land use.

Vertical illuminance—the amount of light falling on a vertical surface, such as a wall (compare horizontal illuminance).

Wayfinding—finding one's way to a destination. Wayfinding is spatial problem-solving encompassing three interdependent processes: information processing, decision making, and the development of a plan of action.

Wheel load—The load carried by and transmitted to the supporting structure by one wheel of a vehicle.

Wheel stop—a bumper or block placed at the head of a parking stall to restrain a vehicle from moving forward.