Repairing and Maintaining Airport Parking Structures While in Use

DETAILS

46 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-27094-6 | DOI 10.17226/22561

AUTHORS

K. Nam Shiu, Kurt L. Salm, and Jonathan Beckstrom; Airport Cooperative Research Program; Transportation Research Board; National Academies of Sciences, Engineering, and Medicine

AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP SYNTHESIS 47

Repairing and Maintaining Airport Parking Structures While in Use

A Synthesis of Airport Practice

CONSULTANTS
K. Nam Shiu
Kurt L. Salm
and
Jonathan Beckstrom
Walker Restoration Consultants
Elgin, Illinois

SUBSCRIBER CATEGORIES
Aviation • Terminals and Facilities

Research Sponsored by the Federal Aviation Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2013
www.TRB.org

AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), Airlines for America (A4A), and the Airport Consultants Council (ACC) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

Research problem statements for the ACRP are solicited periodically but may be submitted to the TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

Once selected, each ACRP project is assigned to an expert panel, appointed by the TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

ACRP SYNTHESIS 47

Project A11-03, Topic S09-05
ISSN 1935-9187
ISBN 978-0-309-27094-6
Library of Congress Control Number 2013936326

COPYRIGHT INFORMATION

NOTICE

The project that is the subject of this report was a part of the Airport Cooperative Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

The Transportation Research Board of the National Academies, the National Research Council, and the sponsors of the Airport Cooperative Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of the report.

Published reports of the

AIRPORT COOPERATIVE RESEARCH PROGRAM

are available from:

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

and can be ordered through the Internet at
http://www.national-academies.org/trb/bookstore

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

Cover Figure: Denver Airport, garage roof. *Credit*: Denver International Airport.

FOREWORD

Airport administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the airport industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire airport community, the Airport Cooperative Research Program authorized the Transportation Research Board to undertake a continuing project. This project, ACRP Project 11-03, "Synthesis of Information Related to Airport Practices," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an ACRP report series, *Synthesis of Airport Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Gail R. Staba
Senior Program Officer
Transportation Research Board

Travelers require constant access to airport parking structures. Because of this, undertaking maintenance and structural repair in an airport parking structure presents many challenges, such as maintaining a high level of service at all times and establishing appropriate patron and asset protections. As a result, it is desirable to have a balanced approach to meet those challenges. The objective of this synthesis report is to provide information on developing and implementing successful maintenance and repair strategies for in-use airport parking structures that involve the least impact on the airport patrons, revenue stream, and facility operations. A group of 15 airports were identified and contacted for their participation in this survey. Twelve airports (eight large hubs and four medium hubs) responded.

K. Nam Shiu, Kurt L. Salm, and Jonathan Beckstrom, Walker Restoration Consultants, Elgin, Illinois, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

REPAIRING AND MAINTAINING AIRPORT PARKING STRUCTURES WHILE IN USE

SUMMARY

Airport parking structures are integral to the travel experience and provide an important revenue source for airport operations. Like any physical asset, a parking structure has a finite service life and requires regular maintenance and periodic structural repair and restoration. Because of the constant access required by travelers, undertaking maintenance and structural repair in a parking structure while it remains in use presents many challenges, including maintaining a high level of services at all times and establishing appropriate patron and asset protections. As a result, it is desirable to have a balanced and methodical approach to meet those challenges.

The objective of this synthesis report is to provide information on developing and implementing successful maintenance and repair strategies for in-use airport parking structures that have the least impact on the airport patrons, revenue stream, and facility operations. A group of 15 airports were identified and contacted for their participation in this survey. Twelve airports (eight large hubs and four medium hubs) responded, for a response rate of 80%. Survey questionnaires were developed and sent to the airport operators and managers prior to administration of the telephone interviews.

Literature indicated that establishing and following formal asset management protocols is beneficial to protecting an airport's capital assets; so an overall airport facility asset management program should include an asset management module for airport parking structures. Having such a module also allows planners to align funding and staffing resources for parking with long-term airport goals. The asset management program also helps focus on and clarify when and what type of renewal (repair and maintenance) can be undertaken systematically for the parking structures so as to minimize disruption while maintaining round-the-clock operations. Key components of a successful in-use renovation include understanding the background and historical data of the parking structure; establishment of renewal approaches; involvement of all stakeholders in planning to meet parking demands and level of service during repair; and communication of anticipated changes to affected parties.

Survey data indicated that airport parking operators and managers already keep track of financial operations data, parking space demand throughout the year, and the history of maintenance and repair on the parking structures. These records allow managers to schedule the renewal activities for slower parking demand periods and thus maximize the number of parking spaces that can be made available for repair.

Parking structures in surveyed large hubs were found to have an average age of about 19 years. Annual and scheduled maintenance have been undertaken regularly but typically on an as-needed basis. Eight of the 12 surveyed airport hubs have annual budgets set aside for parking structure renewal. Three of the eight large hubs surveyed have undertaken significant restoration work in their parking structures in the past 10 years. As parking structures age, more renewal projects can be anticipated. However, depending on the condition of the parking structure, as-needed repair may not be a cost-effective approach to maintain the parking structure.

A successful renewal effort for airport parking structures includes maintaining a perceived high level of service throughout the construction process. Such a perception can be boosted by early and continued involvement of all stakeholders, including airport management, parking operators, in-house maintenance department, airlines, airport tenants, and other support services such as signage and finance departments.

With so many stakeholders, good communication is critical, especially in the construction phase of the renewal process. Effective airport parking operators inform parking patrons of activities well in advance and at strategic locations as they approach the work zone. Multiple means of communication, from traditional newspapers to highly sophisticated digital electronic guidance systems, have been successful in reaching a broad range of patrons. The better the public and airport users are informed, the easier patrons can adjust to the temporary changes in the traffic pattern and the parking arrangement during construction. Incentives such as fee discounts can be used to compensate for this temporary inconvenience.

This synthesis found that there is no established deterioration curve for parking structures. Renewal projects are typically undertaken as a result of observed distress or deterioration. However, if definitions of deterioration characteristics of parking structures were made available, a renewal program could be developed that is more cost-effective and performed at optimum intervals. More research is needed to establish a typical deterioration curve for parking structures.

Research is also needed to formulate guidelines for developing asset management programs for airport parking structures. Although overall airport asset management guidelines are available, a specific framework pertaining to parking structures is not. More focused guidelines may promote wider adoption of asset management programs. In addition, keeping a database on unit renewal costs for parking structures may provide helpful tools in budgeting and establishing long-range asset strategies.

CHAPTER ONE

INTRODUCTION

OBJECTIVE

Airport parking structures are critical support elements of the airport system. Since many airports operate around the clock every day of the year, their parking structures are in use at all times, even during repair and maintenance. This synthesis focuses on how parking operators maintain and repair in-use airport parking structures while minimizing adverse impact on airport operations or patron usage.

UNIQUE ATTRIBUTES OF PARKING STRUCTURES AT AIRPORTS

Airport parking must accommodate air travelers, meeters and greeters, airport employees, and other visitors requiring hourly or daily parking. As such, airport parking serves as a link between transportation modes, allowing drivers to become pedestrians and then airline passengers. At large or medium-sized hubs, there is typically more than one type of parking accommodation: close-in parking structures, which are usually located next to the airport terminals; and off-site parking lots, which may be operated by the airport or by other enterprises. Access between close-in parking structures and terminals is usually by foot; vehicles are primarily self-parked, though valet parking may also be available. Access to remote lots may be by foot or by motorized conveyance, usually free shuttles.

Drivers choose between closer-in or remote parking based on price, availability of spaces, and level of convenience and services provided. Therefore, fees for on-site airport parking that provides vehicular cover as well as proximity to the terminal are typically among the highest; and as a result, closer-in structures generate the highest revenue per parking space.

Airport parking structures are major capital assets that provide significant non-aeronautical revenue for airport operations and influence patrons' impressions of the overall airport facilities. They typically operate 24/7, and are expected to provide easy access to terminals, sufficient available spaces, and bright, clean, and safe surroundings. Like other capital assets, such as runways, taxiways, and terminals, parking structures require regular upkeep and maintenance. And, as many travelers get their first and last impressions of the airport entering and departing the parking structures, commercial airport hubs competing for passenger traffic should consider continuing to upgrade and maintain their parking structures that serve as a gateway to their airport and geographical regions.

DIVERSE ELEMENTS OF AIRPORT PARKING STRUCTURES

Airport parking structures vary in their layouts, construction methods and materials, and the environmental stressors they face. The design of airport parking facilities is affected by the available space, vehicle access, demand for parking, airport layout, and climate. The facility can be a stand-alone parking structure or a complex of interconnected facilities. Access from the parking structure to the airport terminals may include pedestrian bridges, walkways, tunnels, shuttle buses, trams, trains, or people-movers. These connecting elements are critical to planning and preparing for both pedestrian and vehicular traffic changes during the repair process.

The geographic location and climatic exposure of airport parking structures cause them to suffer varying degrees of deterioration and impacts to anticipated service life. According to American Concrete Institute (ACI) committee report 362.1R-12 (*1*), concrete airport parking structures are designed for five geographic zones with different exposure conditions and different weather-related wear. For example, structures in the northern Zone III climate are exposed to freezing and thawing cycles, as well as chloride ion penetration into the concrete from de-icing salts. In contrast, structures in the southern Zone I climate are rarely exposed to any of these factors. Further description of these geographic zones is presented in chapter three.

Even without environmental stressors, physical structures deteriorate over time, requiring maintenance to ensure continued function. In this document, maintenance will be defined to include routine (regular) maintenance and preventive maintenance. Definitions of design service life and maintenance terms are presented in the Glossary.

Similarly, even with regular maintenance, parking structures periodically need repair, restoration, or rehabilitation. To take the broadest view, the word "renew" has been used to include repair, rehabilitation, restoration, reconstruction, and preservation. More specific definitions for repair, rehabilitation, restoration, and preservation are presented in the Glossary.

CHALLENGES

Meeting parking demand and maintaining a high level of service for parking patrons during repair or maintenance work pose significant challenges to airport operators. Parking

managers try to limit the duration of repair and reduction of parking spaces (i.e., disruption to patrons) while maximizing cost-effectiveness of the repair. Factors to consider in determining the number of available parking spaces that can be taken out of service during repair work include the number of parking spaces and length of time those spaces are unavailable to meet parking demand; the location of the parking spaces relative to the terminal; the time of year the work is scheduled; projected revenue loss; construction area conditions; any additional projects scheduled for the same time that may interact with this project; and traffic flow and accessibility.

Taking parking spaces out of service not only results in a likely increase in the amount of time patrons need to locate available parking spaces, thereby delaying their arrival at the air departure gate or other airport destination, but can also add entry or exit time at the parking structure. Since airport parking patrons are usually in a hurry to catch a flight, any delay can add to their anxiety. To retain airport parking customers, it is imperative to minimize the inconvenience and anxiety level of the patrons during the repair construction. Therefore, the timing and duration of closing spaces are considerations for construction planners. Managing parking space closures for a few hours during the middle of the night is significantly less complicated and disruptive than closing parking spaces for days or weeks during a peak traveling period.

Revenue loss from the closing of spaces, particularly for an extended period, can have a significant financial impact to the airport. In addition, the temporary loss of patrons can result in a permanent loss of revenue if customers find more convenient alternate means of accessing the airport. Business development and marketing statistics have long suggested that the cost of recovering a lost customer may be six to seven times more than the cost of acquiring a new customer (*2*), so the financial impact of inconveniencing patrons is not only significant but could be long-lasting.

Construction sites are characteristically unsightly, and if not properly addressed can produce a bad impression of airport facilities. Airborne dust, construction materials and debris, and high noise levels can be both a safety hazard and a nuisance. Furthermore, incidental damages to vehicles during repair could result in monetary claims by vehicle owners.

Additionally, when parking spaces and driving lanes are blocked off for repair construction, it is essential that temporary vehicular and pedestrian traffic circulation patterns are designed and laid out with safety and simplicity as high priorities. To avoid traffic bottlenecks and unsafe interactions between vehicles and pedestrians, it is essential to include maps and signage in planning.

METHODOLOGY

The report approach and methodology included a review of literature, a survey of selected airports, and a synthesis of survey data. The review of literature covered the following topics: parking metrics for capacity, demand, levels of service, and quality of service; asset management planning for airport facilities and for parking structures; life-cycle analysis for parking structures; and communications among stakeholders, parking patrons, and the community.

A selected group of 15 airports was contacted, from which 12 agreed to participate in the telephone survey (an 80% participation response) (Table 1). Of survey respondents, eight are large commercial hubs and four are medium commercial

TABLE 1
SURVEY PARTICIPANTS

CODE	NAME OF AIRPORT	HUB SIZE	STATE	NO. OF PARKING DECKS
ATL	Hartsfield–Jackson Atlanta International Airport	Large	GA	8
DFW	Dallas/Ft. Worth International Airport	Large	TX	14
DIA	Denver International Airport	Large	CO	7
LAS	McCarran International Airport	Large	NV	3
MDW	Chicago Midway International Airport	Large	IL	2
MSP	Minneapolis–St. Paul International Airport	Large	MN	6
ORD	Chicago O'Hare International Airport	Large	IL	1
PHX	Phoenix Sky Harbor International Airport	Large	AZ	5
PDX	Portland International Airport	Medium	OR	2
RDU	Raleigh–Durham International Airport	Medium	NC	4
SDF	Louisville International Airport	Medium	KY	1
SNA	John Wayne Airport	Medium	CA	4

FIGURE 1 Locations of the 12 surveyed hubs.

hubs. The airports that provided data are listed in Appendix C. The locations of the 12 surveyed airports are shown in Figure 1. Note that these airports are located in both the northern and southern climates as well as in the east, central, and west regions of the United States.

The questionnaire and telephone conference calls supplied information on each airport's parking structure(s); its regular maintenance programs; repair, restoration, and rehabilitation programs; issues that impact parking operations during renewal; critical steps to maintain services and user satisfaction; communication issues among involved parties and customers; and specific case studies. Appendix A presents a copy of the survey questionnaire and summaries of collected information from the 12 respondents.

REPORT ORGANIZATION

Chapter two describes the overall asset and infrastructure management for airports. Airports can align the long-term goals for the airport parking structures with the overall airport planning. Chapter two also presents key components of the asset management plan element for airport parking structures, including the usage level of the airport parking structures throughout the year and their financial operating data.

Chapter three discusses the impact of existing conditions and how different structures can be maintained to extend their service life. Since different structural systems have different inherent characteristics, chapter three presents factors that affect durability and service life of each type of structure.

Chapter four discusses routine and preventive maintenance approaches that can be established depending on the long-term goals of each facility. Survey results indicated that almost all airports have an active routine maintenance program, though the level and extent vary. In addition to maintenance, more in-depth repair, rehabilitation, and restoration are needed to maintain and extend service life.

Chapter five presents important steps in maintaining a high level of service for airport parking structures while minimizing inconvenience to parking patrons.

Chapter six outlines the importance of communication between the airport facility operators and the parking patrons, airlines, airport tenants, and the community in general.

Chapter seven summarizes findings and recommendations for further research.

Appendix A contains the survey questionnaire and results. Appendix B presents case examples. Appendix C lists survey participants. Appendix D is a checklist of typical structural elements of airport parking facilities.

CHAPTER TWO

RENEWAL PLAN FOR AIRPORT PARKING STRUCTURES

Airport parking structures are a major asset at airports and can be included as an element of the airport asset management plan, particularly because these structures may be exposed to harsh environmental factors including precipitation, severe temperature cycles, and contaminants (*1*).

OVERALL AIRPORT ASSET MANAGEMENT

The overall airport asset management program represents a roadmap of how the capital facilities are maintained. With an asset management program, the emphasis shifts from simple repair to renewal of the infrastructure in a cost-effective and sustainable manner. Findings from other industries such as gas, oil, and transit systems suggest that asset management plans enable agencies to do more with less, to make better financial and capital investment decisions, and to better serve the stakeholders.

Guidelines have been published for setting up an asset management program for airport facilities. *ACRP Report 69* (*3*), entitled *Asset and Infrastructure Management for Airports—Primer and Guidebook*, outlines a holistic integration of process and systems. Figure 2 shows a chart of how the different components of the system work together. Figure 3 from the report shows the 10-step generic approach to developing an asset management plan.

PARKING STRUCTURES IN THE AIRPORT ASSET MANAGEMENT PROGRAM

Having a specific asset management plan for the airport parking structures would formalize strategies to minimize disruption while taking into account the financial impacts of removing parking spaces from use during construction. As a capital asset, the parking structure must remain operational at all times to optimize non-aeronautical revenue. Having the parking structure management plan integrated with the overall airport capital asset management policy allows for integration of long-range airport planning for parking structures, appropriate allocation of funding and human resources, and coordination with other airport facilities.

An asset management plan for airport parking structures would include life-cycle cost analysis (LCCA). LCCA inputs are determined for a set service period and include regular annual maintenance costs, the projected costs for scheduled renewal plans within set time intervals, and loss of revenue during the renewal projects. LCCA compares total present value of keeping the parking structure for a given period of time with the replacement costs for a similar parking structure. Such analysis provides a cross-check on the cost-effectiveness of maintaining and keeping an existing parking structure.

In addition, when an airport parking structure renewal plan is integrated with the overall airport asset management program, funding for the renewal plan becomes easier to justify.

However, according to survey responses, none of the 12 surveyed airports has a parking structure asset management program in place. Eight do have a regular renewal budget for their parking structures, but even those with set budgets only undertake renewal projects as needed or when there is known distress or an established issue. The survey also reveals that many responses do not perform LCCA for airport parking structures. One reason could be that the average age of airport parking structures is generally less than 20 years old, so the question of whether replacement is more cost-effective than renewal has not yet become an issue (*5*).

The role and competencies of an asset management organization is shown in Figure 4. Each airport facility, including parking structures, would be included as an element of the overall asset management plan. Renewal planning for airport parking structures falls under implementation of the asset management plan in Role 4. A typical asset management plan in the *ACRP Report 69* (*3*) includes the following steps, with applications to parking structures added:

1. State of the Assets: Summarizes the current condition and performance of the assets.
2. Levels of Services: Outlines the current and target levels of service.
3. Growth and Demand: Shows the forecasted growth and demand requirements for the planning period. Survey respondents indicated that many keep detailed records of how their airport parking structures are used, including information on parking occupancy and demand throughout the year. Graphic presentation of the data could provide a simple and quick visual understanding of the information. Figure 5 shows a sample of the actual parking overflow report used

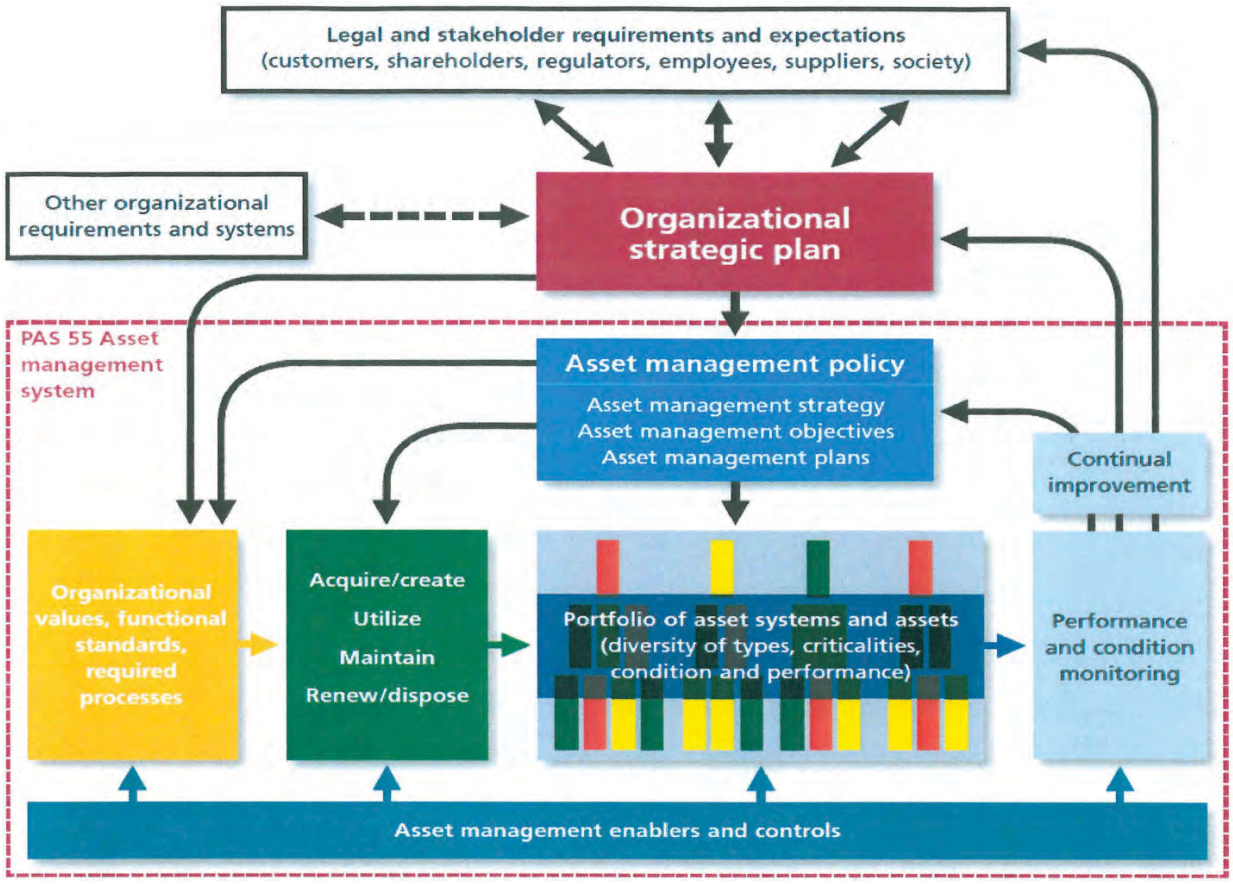

FIGURE 2 Holistic integration of processes and systems for asset management [*Source:* PAS 55 (*4*)].

at the Minneapolis–St. Paul International Airport for planning the following year's construction schedule.

4. Life-Cycle Management: Describes the current operations, maintenance, and capital renewal and augmentation or expansion plans and approaches. Figure 6 shows the typical life-cycle cost variation through the effective life of a structure. As an airport parking structure ages, renewal reduces the cost of operations and regular maintenance and overall cumulative cost. But when this same renewal work is performed later in the structure's life, renewal becomes more expensive and may culminate in a decision to replace the airport parking structure before the end of its initial anticipated effective life.

Figure 7 shows the typical cost flow history (*3*). During the lifetime of an airport parking structure, the highest expenditure is initial construction, with lower costs for routine maintenance interspersed with

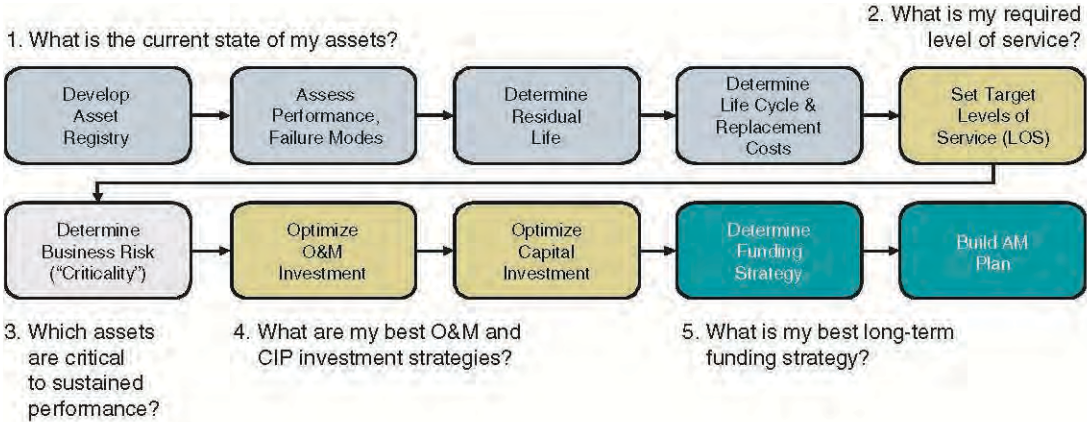

FIGURE 3 EPA's five core questions in a 10-step approach to developing asset management plans [*Source: ACRP Report 69* (*3*)].

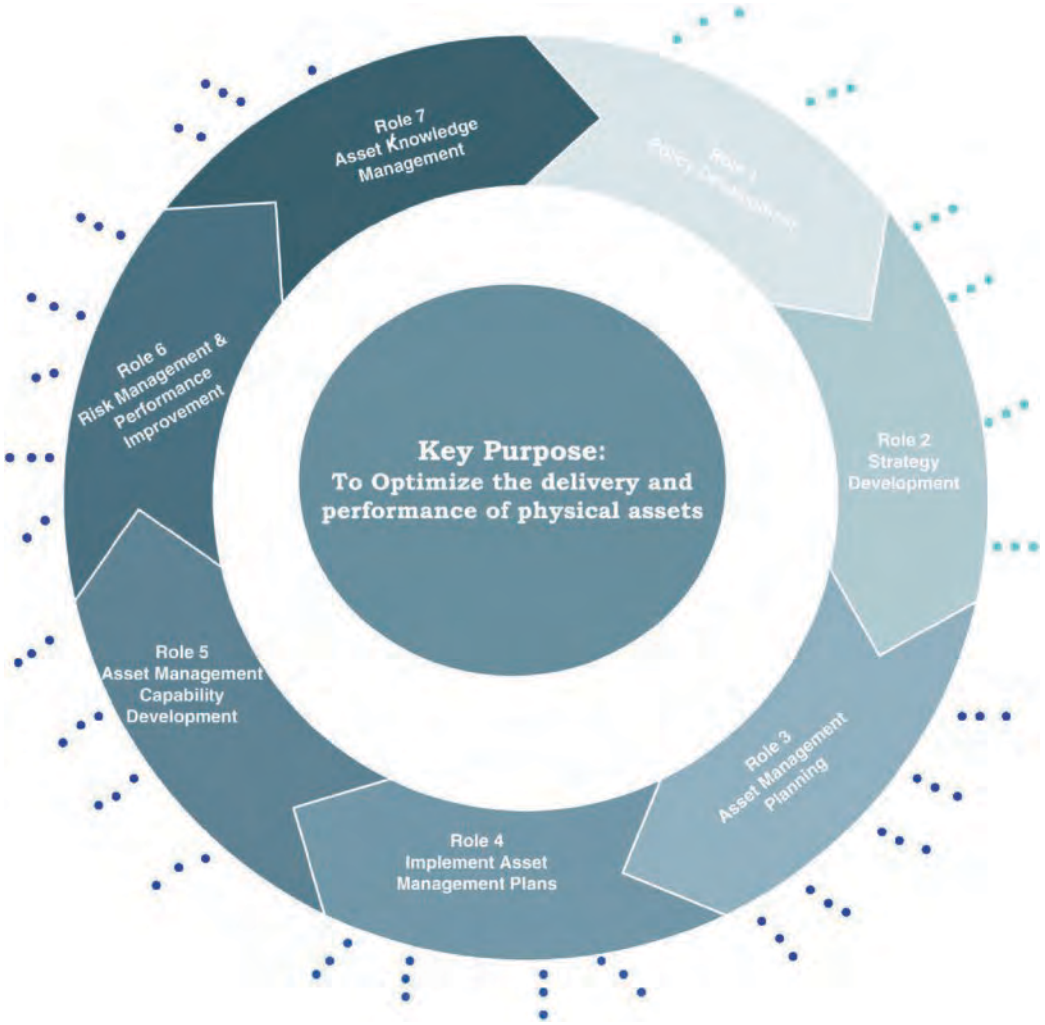

FIGURE 4 Roles and competencies for an Asset Management Organization [*Source: ACRP Report 69* (*3*)].

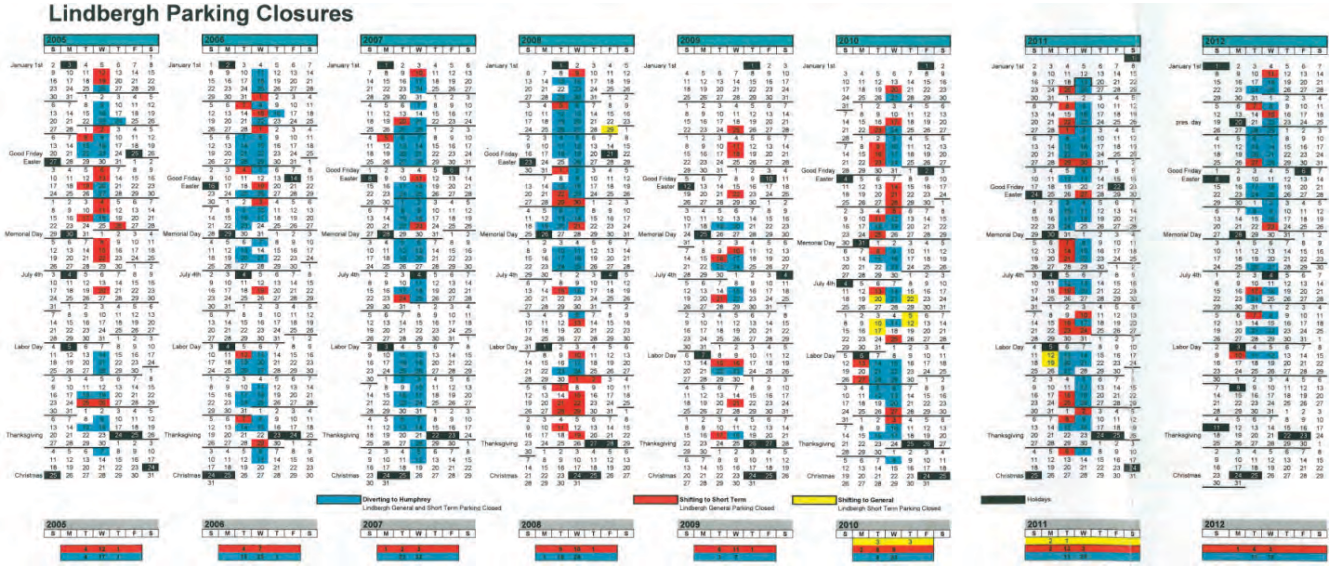

FIGURE 5 Parking space demand report over different months (*Source:* Minneapolis/St. Paul International Airport).

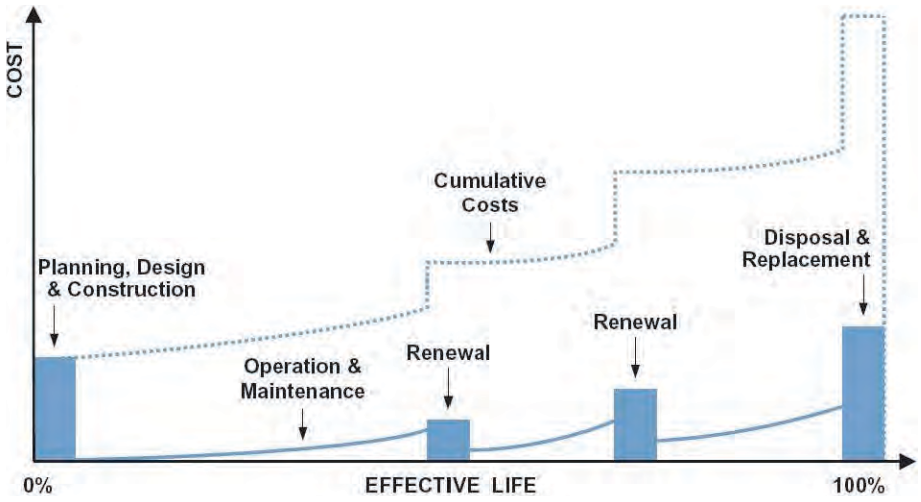

FIGURE 6 Life-cycle components [*Source: ACRP Report 69* (*3*)].

larger expenditures for renewal and restoration until the parking structure is deconstructed, salvaged, and replaced. If an airport parking structure is to be taken out of service because it is no longer functional or has reached the end of its service life, the asset management plan would anticipate replacing the lost parking spaces as well as meeting the anticipated future parking demand for that location. This may well mean planning to open a new parking structure before the old one goes out of service.

5. Risk Profile: Describes how risk exposure is evaluated and identifies at-risk assets.
6. Management Strategies: Describes the operations, maintenance, and capital investment strategies determined for the planning period. This may include changes to maintenance strategies from unplanned as-needed or proactive maintenance or it could include changes to emergency response plans for specific events.

Figure 8 shows the typical relationship between life-cycle cost and renewal intervals (*6*). This graph shows that there is an optimal interval when an airport parking structure should undergo renewal. Before reaching that optimal interval, more frequent or more extensive rehabilitation would result in higher life-cycle costs; however, an interval extending too long past the optimal point would cause an increase in the life-cycle costs as a result of delayed or deferred repair and maintenance.

7. Financial Planning: Summarizes all costs associated with the implementation of the management strategies described in No. 6. It also includes a funding strategy and the associated impact on key financial indicators. Survey responses indicated that financial data are routinely collected and tracked by airport operators and parking managers. Financial data pertinent to the renewal process includes costs and revenue during routine operations; annual maintenance costs; and the annual budget for short to medium-term repair.
8. Business Improvement Planning: Describes any process improvements or projects required to improve the quality of asset management planning at the airport.

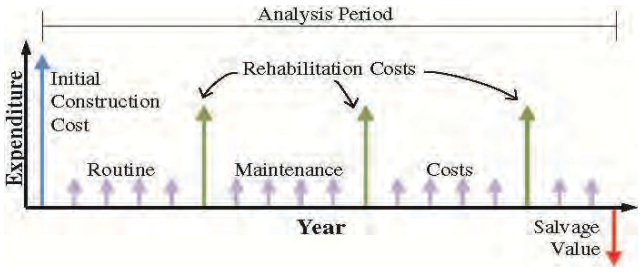

FIGURE 7 Cost flow diagram [*Source: ACRP Report 69* (*3*)].

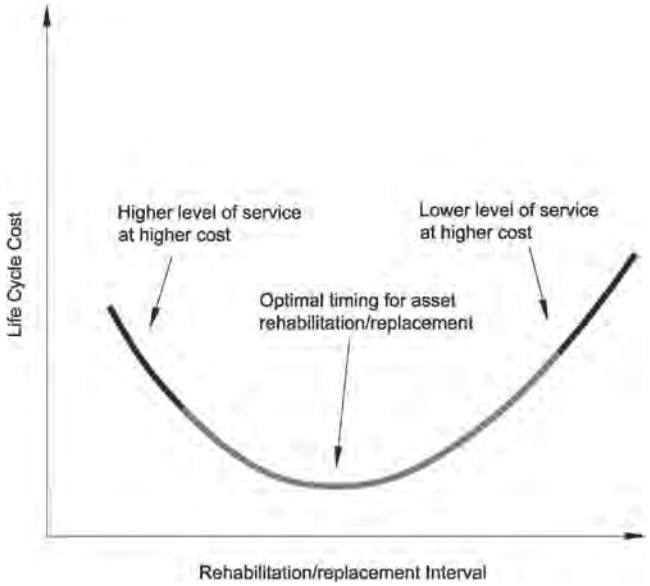

FIGURE 8 Relationship between life-cycle cost and intervention interval [*Source: TCRP Report 157* (*6*)].

Survey respondents indicated that though many of the asset management steps have been undertaken for airport parking structures, there is no formal recognition of airport parking structures as an element of the airport asset management plan.

IMPLEMENTING AND MANAGING PARKING STRUCTURE RENEWAL

A renewal plan of a specific parking structure would need to recognize its life-cycle costs and service demands before considering different renewal approaches or identifying cost-effective repairs. Renewal activities may temporarily remove revenue-producing parking spaces, and extended renewal disruption could further reduce revenue. However, delaying repair and maintenance is neither viable nor prudent. Deferred maintenance generally results in longer down time, lower level of services, and potentially a reduction in asset service life. A good and comprehensive renewal plan addresses the costs of the loss of parking spaces during construction, the operational requirements, and renewal funding.

An effective renewal plan also requires a history and evaluation of the airport parking structure; planning for maintenance and repair; a plan to meet patrons' parking needs and maintain a high quality of service during renovations; and methods of communication to manage service disruptions.

Structural repair also affects parking managers' ability to maintain quality levels of service. As a result, renewal projects are typically undertaken in off-peak seasons or at lower-volume hours. Survey responses provide some successful steps taken to limit the impact of repair construction on parking services and operations at the airport.

One measure of perceived high quality of service for parking patrons is how quickly open spaces can be located. Dallas/Fort Worth International Airport (DFW) indicated that when parking demand approaches 85% of capacity, the time required to find an open space goes up significantly. Literature reports that parking supply is perceived full by users when 90% of spaces are full. Extended search time for a parking space is not acceptable to airport patrons because of the time constraints on catching departing flights.

Whenever there are changes at parking facilities, such as changes to parking stall location or availability, traffic circulating patterns, maneuverability, directness of routing, frequency of transfer services, or facility aesthetics, it is best to let the parking patrons and stakeholders know well in advance. Communication between the airport parking operator and the patrons is important and requires attention to detail.

CHAPTER THREE

DOCUMENTATION OF HISTORY AND EXISTING CONDITIONS

The process of undertaking renewal for an in-use airport parking structure is summarized in a flow chart shown in Figure 9. There are four major components in the renewal planning: a history and condition evaluation; selection of appropriate renewal design and approaches; preparation of construction documents; and detailed plans for construction administration and monitoring. This chapter presents effective practices in documenting airport parking structure existing conditions and renewal history.

Documentation of the history and condition of the airport parking structure includes a physical description, including the type of construction, geographic location and environmental exposure, age, deterioration, and built-in deficiency; and existing conditions and renewal history.

Questionnaire responses indicated that all surveyed airport hubs are keeping records on the existing conditions at their parking structures**.** However, respondents indicated that the physical description and renewal history data are usually retained by the facility department rather than the parking operations department.

TYPES OF CONSTRUCTION

The most common types of airport parking structure construction, used in 49 of 51 surveyed structures, are steel and concrete construction. Steel structures were reported to be 22 and 26 years old. The common concrete structural systems are prestressed (post-tensioning) cast-in-place concrete; precast concrete; and conventionally reinforced concrete (short span).

GEOGRAPHIC LOCATIONS AND EXPOSURE

Parking structures are subjected to harsh and corrosive environments (*7*), including:

- Exterior weathering (thermal cycles, ocean salt sprays, freezing and thawing cycles, and water damage, etc.)
- Wear and tear from vehicular traffic
- De-icing chemicals that promote corrosion of embedded steel
- Mechanical damage from snow removal operations.

The primary deterioration experienced by concrete parking structures is corrosion of embedded reinforcement steel (*8*) such as mild steel bars (rebar) and high strength prestressed steel tendons. Chloride ion-induced corrosion is ranked first among causes of steel corrosion in concrete; the second most prevalent factor is freezing and thawing damage.

Concrete parking structures are categorized and designed for the following five zones recommended by the ACI and shown in Figure 10 (*8*):

- Zone III—Exposed to moisture with freezing and thawing cycles and de-icing salts
- Zone II—Exposed to moisture with freezing and thawing cycles but no de-icing salts
- Zone I—Exposed to moisture; that is, all others except Zones CC-I and CC-II
- Zones CC-I—Areas within 1 mile of salt water bodies
- Zone CC-II—Areas within 2 to 5 miles of salt water bodies.

Parking structures located in Zone III are expected to be exposed to harsher environments than Zones I, II, or CC-I and CC-II. Consequently, parking structures in Zone III are anticipated to experience accelerated deterioration. Airport parking structure renewal plans would need to account for climatic exposure (*8*). Proportionally, renewal intervals in areas of climatic extremes are typically shorter and the renewal and cumulative costs higher (see Figure 6).

AGE OF FACILITIES

The age of the parking facility has a direct impact on the type and frequency of renewal plans (*7*). More age-related deterioration equates to more frequent, more extensive, or more costly renewal. Additionally, the timing of renewal and the existence of built-in deficiencies in structures are factors in deterioration.

Timing of Renewal

The rate of deterioration for airport parking structures accelerates with time. An empirical deterioration curve is shown in Figure 11 (*7*). The *x*-axis represents the time since construction and the *y*-axis indicates the level of sustained deterioration or repair/restoration costs. Each parking structure would have its own specific deterioration curve.

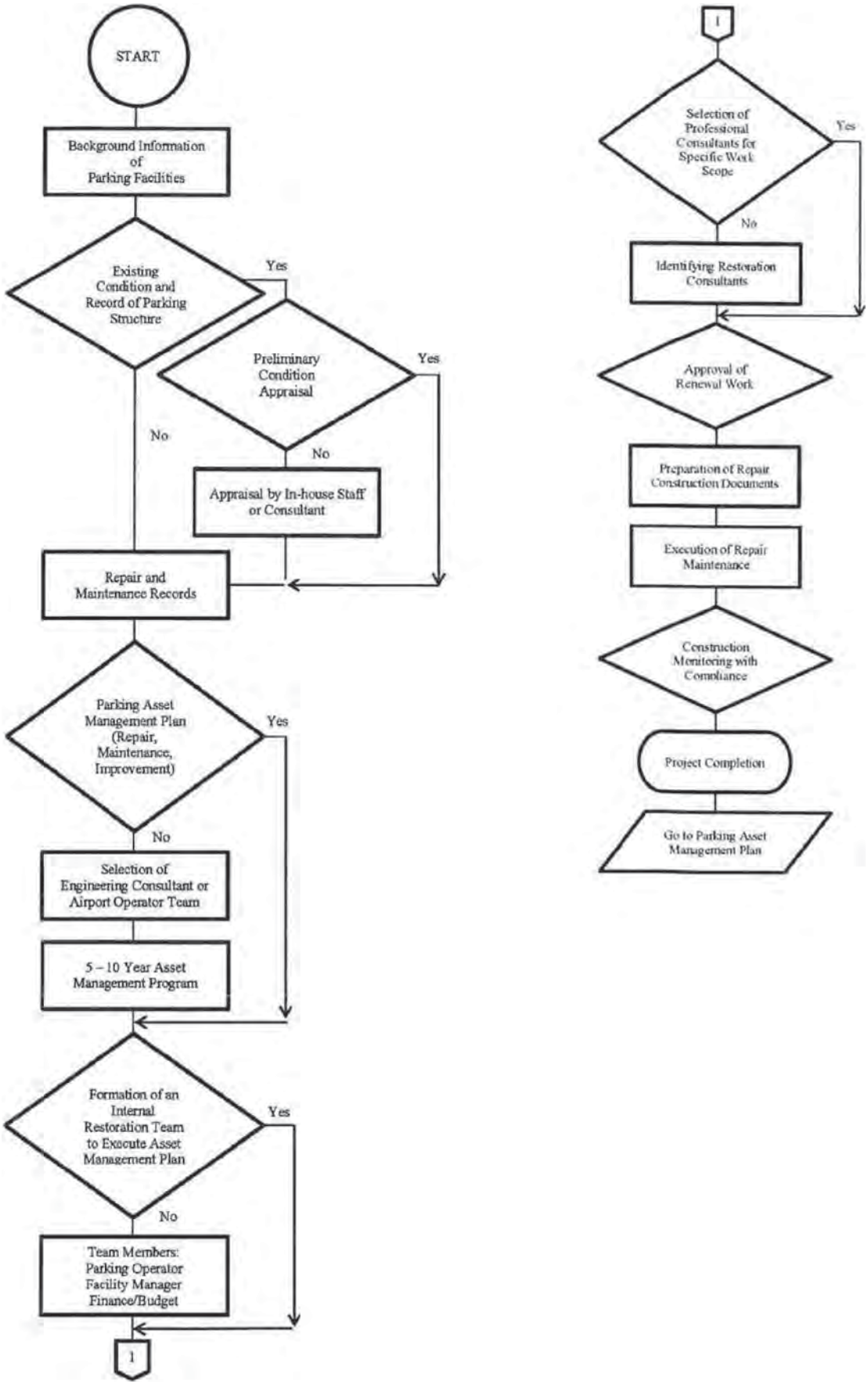

FIGURE 9 Parking facility renewal plan.

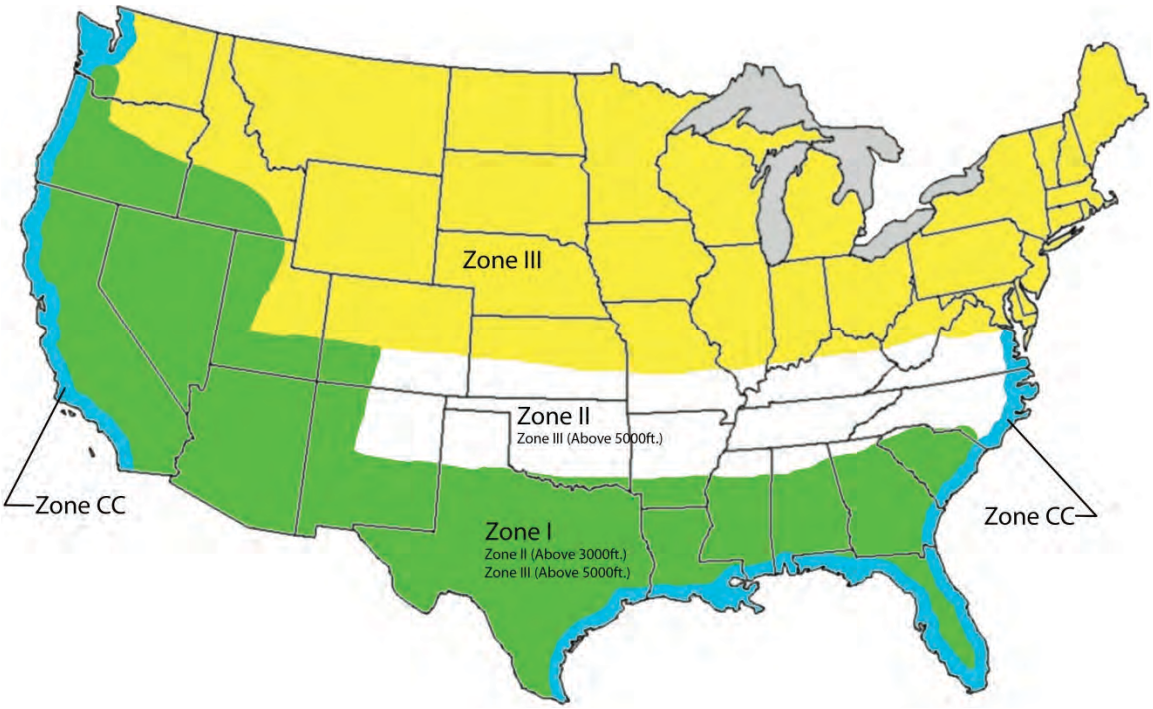

FIGURE 10 Climatic exposure zones for parking structures (*8*). Note: Hawaii and Alaska were not included in the documented figure [*Source:* American Concrete Institute (ACI) Technical Committee 362].

Deterioration necessitates regular renewal. At point A on the curve in Figure 11, a renewal plan is undertaken, reducing the level of deterioration down to point A^1. The distance from A to A^1 represents the renewal costs. However, if the renewal program is not carried out until point B, the parking structure will have sustained more deterioration (point B is noticeably higher than point A). At that point, costs for renewal would be larger than that at point A (point B to point B^1 is longer than point A down to A^1). Even then, the deterioration level at point B^1 would still be higher than the deterioration level at point A^1 and the cost greater with less improvement. In summary, Figure 11 illustrates that the earlier the renewal

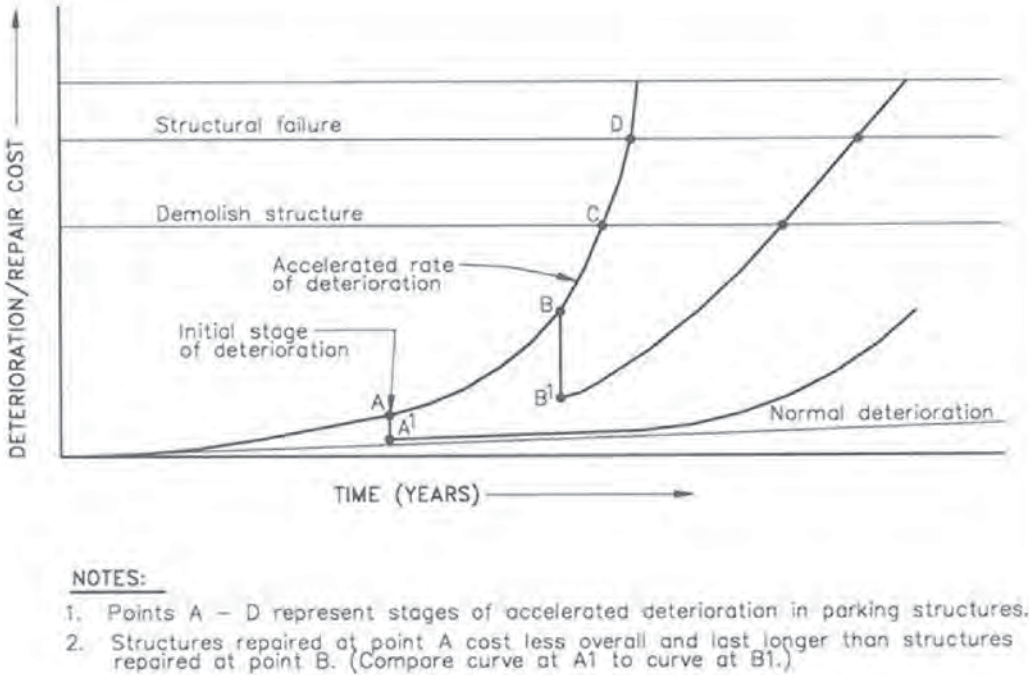

FIGURE 11 Parking structure deterioration curve (*Source: Parking Structures: Planning, Design, Construction, Maintenance and Repair*) (*7*).

process starts, the more cost-effective the renewal process will be.

There are different models simulating the deterioration of parking facilities (*7, 9*). However, almost all of them are empirical, and more research is needed to develop a typical deterioration curve for airport parking structures.

Built-in Deficiency

Older airport parking structures have built-in deficiencies that were not recognized by design professionals at the time of design and construction. Prior to the 1970s, corrosion-related deterioration in concrete structures was not fully understood, and had not been identified as the prime deterioration cause for concrete structures. Consequently, parking structures built in the 1970s do not have the same level of protection against corrosion for embedded steel as those built in later years. For example, concrete cover over reinforcing steel was specified at ¾ inch in the 1970s instead of the current 1½ inches (*5, 10*). With less concrete cover protection, the reinforcing bars are more likely to be exposed to chloride ions. Consequently, local delamination and spalls are more commonly found on parking floor slabs built in the 1970s than those in newer structures.

For pre-stressed concrete construction, new developments in the past 25 years are more distinct and significant. From 1955 to 1975, a single high-strength wire with a button head anchorage was used. The wire was protected with rust-inhibiting grease wrapped inside paper sheathing. This system, though effective and functional, provides little to no protection against corrosion. From 1975 to 1985, the paper sheathing was replaced with plastic. The plastic sheathing provides much better corrosion protection against chloride ion contamination. After 1985, a new encapsulated seven-wire strand system was introduced. Full encapsulation further reduces the possibility of unanticipated tendon exposure during the stressing operation in construction. The result is that newer pre-stressed concrete structures experience far less deterioration than their earlier counterparts.

As building technology evolves, designs for parking structures become more sophisticated. Commonly encountered deterioration is mitigated with newer hardware and better practices, resulting in more durable parking structures that require less frequent renewal.

Survey respondents provided two examples of major renewal for airport parking structures. The parking structure at Chicago O'Hare International Airport (ORD) was built in 1969 and underwent a major three-year renewal program beginning in 1995, when it was 26 years old. The airport parking structures at Denver International Airport (DEN) were built in 1993 with pre-topped precast concrete double-tee girders and underwent sealant replacement in phases for all joints between 1998 and 2009, beginning when the parking structure was about five years old. Both airports are located in the ACI climatic exposure Zone III.

EXISTING CONDITIONS AND RENEWAL HISTORY

Survey respondents indicated that airports are keeping maintenance records for their parking structures, which provide managers information on what has been done and what needs to be scheduled in the future. Records include condition appraisal reports, repair construction documents, repair contracts, repair construction field reports, and records of renovation and component replacement.

Airport operators often perform annual walk-throughs to visually evaluate the condition of their parking structures. This information can be used to understand the condition of the structure and approximately what stage the deterioration has reached. However, periodic and more in-depth evaluations of the parking structures are needed. The industry standard evaluation process is outlined in the attached flow chart as shown in Figure 12 (*11*). The process starts with a preliminary evaluation or condition survey. The purpose of the preliminary evaluation is to:

- Document visible distress such as cracking, exposed corroded reinforcement, water stains or leaks through cracks or expansion joints, spalled concrete, and corrosion staining.
- Assess condition of previous repairs, if applicable.
- Evaluate performance of routine and preventive maintenance items.
- Identify areas that may need further investigation and/or repairs.

Survey respondents indicated that preliminary investigations are commonly performed annually by in-house staff. In some airports, managers engage engineering consultants to provide both the preliminary and subsequent in-depth evaluations and investigations.

During detailed investigations, unusual conditions are highlighted and evaluated. For example, when previous repairs are not performing as expected, the root cause(s) for the premature failure of the repair or the reasons for continuing deterioration are investigated, and then a new repair approach is developed.

A typical case is one reported at O'Hare. Parking structure replacement expansion joints failed within two years after installation, although the anticipated service life of the expansion joints was 10 years. Investigation into the likely causes of the observed distress resulted in specifying more durable replacement expansion joints to be installed that successfully corrected the unexpected low performance of the failed expansion joints. More detailed information about this case history can be found in Appendix B.

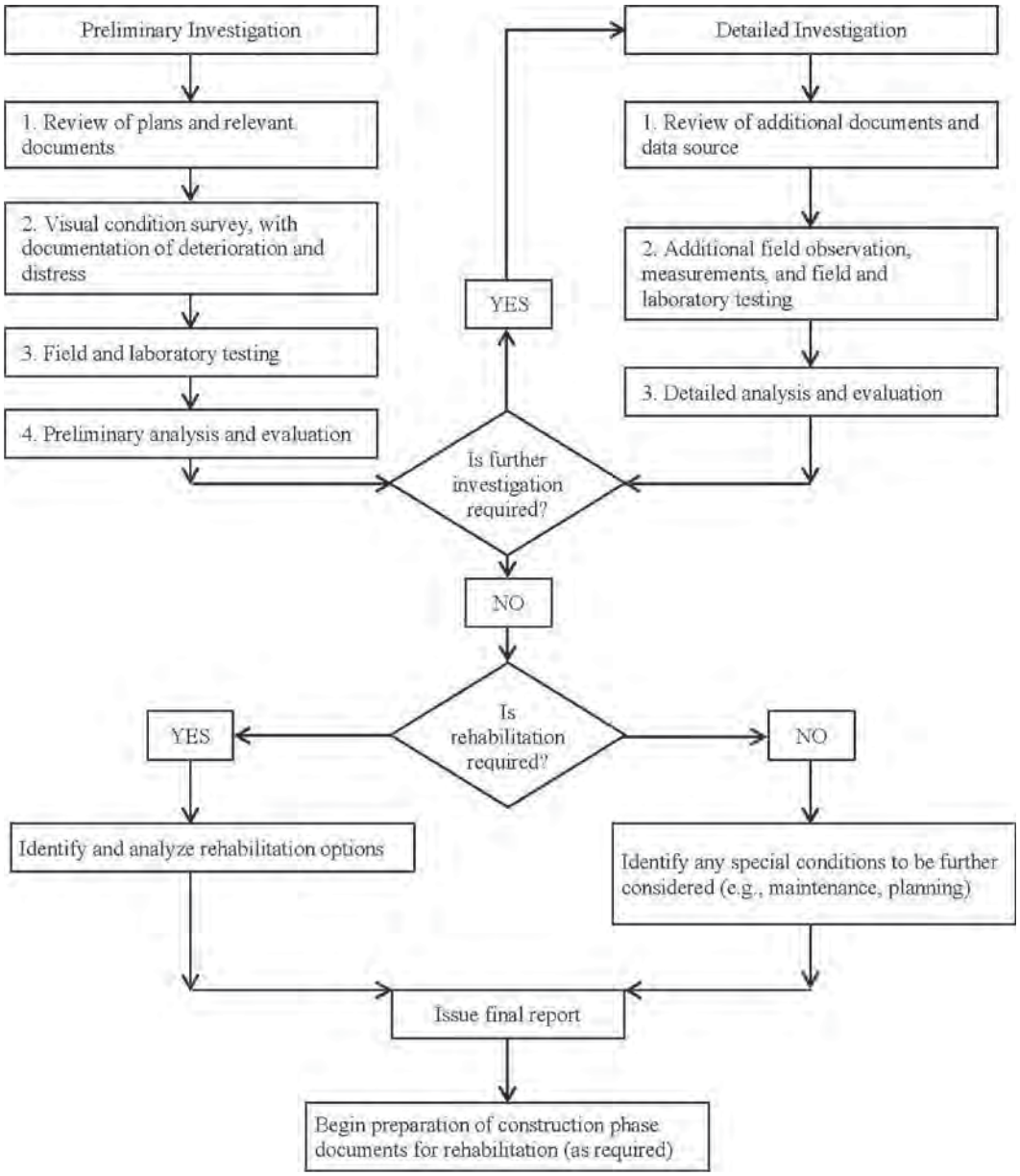

FIGURE 12 Evaluation process [*Source:* American Concrete Institute ACI Committee 364.1R (*11*)].

CHAPTER FOUR

REPAIR AND MAINTENANCE APPROACHES

Some airport hubs have annual budgets set aside for repair and maintenance projects of their parking structures. Eight out of the 12 airports surveyed have established budgets for renewal ranging from $45,000 for cleaning, signage replacement, and minor repairs, to $5,000,000 for replacing deteriorated caulk joints. However, all respondents with set aside renewal budgets only undertook work when there were reported issues or noted distress in the parking structures.

Airport parking managers were queried regarding prioritization of the following three factors in planning a renewal program: budget; level of service; and asset protection. Six of the 12 indicated that level of service was the most important factor, whereas the others identified asset protection as their priority. This reflects the peculiar characteristic of airport parking structures' being operated both as a customer-based service and as part of the airport infrastructure and major capital investment. Although budget appeared to be of lower priority at the surveyed hubs, the apparent low priority might be a result of the small survey sample size, and that only large and medium hubs were surveyed.

According to Weant and Levinson 1990 (*12*), effective renewal planning would include both routine and preventive maintenance, and structural repair, rehabilitation, and restoration.

ROUTINE AND PREVENTIVE MAINTENANCE

Typical parking structures have expected service life of 40 to 50 years. Routine and preventive maintenance includes many activities that can be completed either quarterly or annually by in-house personnel. Resource materials have been published and are available from professional organizations such as International Parking Institute (IPI) on how to perform routine and preventive maintenance for airport parking structures (*7, 13–16*). Sample annual checklists can be modified for specific airports. Such a structural checklist can be found as Appendix D.

Survey respondents reported that airport parking operators are aware of the benefits of performing routine and preventive maintenance. For example, two respondents reported performing recommended regular wash-downs of the parking structures (*13–15*) at least every six weeks, and two others scheduled them semi-annually; whereas two more preformed them annually. This work item is especially necessary in northern climates where de-icing salts are brought into the facilities by vehicles with clinging snow. Table 2 shows the frequency of wash-downs among the survey participants.

However, the level of maintenance was typically limited only to parking slab wash-downs and cleaning of drains. Only two airports reported programmatically addressing other maintenance items such as sealants, minor patches, or expansion joints. Other maintenance items are not regarded as unimportant, but are generally addressed on an as-needed basis.

Budget

A survey was conducted in 1990 of parking facility owners regarding costs of maintaining new and existing parking structures (*7*). The average annual maintenance costs for a new structure and a 20-year-old structure are shown in Figures 13 and 14, respectively. Also listed in the tables are the common items that are included in the maintenance program. In addition to routine and preventive maintenance, the tables have a listing for "replacement maintenance." Replacement maintenance is defined as replacement costs of items that have reached their service life during the service life of the parking structures, such as revenue collection systems, drainage systems, or lighting systems. The maintenance unit cost per area per year is useful in budgeting and developing the asset management plan for parking structures.

Based on the information in Figures 13 and 14, the average maintenance cost for a new parking structure is about $0.46/sq foot/year and the average maintenance cost for a 20-year old parking structure is about $0.58/sq foot/year in 1990 dollars. Although the data was collected in the 1990s, the tables provide a template of different items to be included in the maintenance program. With that template, the average annual unit maintenance cost can be developed for any specific parking structure based on its historical cost data base.

STRUCTURAL REPAIRS, REHABILITATION AND RESTORATION

The selection of a renewal approach should take into consideration the structure's deterioration history; and repair alternatives (*7*). The maintenance cost history of a parking structure

TABLE 2
SLAB WASH-DOWN FREQUENCY

Wash Down Frequency	Number of Participants
Every 6 weeks or less	2
Semi-annually	2
Annually	2
Every other year	2
Greater than 2 year intervals	1
As needed or not planned	3

allows a deterioration curve to be developed by plotting the annual renewal costs versus time. Knowing where the parking structure is on the deterioration curve helps the engineer to design and plan a proactive renewal program.

The restoration industry for concrete structures has been evolving rapidly in recent years. In 1996, Vision 2020 (*17*) was established under the Strategic Development Council of ACI. One of its 13 goals was to develop a repair code (*18*) similar to the building code for new structures. Since 2006, the repair code (ACI 365) has been developed and is expected to be adopted by the concrete industry in 2013. Once it is adopted, concrete repair guidelines will result in repairs with higher quality and durability.

Table 18-6 Annual Maintenance Cost (New Facility)

		Construction Cast-in-place		Age 0	Cars 1000	SF 320,000
Item Description	Quantity	Unit Price	Total Cost	Time	$/car/Yr	$/SF/Yr
Preventive Maintenance						
Sealants Floor Slab	10,000	3.00		10	3	0.01
Architectural Sealants	2,600	3.50	9,000	12	1	0.00
Expansion Joints	96	80.00	8,000	10	1	0.00
Penetrating Sealer	256,000	0.50	128,000	5	26	0.08
Traffic Topping	-	2.25	-	15	0	0.00
Supplemental Drains & Piping	-	1800.00	-	25	0	0.00
Miscellaneous	-		-			
Subtotal			**175,000**		**$31.00**	**$0.09**
Replacement Maintenance						
Replace Drainage System	320,000	0.65	208,000	25	8	0.03
Replace Lighting System	320,000	1.75	560,000	25	22	0.07
Replace Parking Revenue Control	320,000	0.32	102,000	6	17	0.05
Replace Signage	1	30,000	30,000	25	1	0.00
Replace Elevators	2	120,000	240,000	25	10	0.03
Miscellaneous			-			
Subtotal			**1,140,000**		**$58.00**	**$0.18**
Routine Maintenance						
Maintain Joint Sealants	1	1,500	2,000	1	2	0.01
Maintain Traffic Topping			-	1	0	0.00
Interim Slab Patching			-	1	0	0.00
Interim Beam & Column Patching			-	1	0	0.00
Stairtower Maintenance	1	2,000	2,000	1	2	0.01
Maintain Drainage System	1	1,000	1,000	1	1	0.00
Maintain Lighting	1	6,000	6,000	1	6	0.02
Maintain Parking/Revenue Control	1	2,000	2,000	1	2	0.01
Annual Inspections	1	5,000	5,000	3	2	0.01
Maintain Elevators	12	500	6,000	1	6	0.02
Miscellaneous	1	2,000	2,000	1	2	0.01
Sweeping/Cleaning	12	1,000	12,000	1	12	0.04
Power Wash Floors	4	2,000	8,000	1	8	0.03
Painting	1	10,000	10,000	1	10	0.03
Subtotal			**56,000**		**$53.00**	**$0.19**
Average Annual Maintenance Cost					**$142.00**	**$0.46**

FIGURE 13 1990 Annual maintenance cost (new structure) [*Source:* Chrest et al. 2000 (*7*)].

Table 18-7 Annual Maintenance Cost (20 Year Old Facility)

		Construction Cast-in-place		Age 20	Cars 1000	SF 320,000
Item Description	Quantity	Unit Price	Total Cost	Time	$/car/Yr	$/SF/Yr
Preventive Maintenance						
Sealants Floor Slab	10,000	3.00	30,000	10	3	0.01
Architectural Sealants	2,600	3.50	9,000	12	1	0.00
Expansion Joints	96	80.00	8,000	10	1	0.00
Penetrating Sealer	-	0.50	-	5	0	0.00
Traffic Topping	256,000	2.25	576,000	15	38	0.12
Supplemental Drains & Piping	10	1800.00	18,000	25	1	0.00
Miscellaneous	1	50,000	50,000	10	5	0.02
Subtotal					**$49.00**	**$0.15**
Replacement Maintenance						
Replace Drainage System	320,000	0.65	208,000	25	8	0.03
Replace Lighting System	320,000	1.75	560,000	25	22	0.07
Replace Parking Revenue Control	320,000	0.32	102,000	6	17	0.05
Replace Signage	1	30,000	30,000	25	1	0.00
Replace Elevators	2	120,000	240,000	25	10	0.03
Miscellaneous			-			
Subtotal					**$58.00**	**$0.18**
Routine Maintenance						
Maintain Joint Sealants	1	1,500	2,000	1	2	0.01
Maintain Traffic Topping	1	2,000	2,000	1	2	0.01
Interim Slab Patching	1	3,000	3,000	1	3	0.01
Interim Beam & Column Patching	1	2,000	2,000	1	2	0.01
Stairtower Maintenance	1	2,000	2,000	1	2	0.01
Maintain Drainage System	1	1,000	1,000	1	1	0.00
Maintain Lighting	1	6,000	6,000	1	6	0.02
Maintain Parking/Revenue Control	1	2,000	2,000	1	2	0.01
Annual Inspections	1	7,000	7,000	1	7	0.02
Maintain Elevators	12	1,000	12,000	1	12	0.04
Miscellaneous	1	4,000	4,000	1	4	0.01
Sweeping/Cleaning	12	1,000	12,000	1	12	0.04
Power Wash Floors	4	2,000	8,000	1	8	0.03
Painting	1	10,000	10,000	1	10	0.03
Subtotal					**$73.00**	**$0.25**
Average Annual Maintenance Cost					**$180.00**	**$0.58**

FIGURE 14 1990 annual maintenance cost (20-year-old structure) [*Source:* Chrest et al. 2000 (*7*)].

The repair industry is also becoming more adept at extending the anticipated service life of structures. New methods such as passive cathodic protection for embedded reinforcement bars have become readily available and successfully implemented in large restoration projects (*18, 19*). Better repair alternatives are available for parking structures as well. For example, in addition to the removal and replacement of concrete spalls, the use of denser high performance concrete, application of epoxy coating on reinforcement bars, use of corrosion inhibitor in the repair concrete, and installation of passive cathodic protection anodes can extend the life of the repair patches. The more layers of protection that are used, the longer the expected service life of the repair patches will be. Although the unit costs may increase with each additional protection, the repair durability increases proportionally, reducing the need for more frequent repair.

An example of choosing a repair approach was reported by Shiu and Stanish (*18*). A project field investigation of a deteriorated parking structure indicated that, over time, the reinforced concrete floor slabs had been saturated with chloride ions. As such, the embedded reinforcing bars of the floor slabs were expected to corrode at an accelerating rate in the coming years. Localized patches did not resolve the ongoing corrosion deterioration inside the floor slabs. Routine patching resulted in spalls repair every four to five years. A more in-depth evalua-

tion indicated that the continual demand for concrete slab repair could be mitigated with full slab replacement. A 20-year cost analysis was performed comparing full slab replacement with the ongoing slab repair at five-year intervals. The conclusion was that full-depth floor slab replacement not only represented a more cost-effective solution to the corrosion deterioration of the parking facilities, but also generated a higher service level with much less nuisance to the parking patrons.

There is ongoing research (*20*) to understand and predict the anticipated durability offered by different concrete protection systems. Currently, there is no definitive model accepted by the restoration profession (*5*). Engineers are using empirical data from past experience to guide their repair design. In summary, exploring different approaches can yield more effective repair methods of improving asset protection and minimizing disruption.

CHAPTER FIVE

MAINTAINING QUALITY OF SERVICES DURING RENEWAL OF AIRPORT PARKING STRUCTURES

The *Highway Capacity Manual* (TRB 2010) (*21*) provides a definition of quality of service for transportation facilities. The following paragraph is quoted from that guidance document.

> Quality of service describes how well a transportation facility or service operates from a traveler's perspective. Quality of service can be assessed in a number of ways. Among them are directly observing factors perceivable by and important to travelers (e.g., maneuverability), surveying travelers, tracking complaints and compliments about conditions, forecasting traveler satisfaction by using models derived from past traveler surveys, and observing services not directly perceived by travelers (e.g., average time to clear an incident) that affect measures they can perceive (e.g., speed or arrival time at aircraft departure gate).

Factors that influence travelers' perceived quality of service have been found to include:

- Travel time, speed, and delay
- Number of stops incurred
- Travel time reliability
- Maneuverability
- Comfort
- Convenience
- Safety (actual or perceived)
- User cost
- Availability of facilities and services
- Facility aesthetics
- Information availability (e.g., wayfinding signage, route and schedule information).

Many of these factors also pertain to quality of service for airport parking and are of interest to airport parking managers. Survey respondents revealed that quality of service is ranked high in priority for airport parking management, because:

- Parking facility operation is a significant revenue source for the airport.
- More expensive and close-in airport parking structures compete with less expensive on- and off-site parking.
- Airports compete with other nearby airports for travelers.
- Airport travelers and visitors demand high quality parking services.

Survey participants stated that if the areas closed during construction are not adequately maintained or perceived as too much of an inconvenience, the patrons may consider alternatives that might become permanent choices. Alternatives to on-site parking include:

- Parking at remote airport lots
- Parking at independent off-site facilities
- Cab, shuttle, and limousine service drop off/pick up
- Public transportation to/from the airport (bus and light rail)
- Lower-priced remote parking
- Family or friends taking the patron to the airport.

PLANNING TO MINIMIZE PARKING PATRON DISRUPTION

Maintaining a quality level of parking services during repair construction involves planning to minimize patron disruption and engaging interested parties and stakeholders.

Tracking the peak travel days of the week and the peak travel months of the year allows airports to schedule repair and maintenance during periods of lower parking demand. The goal is to avoid the peak parking demand periods when scheduling major repair construction that impedes parking entry/exit, limits access to parking spaces, or lowers the number of spaces needed to accommodate demand.

Airport parking managers identified stakeholders that need to be included for maintaining airport parking services as follows:

- Airport managers
- Airport parking operators
- Airport engineers, including architectural/structural, mechanical, and electrical workers
- City, county, or state managers and involved departments
- Airlines or concessionaires
- Ground transportation managers
- Maintenance groups
- Information technology departments
- Marketing and public relations
- Planning committees
- Financial managers
- Contractors.

Involving all stakeholders in the planning for airport parking structure repair allows early identification and response

to otherwise unanticipated issues during repair construction. More information is presented in Appendix A: Survey Questionnaire and Results.

LEVEL OF SERVICE

LOS is defined by the *Highway Capacity Manual* as a quantitative stratification of a performance measure or measures that represent quality of service (TRB 2010) (*21*). For the purposes of this report, level of service and quality of service are used interchangeably. There are three main areas that affect the parking level of service (*22*, *23*):

- Number of available parking spaces to satisfy demand
- Surrounding conditions during repair
- Signage and wayfinding.

NUMBER OF AVAILABLE PARKING SPACES TO SATISFY DEMAND

Parking operations records provide detailed information on the parking supply and demand at any particular time of the year. The number of spaces that can be taken out of service without adverse impact is the difference between the parking space demand during the selected renewal construction time period and the available parking supply, with some allowances for vehicle maneuvering and poorly parked vehicles that take up additional space. Traditionally, 85% occupancy is considered at capacity (*12*).

The time required to locate an available parking space is also a major factor. Interviews with parking managers indicated that when parking space demand reaches the 85% capacity, the time required to locate a space increases significantly. Parking operators can help by providing additional staff to direct traffic or use electronic and lighted parking guidance systems to identify available spaces.

Areas requiring closure during construction may change for different repair items. For instance, when a parking structure is undergoing concrete slab repair, the parking level immediately below the repair area and additional spaces for equipment and materials and maneuvering need to be vacated for safety reasons. Other demands include staging and storage areas for the repair contractor and the temporary traffic routes needed for vehicular access to parking spaces.

CONDITIONS DURING REPAIR

There are different concerns during parking structure repair relating to parking patrons and repair contractors. Designated repair construction areas are best shielded from the public for safety reasons, shielding patrons from injury while walking through the construction work zones. Typically, the construction areas are enclosed to screen messy conditions; this also limits the amount of dust and noise impacts on the surrounding environment.

Construction requirements are generally spelled out in the contract specifications and are the responsibility of the repair contractors. Survey interviewees offered some effective methods of preventing cars parking in construction zones, including advance communication through signage and use of heavy barriers, such as water-filled barriers instead of fencing, yellow tape, or workhorses. It is best to use reflective materials because of the potentially low light levels within parking structures.

Vehicles are sometimes found improperly parked inside the work zones even after the fencing has been erected and installed. Removal of those vehicles is necessary for safety reasons and protection of property. When vehicles do need to be relocated, it is important to have established protocols to notify the vehicles' owners, either through the airport's police or other 24-hour emergency/information services, so that they can retrieve their vehicles.

SIGNAGE AND WAYFINDING

Information availability is important to parking patrons' perceived quality of service. Repair construction removes selected parking stalls and maneuvering areas from service and then returns these areas to service after completion of the repair. It is important the temporary signage always be displayed in key locations to direct traffic around the areas under construction and to provide directions for the modified ingress and egress of the parking facilities and airport terminals.

Six of the 12 surveyed airports reported assigning the responsibility for providing temporary signage during repair construction to the repair contractors. However, airport managers usually retain the right to approve the signs in advance. In other cases, outside wayfinding consultants or an in-house signage department may assume the responsibility. Louisville International Airport, for instance, assigns responsibility for the temporary signage during repair construction to its in-house signage department.

The *Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways* (*24*) provides a compendium of signs, signage specifications, and recommended sign layouts and may assist airport parking managers in relaying wayfinding information. *ACRP Report 52, Wayfinding and Signing Guidelines for Airport Terminals and Landside* (*25*), provides an additional resource on laying out airport signage.

Airport parking manager interviewees reported that temporary signs need to be seen by parking patrons both in advance and during repair construction, but also be consistent with the layout and style of airport signage standards.

Airport parking signs (*21*) should designate:

- Airport entry or roadway
- Entry to airport parking structures

FIGURE 15 Entrance sign showing current information and parking availability (*25*) (*Source: ACRP Report 52*).

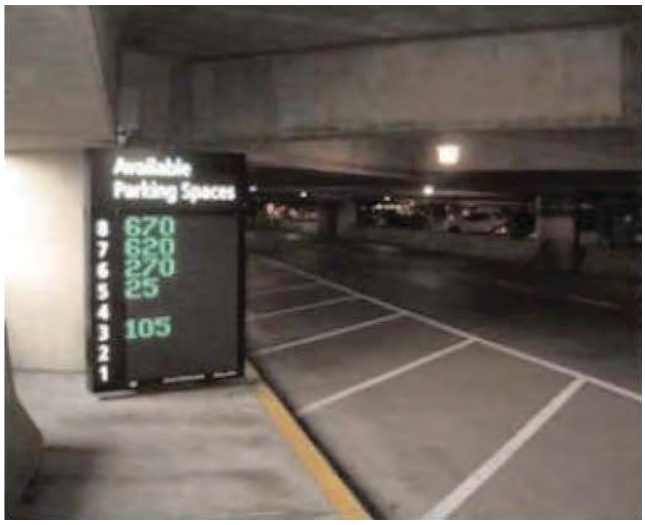

FIGURE 16 Sign in the parking structure directing traffic to open parking spaces (*25*). (*Source: ACRP Report 52*).

- Directional signs within facilities
- Pedestrian directional signs
- Exit(s) from airport parking structures.

During repair construction, airport entry or roadway signs such as the one shown in Figure 15 should show current information on parking availability. Within each parking facility, availability signs direct traffic to open parking spaces. A typical parking availability sign at Seattle-Tacoma International Airport is shown in Figure 16.

ADDITIONAL SERVICES

Depending on the length of time parking spaces are unavailable, surveyed parking managers sometimes provide incentives, such as discounted fees or shuttles to other parking locations; or make available additional services such as valet parking to parking patrons during repair construction. The purpose is to lessen the impact of inconvenience and the negative effect of a lower level of service.

Survey respondents reported that many airports have remote surface parking lots to handle long-term or economy parking or volume overflow. When parking spaces at structures next to the terminals are taken out of service, customers may be directed to the remote parking structures or surface lots, which typically have less expensive rates. Additionally, remote parking facilities at the airports typically have free shuttle buses, electric trains, or people-mover services to take patrons back to their respective airside terminals. However, if the parking operator intends to use remote parking to offset the loss of close-in terminal parking, early communication to the public allows patrons to set aside extra time to park their vehicles.

Valet services are available at some airports, but patrons may be deterred from using the service by the established fee. Airport parking managers can offer valet parking with reduced fees during repair construction if capacity allows.

CHAPTER SIX

COMMUNICATION

Communicating changes to the normal availability and wayfinding of airport parking to patrons has been proven to be effective in maintaining parkers' loyalty in the face of changed conditions that may inconvenience them. Before and during airport parking structure maintenance and repair, parking managers can make use of a wide range of media, from traditional print and news outlets to electronic message boards and signage to e-mails and social media.

Internally, the free flow of information among airport facility managers, parking operators, airlines, airport tenants, and the community is also important in keeping the airport parking structure operation running smoothly during repair construction and keeping parking patrons from experiencing a lower quality of service.

CHARACTERISTICS OF AN EFFECTIVE PROGRAM

Communication means and media are continually evolving; however, key elements in effective communication are the same (*26, 27*); and include targeting the appropriate audience with the appropriate means; making information available in a timely manner; and making information as simple, direct, and comprehensive as possible.

Different audiences have different information needs. Information must reach external target audiences, including airport users, visitors, and repair contractors (including their subcontractors); and internal audiences, including parking operators, airport managers and executives, employee representatives, and airport tenants.

External parking customers are interested in the time and date of closure and re-opening of certain airport parking structures, available spaces, and directions to the interim parking facilities. The goal is to provide this information early and repeatedly so that the external customers can plan and adjust their schedule accordingly. Early communication should also be integrated with early planning for an alternative parking program.

Diverse communication means are needed to reach this broad audience: static and dynamic road signs, directional signs, TV or radio broadcasting, and the Internet, the airport webpage, and social media. How much advance communication is needed depends on the nature and scope of the renewal. For example, Dallas/Fort Worth International Airport gives 30 days' advance warning for parking areas where towing will occur. In addition, planning for information should be detailed, as these messages need to be simple, direct, and comprehensive (*27*). If the message was not caught, or the interest not piqued, the audience will be lost.

To the internal audience, the message is to be precise and focused. Commonly-used methods include phone calls, voice mails, e-mails, meeting minutes, interoffice memoranda, company intranet, letters, and announcements. In recent years, project-specific websites have been created and successfully used to facilitate information sharing in construction projects.

MEANS OF COMMUNICATION

The following is a list of communication media and means that could be used by airport parking managers before and during airport parking structure repair to notify stakeholders of changed conditions (*28*):

Traditional

- Newspapers
- Radio announcements (popular news/weather/traffic stations)
- Intercom transmissions by airport (repeating announcements)
- Meetings
- Memoranda
- Television news
- Newsletters—internal and external.

Signage

- Posters inside airport facilities
- Signage on approach ramps and roadsides
- Digital and dynamic signage
- Electronic monitoring and parking guidance systems (*29, 30*).

Internet

- E-mails
- Social media, such as Facebook, Twitter, LinkedIn, etc.
- Websites.

Based on survey responses, traditional means are more frequently used. Signage at the approach ramps or at the entrance gates is the next most common method of directing people to parking stalls during repair construction. There are many resources for preparing parking signage, such as the *MUTCD* (*24*) and *ACRP Report 52, Wayfinding and Signing Guideline for Airport Terminals and Landside* (*25*). Literature suggests that it is preferable for airport parking signage to be consistent with MUTCD, as drivers are already familiar with the appearance and layout of standard roadway signage.

Advanced parking management systems (*29, 30*) electronically track and display the availability and location of open parking spaces, reducing the time required to locate a stall. Although this type of parking management system is relatively new and can be a significant capital expense, such systems have proven to be an effective tool in maintaining a high level of service when some parking areas are closed.

CHAPTER SEVEN

CONCLUSIONS AND FUTURE RESEARCH NEEDS

CONCLUSIONS

Based on the literature and telephone survey responses of 12 airport hubs, findings and observations of this synthesis's authors are summarized as follows:

1. As major capital assets of the airport infrastructure, parking structures are systematically protected and maintained by airport operators and managers. Many airports have some repair and/or maintenance program in place. The parking managers also identify protection of airport parking structures as a priority.
2. Developing an asset management module for parking structures as part of the overall airport asset management program would focus and clarify how repair and maintenance of the parking structures can be best undertaken while maintaining around-the-clock operations.
3. Airport managers track financial operating data, parking space demand throughout the year, and the history of previous maintenance and repair of the parking structures. These records provide information necessary for parking managers to schedule renewal activities in lower parking demand periods and to maximize the parking spaces for repair.
4. Surveyed airports perform annual and scheduled maintenance on their parking structures. Eight of the 12 respondents have annual budgets set aside for parking structure renewal. However, most airports perform repair only as needed. Parking structures in the large surveyed hubs have an average age of about 19 years old. Three of eight large hub airports surveyed have undertaken significant renewal of their parking structures in the past 10 years, particularly for older parking structures (see Appendix B).
5. Survey respondents indicated that maintaining a high perceived level of service throughout the repair construction process is important for a successful renewal program.
6. Early involvement of all stakeholders is important. Stakeholders include airport management, parking operators, in-house maintenance departments, airlines, airport tenants, and other support services such as the signage department and finance departments. Stakeholder involvement is best engaged in the planning stage and continued through execution of the repair construction.
7. With so many stakeholders, good communication is important, especially in the execution phase of the renewal process. It is best to inform parking patrons early and at strategic locations as they approach the work zone. Multiple means of communication can be used to reach a broader audience. Some airport parking managers use additional incentives to maintain perceived quality of service to parking patrons.

FUTURE RESEARCH NEEDS

1. Development of a typical deterioration curve for parking structures could be used to optimize repair frequency and approach. Currently, a parking structure deterioration curve is only theoretical and conceptual in nature. Renewal projects are typically undertaken as a result of observed distress or deterioration. If a deterioration curve of parking structures were available, a proactive renewal program could be developed resulting in cost-effective repair approaches with optimum repair intervals.
2. There is need to develop a specific asset management program for airport parking structures in addition to the available guidelines for overall airport asset management programs. Because of the particular requirements of airport parking structures, more focused guidelines would encourage wider adoption of asset management programs for parking structures. In addition, keeping a current database on unit renewal costs for parking structures would be helpful to managers in budgeting and establishing long range asset programs.

GLOSSARY OF TERMS, ABBREVIATIONS, AND ACRONYMS

Asset management (AM) as defined by PAS 55—Systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks, and expenditures over their life cycles for the purposes of achieving its organizational strategic plan.

Cast-in-place concrete (CIP)—Concrete that is deposited and allowed to harden in the place where it is required to be in the completed structure, as opposed to precast concrete.

Cathodic protection (CP)—A technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell. There are two types of CP: active and passive. Active CP involves impressed electric current to make to metal to be protected cathode. Passive CP uses the relative inherent potential of the different metals to change the cathodic position. For example, zinc will be more likely to corrode than steel.

Concrete—Mixture of hydraulic cement, aggregates, and water, with or without admixtures, fibers, or other cementitious materials.

Concrete patch—A new layer or section of concrete that restores the strength and look of a concrete surface and protects against further damage, extending its life.

Corrosion—Destruction of metal by chemical, electrochemical, or electrolytic reaction with its environment.

Corrosion inhibitor—A chemical compound, either liquid or powder, that effectively decreases corrosion of steel reinforcement before being embedded in concrete, or in hardened concrete if introduced, usually in very small concentrations, as an admixture.

Delamination—A horizontal splitting, cracking, or separation within a slab usually parallel to, and generally near, the upper surface caused by the corrosion of reinforcing steel or freezing and thawing.

Deterioration—(1) Physical manifestation of failure of a material (e.g., cracking, delamination, flaking, pitting, scaling, spalling, staining) caused by environmental or internal autogenous influences on rock and hardened concrete as well as other materials; (2) decomposition of material during either testing or exposure to service.

Expansion joint—(1) A separation provided between adjoining parts of a structure to allow movement where expansion is likely to exceed contraction; (2) a separation between pavement slabs on grade, filled with a compressible filler material; (3) an isolation joint intended to allow independent movement between adjoining parts.

Hub—An airport classification for primary commercial service; i.e., having more than 10,000 passenger boardings per each year. There are four types of hubs under the primary commercial services: large, medium, small, and non-hub. Their respective definitions are as follows:

- **Large hub—**A commercial service airport that has 1% or more of the total United States passenger boardings in the most current calendar year ending before the start of the current fiscal year.
- **Medium hub—**A commercial service airport that has at least 0.25% but less than 1% of the total United States passenger boardings in the most current calendar year ending before the start of the current fiscal year.
- **Small hub—**A commercial service airport that has at least 0.05% but less than 0.25% of the total United States passenger boardings in the most current calendar year ending before the start of the current fiscal year.
- **Non-hub—**A commercial service airport that has more than 10,000 passenger boardings but less than 0.05% of the United States passenger boardings in the most current calendar year ending before the start of the current fiscal year.

ISO (International Organization for Standards)—Organization recognized as producing and publishing international standards for all subject areas in the world. This non-governmental agency forms a network between both the public and private sectors.

Level of service (LOS)—A quantitative measure of the conditions in a particular traffic-carrying component. Applied to geometrics, other design parameters, flow capacity, and queuing at entry/exit points herein.

Life-cycle costs—Sum of all recurring and onetime costs over the full lifespan or a specified period of an asset under consideration.

Long-term parker—A parker who stays in a facility more than three hours. May be either a daily-fee or monthly parker.

Maintenance—Taking periodic actions that will either prevent or delay damage or deterioration or both. Maintenance includes routine or regular maintenance and preventive maintenance.

Parking bay—Rows of parking with an aisle in between. A parking bay may be single-loaded (with parking on one side only) or double-loaded (with parking on both sides).

Parking structure—A multistory parking facility that meets code requirements for natural ventilation. May be called a parking deck or parking ramp.

Post-tensioning—Method of pre-stressing in which steel is tensioned after concrete has hardened.

Precast concrete—A concrete member that is cast and cured in other than its final position; the process of placing and finishing precast concrete. (See also cast-in-place.)

Preservation—The process of maintaining a structure in its present condition and arresting further deterioration.

Pre-stressed concrete—Concrete in which stresses of such magnitude and distribution are introduced that the tensile stresses resulting from the service loads are counteracted to the desired degree.

Pretensioning—Method of prestressing in which steel is tensioned before the concrete hardens.

Preventive maintenance—A schedule of planned maintenance actions aimed at the prevention of breakdowns and failures.

Rebar—The reinforcing bar-ribbed steel bars installed in foundation concrete walls, footers, and poured-in-place concrete structures. Rebar comes in various thicknesses and strength grades.

Rehabilitation—Project to rebuild or replace parts or components of an asset to restore it to a required functional condition and extend its life, which may incorporate some modification. Generally involves repairing the asset to its original level of service without resorting to significant upgrading or renewal, using available techniques and standards.

Remaining life—Time remaining until an asset ceases to provide the required service level or economic usefulness.

Renewal program—A program that incorporates preservation, repair, restoration, and rehabilitation, including upgrades using available techniques and standards.

Repair—To replace or correct deteriorated, damaged, or faulty materials, components, or elements of a structure.

Replacement—Complete replacement of an asset that has reached the end of its asset life, so as to provide a similar or agreed alternative level of service.

Replacement cost—Cost of replacing an existing asset with a substantially identical new asset in current dollars.

Restoration—The process of re-establishing the materials, form, and appearance of a structure to those of a particular era of the structure

Sealant (joint sealant)—Compressible material used to exclude water and solid foreign materials from joints.

Sealer—A colorless liquid that is applied to the surface of hardened concrete to either prevent or decrease the penetration of liquid or gaseous media (for example water, aggressive solutions, and carbon dioxide) during service exposure; that is absorbed by the concrete; and that leaves little or nothing visible on the surface.

Service life of building component or material—The period of time after installation (or in case of concrete, placement) during which all the properties exceed the minimum acceptable values when routinely maintained. To accurately estimate service life, definition of the end-of-life would need to be defined. There are three types of service lives: technical service life, functional service life, and economical service life.

- Technical service life is the time in service until a defined unacceptable state is reached, such as spalling of concrete, safety level unacceptable, or failure of elements.
- Functional service life is the time in service until the structure no longer fulfills the functional requirements or becomes obsolete as a result of the change in functional requirements such as the needs for increased clearance, higher axle and wheel loads, or road widening.
- Economic service life is the time in service until replacement of the structure (or part of it) is economically more advantageous than keeping it in service.

Short-term parker—A parker who stays in a facility three hours or less.

Signage (signs)—The system of signs providing directions, warnings, and commands to the user.

Slab—A molded layer of plain or reinforced concrete, flat, horizontal (or nearly so), usually of uniform but sometimes of variable thickness, either on the ground or supported by beams, columns, walls, or other framework.

Spall—A fragment, usually in the shape of a flake, detached from a larger mass by a blow, by the action of weather, by pressure, or by expansion within the larger mass.

Speed ramp—A paved path connecting two parking bays with a grade differential of 2 to 5 ft.

Strengthening—The process of increasing the load-resistance capacity of a structure or portion thereof.

Structural steel—Rolled steel structural shapes, plates, and assemblies, as opposed to steel reinforcement.

Tendon—A steel element such as a wire, cable, bar, rod, or strand used to impart pre-stress to concrete when the element is tensioned.

Traffic-bearing waterproofing membrane—A waterproofing membrane that is applied to the top surface of the concrete floor slabs and is exposed to vehicular traffic

Wearing course—A topping or surface treatment to increase the resistance of a concrete pavement or slab to abrasion.

REFERENCES

1. American Concrete Institute (ACI), Committee 362.1R-12, *Guide for the Design and Construction of Durable Concrete Parking Structures*, ACI, Farmington Hills, Mich., 1994.
2. Ethan, B., "The Value of an Existing Customer," Flowtown [Online]. Available: http://www.flowtown.com/blog/the-value-of-an-existing-customer#ixzz12k1JvufP.
3. GHD, Inc., *ACRP Report 69: Asset and Infrastructure Management for Airports—Primer and Guidebook*, Transportation Research Board of the National Academies, Washington, D.C., 2012, 127 pp.
4. British Standards Institute (BSI), PAS 55-2:2008, Asset Management. Guidelines for the Application of PAS 55-1, BSI, London, U.K., 2008.
5. *Building Code Requirements for Reinforced Concrete* [*American Concrete Institute* (*ACI*) *318-81*], ANSI A89.1-1972, Report by ACI Committee 318—Structural Building Code.
6. Spy Pond Partners, LLC; KKO & Associates, LLC; Harry Cohen; and Joseph Barr, *TCRP Report 157: State of Good Repair: Prioritizing the Rehabilitation and Replacement of Existing Capital Assets and Evaluating the Implications for Transit*, Transportation Research Board of the National Academies, Washington, D.C., 2012.
7. Chrest, A.P., M.S. Smith, S. Bhuyan, D.R. Monahan, and M. Iqbal, *Parking Structures: Planning, Design, Construction, Maintenance and Repair*, 3rd ed., Kluwer Academic Publishers, Dordrecht, the Netherlands, 856 pp., 2000.
8. American Concrete Institute (ACI), Technical Committee 362.1R-97, *Guide for the Design of Durable Parking Structures*, ACI, Farmington Hills, Mich., 1994.
9. American Concrete Institute (ACI), Committee 365.1R-00, *Service Life Prediction—State-of-the-Art Report*, ACI, Farmington Hills, Mich., 2000.
10. *Building Code Requirements for Reinforced Concrete and Commentary* [*American Concrete Institute* (*ACI*) *318R-08*], Report by ACI Committee 318—Structural Building Code.
11. American Concrete Institute (ACI) Committee 364 .1R-07, *Guide for Evaluation of Concrete Structures before Rehabilitation*, ACI, Farmington Hills, Mich., 2007.
12. Weant, R.A. and H.S. Levinson, *Parking*, Eno Foundation for Transportation, Washington, D.C., 1990.
13. American Concrete Institute (ACI) Committee 362.2R-00, *Guide for Structural Maintenance of Parking Structures*, ACI, Farmington Hills, Mich., 2000.
14. National Parking Association, *Parking Garage Maintenance Manual*, Washington, D.C., 4th ed., 2004.
15. Precast Concrete Institute (PCI), *Maintenance Manual for Precast Parking Structures*, PCI, Chicago, Ill., 2004.
16. Morgan, J.S. and D.E. Moser, "Surface Parking Lot and Parking Structure Maintenance," *Office & Commercial Real Estate Magazine*, Spring/Summer 2009, p. 12.
17. *Vision 2020, A Vision for the Concrete Repair, Protection, and Strengthening Industry*, Strategic Development Council of American Concrete Institute, Farmington Hills, Mich., April 2006.
18. Shiu, K.N. and K. Stanish, "Extending the Service Life of Parking Structures—A Systematic Approach," *Concrete International*, Apr. 2008, pp. 43–49.
19. Walker Restoration Consultants, *Restoration of Parking Levels at Aon Center, Chicago, Illinois 2008 and 2009.*
20. Paul Tourney, Tourney Consulting, "Development of Criteria for a Potential Protocol to Evaluate Corrosion Mitigating Technologies," Sponsored by U.S. Bureau of Reclamation and Strategic Development Council of American Concrete Institute, Farmington Hills, Mich., 2011 to 2012.
21. *Highway Capacity Manual*, Transportation Research Board of the National Academies, Washington, D.C., 2010.
22. Smith, M. and T. Butcher, "How Far Will Parkers Walk?" *Parking*, August 1994.
23. Smith, M., "The Level of Service Approach to Parking Design" *Parking*, March/April 1987.
24. *Manual on Uniform Traffic Control Devices* (*MUTCD*) *for Streets and Highways*, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 2009 Edition including Revision 1 and 2 dated May 2012.
25. Harding, J.R., et al., *ACRP Report 52: Wayfinding and Signing Guidelines for Airport Terminals and Landside*, Transportation Research Board of the National Academies, Washington, D.C., 2011, 255 pp.
26. Coley Consultants, "Eight Characteristics of Good Requirements," on Communication [Online]. Available: http://www.coleyconsulting.co.uk/requirements-characteristics.htm.
27. Guerrilla Marketing, "Wonderful and Horrible Advertising" [Online]. Available: http://www.gmarketing.com/articles/173-wonderful-and-horrible-advertising.
28. "History of Communications from Case Drawings to the Web" [Online]. Available: http://www.creativedisplaysnow.com/articles/history-of-communication-from-cave-drawings-to-the-web.htm.
29. Rephlo, J., R. Haas, L. Feast, and D. Newton, *Evaluation of Transit Applications of Advanced Parking Management Systems Final Evaluation Report*, FHWA-JPO-08-052, U.S. Department of Transportation, Washington, D.C., May 9, 2008.
30. *Advanced Parking Management Systems: A Cross-Cutting Study—Taking the Stress out of Parking*, Federal Highway Administration, Washington, D.C., Jan. 2007.

APPENDIX A

Survey Questionnaire and Results

APPENDIX A1

Survey Questionnaire

BASIC FACTS ABOUT STRUCTURED PARKING FACILITIES

1. How many structured parking facilities are there at your airport?
2. If more than one, what is the breakdown in usage (short-term, long-term, etc.)?
3. What is the age of your parking structure(s)?
4. What is/are the structural systems?
   a. Post-tensioned cast-in-place
   b. Precast concrete
   c. Conventionally reinforced concrete (short span)
   d. Proprietary system; e.g., filigree, PSI, etc.
   e. Structural steel with concrete deck
5. In your opinion, how would the structural condition of the garage best be described?
   a. Pristine: as good as the day it was built.
   b. Good: problems generally limited to minor cracking.
   c. Fair: cracking and some spalls and other issues noticeable, but not pressing.
   d. Marginal: leaks and corrosion stains noted in addition to cracks and spalls. Problems with the expansion joints and sealants, leakage, splitting.
   e. Poor: concrete spalls fall and damage cars and leakage is widespread and stains cars and the floors below. Corrosion stains are noticed with some regularity.
   f. Terrible: potholes, exposed corroded reinforcing, large spalls, cracks that leach water and staining are commonplace. Partial collapse could be imminent.
6. How much surface parking is available?
   a. Overflow parking:
   b. Long-term parking:
   c. Rental car lots:
   d. Cell phone waiting:
   e. Cab/limo waiting:
   f. Employee parking:
7. Which of the surface lot types in Question 6 would have some excess capacity to make up for lost spaces under construction?
8. How many speed ramps or helical ramps are there per parking structure?

PARKING FUNCTION AND USAGE

1. What is the car capacity of the structured parking?
2. What is the car capacity of the surface lots?
3. Approximately what percentage of parking garage spaces is utilized at peak times?
4. Approximately what percentage of parking lot spaces is utilized at peak times?
5. Do rental agencies occupy part of your structured parking? If so, what percentage is occupied by rental agencies?
6. Do rental agencies occupy part of your parking lot space? If so, what percentage is occupied by rental agencies?
7. How do patrons access the parking structures?
   a. Walkways on-grade
   b. Elevated walkways
   c. Trams
   d. Buses
8. How do patrons access the parking lots?
   a. Walkways on-grade
   b. Elevated walkways
   c. Trams
   d. Buses
9. What are your peak parking load month(s)?
10. What are your peak parking load days of the week?
11. What days of the week and time of year have the least amount of traffic and parking demand?
12. Who, besides airport patrons, has use of structured parking?
    a. Airport employees
    b. Tenants
    c. Airline personnel
    d. Other users such as security, TSA, etc.
13. Are there any ground transportation staging areas within structured parking?
14. What roadway or curbside access facilities could be impacted by construction; e.g., curbside check-in stations, cab stands, car rental shuttles, etc.?

REGULAR CURRENT MAINTENANCE PROGRAM FOR PARKING STRUCTURE

1. What is the current annual maintenance budget (including funds for known structural repairs)?
2. What types and at what intervals are regular maintenance procedures performed?
   a. Floor wash-downs
   b. Sealant replacements
   c. Penetrating sealer
   d. Re-striping stalls and directional arrows
   e. Minor concrete patching
   f. Expansion joint repairs
   g. Traffic topping (elastomeric membrane with wearing surface or similar) replacement in high traffic areas
3. What types of patron or tenant complaints do you get during parking deck maintenance or construction periods?
4. What is the most frequent/common complaint received?

REPAIR, RESTORATION, AND REHABILITATION PROGRAM

1. Has major restoration been done in the last 5 years?
2. Has major restoration been done in the last 10 years?
3. How long was the total construction schedule?
4. What was the construction budget and actual final cost?
5. Have you developed an operational plan that shows how much and which space and drive lanes can be taken out of service at any given time during the complete renovation of the parking structure?
6. Is your preference for longer term repairs, infrequent restoration and greater per job costs or short-term repairs, more frequent disruptions, and smaller per job costs?
7. Among three criteria (budget, level of service, and asset protection), what was the principal driver of the decision process?

CONSIDERATIONS THAT IMPACT PARKING OPERATIONS DURING RESTORATION

1. If major restoration has been done, what were major operational factors taken into consideration?
2. Are there any times of the year that construction cannot proceed because of traffic load and parking demands such as vacation periods or holidays?
3. What is the largest number of spaces that can be taken out of service for repairs at one time?
4. How many entry and exit lanes can be closed at any given time?
5. Can any ramps be totally closed off at any given time or must all ramps be left partially open (at least one drivable lane at all times)?
6. What shifts do you allow a contractor to work?
   b. Regular daytime hours
   c. Evening
   d. Overnight
   e. Any or all shifts
7. Can any spaces be taken out of service for the full duration of the job to allow for staging, temporary office, sanitation, and material storage?

MAINTAINING SERVICES AND USER SATISFACTION

1. Do you require comprehensive and professionally painted temporary directional signage to guide users around work zones? If so, who provided the signage?
2. Do you use additional staff to direct traffic and assist customers during construction?
3. Do you offer free shuttle service from temporary parking to and from the terminal?
4. Do you offer any incentives to promote the use of temporary parking?
   a. Discount coupons for parking
   b. Free shuttle service to and from terminal
   c. Reduced parking fees
   d. Discount coupons for food or other airport services
5. Do you require and enforce daily cleaning of the work areas in view by the customers?
6. What steps were required to segregate the traveling public from the work area?

COMMUNICATION ISSUES AMONG INVOLVED PARTIES AND CUSTOMERS

1. What do you rely on to communicate the presence of construction activity, rerouting, and relocating parking spaces to the customers?
   a. Limited range continuous radio broadcasts
   b. Signage
   c. Newspaper articles or advertisements (airport paid announcements)
   d. TV news coverage
   e. Website
   f. Electronic monitoring systems
2. Communicating with employees, tenants, vendors, security and others with regular business at the airport.
   a. E-mails
   b. Website
   c. Meetings
   d. Memos
   e. Newsletters
   f. Social media (Facebook, etc.)

SPECIFIC PROJECT CASE STUDIES

1. Based on recent major parking renovation projects, please discuss anything that went particularly well or better than expected as it related to maintaining parking operations.
2. What particular aspects of planning construction logistics contributed to maintaining smooth operations?
3. Based on recent major parking renovation projects, please discuss anything that caused significant disruption in parking operations.
4. What particular aspects of planning construction logistics did not live up to expectations as it related to maintaining parking operations?
5. Can you share any unsuccessful strategies in terms of budgeting, design approach, logistics planning, or construction operations?
6. What measures were taken to stay within the budget?
7. Who were the stakeholders involved in developing the scope, budget, and initiation of the project?

TABLE A1
AIRPORT PARKING STRUCTURES RESULTS

Airport	Parking Structure	Parking Type	Age	Condition	Type
ATL	Domestic N	ST	32	Marginal	PT + PC
	Domestic S	ST	32	Marginal	PT + PC
	International	ST	1	Pristine	PC
	International	LT	1	Pristine	PC
	Rental 1	Rent	2	Pristine	PT
	Rental 2	Rent	2	Pristine	PT
	QICC	Rent	32	Marginal	PC
	Hertz	Rent	32	Poor	PC
ORD	Garage A	ST	43	Good*	PT
DFW	Terminal A: 3 structures	ST/LT	0; 21; 29	varies	PT
	Terminal B: 3 structures	ST/LT	21, 35,33	varies	PT
	Terminal C: 4 structures	ST/LT	*; 15; 16; 26	varies	PT
	Terminal D: 1 structure	ST/LT	7	Pristine	PT
	Terminal E: 3 structures	ST/LT	20; 28; 28	varies	PT
DIA	6 garages	ST/LT	19	G - M	PC
	1 garage	ST/LT	5	G - M	PC
LAS	Gold	ST/LT	16	Good	PT
	T3	ST/LT	1	Pristine	PT
	Silver	ST/LT	27	Good	PC
MSP	T1 - Green/Gold	ST/LT	20	Fair	PC
	T1 - Red/Blue	ST/LT	13	Pristine	PT
	T1 - Maroon	ST/LT	20	Pristine	PT
	T1 - Valet	Valet	28	Good	PT
	T2 - Purple	ST/LT	10	Pristine	PT
	T2 - Orange	ST/LT	4	Pristine	PT
MDW	Terminal	ALL	13	F-M	PT
	Economy	LT	7	Pristine	PC
PHX	E Economy N	LT	12	Good	PC
	E Economy S	LT	5	Good	PC
	Terminal 2	ST	34	Good	PC
	Terminal 3	ST	33	Fair	PC
	Terminal 4	ST	22	Good	PT/SS
PDX	Long-term	LT	2	Pristine	PT
	Short-term	ST	26	Good	SS/PC
RDU	TG1	LT	25	F-M	PT
	TG2	LT	22	F-M	PT
	TG3	ST	13	Good	PT
	TG4	ST	8	Pristine	PT
SNA	A1	ST/LT	22	Good	PT
	A2	ST/LT	22	Good	PT
	B2	ST/LT	22	Good	PT
	C	ST/LT	2	Pristine	PT
SDF	1 garage	ST/LT	15	Good	PT

* Poor prior to restoration

LEGEND	
ST	Short-term parking
LT	Long-term parking
PC	Precast Concrete
PT	Post-tensioned Concrete
SS	Structural Steel
G	Good
F	Fair
M	Marginal

TABLE A2
AIRPORT MAINTENANCE AND RESTORATION RESULTS

Airport	Structured Parking Capacity	Surface Parking Available							Excess capacity for construction	Speed Ramps	Helical Ramps
		Capacity	Overflow	Long-term	Rental	Cell	Cab/Limo	Employee			
ATL	13566	15758		7584						Some on all structures	
ORD	9302	16543		12770		151			Lot G (2748)		2 up & 2 down levels 2,4,6 and 2 up & 2 down levels 1,3,5
DFW	28000	11800		11800					Surface Lots	Some on all structures	
DIA	14950	33317	8328	17579		100	345	7410	Overflow & LT	1 per structure	
LAS	10274	9289	3520	5730			165	1677	Overflow	1 in Gold structure	2 in Silver Structure & 1 each in Gold and T3
MSP	22400	1250			800	36	400		Structures		2 up & 2 down for T1 and 1 up & 1 down for T2
MDW	8426	3904		2542		150	146	1066	Econ Red (1942)		2 in terminal garage
PHX	17009	9165		5000		165		4000	Vacant Lots	1 in T3	2 up & 2 down in T4 and 1 each in economy lots
PDX	6200	10550	1000	7900		35	200	2400	Overflow & LT		2 double helix (2,4,6) 3,5,7
RDU	11000	10383	2785	7300		20	785	1309	All	2 to level 3 TG1 & TG2	TG3 - 2 from level 1 to 5, TG4 – 2 from level 1 to 7
SNA	6497	2762	800	1959				803	Overflow	2 in each structure	
SDF	4150	2201		1440		160	30	601	Cell Lot		1 up & 1 down 4 level helical ramp

(*continued on next page*)

TABLE A2
(*continued*)

Airport	% of Garage Spaces Utilized at Peak Times	% of Lot Spaces Utilized at Peak Times	Rental Agencies in Garage	Rental Agencies in Lots	Patron Access to Structures (Parking Lots)				
					Walkways on-grade	Elevated Walkways	Trams	Buses	Other
ATL			25%	None	X (X)	X (X)	X	X (X)	
ORD	100%	B,C,E-100%, F-50-60%	None	None	X (X)	X (X)	(X)	(X)	
DFW	100% A, C, D; 90% E; 60% B; 100% surface lot		Separate Garage	None	X	X		(X)	
DIA	99%	99%	None	None	X (X)	X		(X)	Elevators
LAS	100% Gold Garage	75%	None	None	(X)	X		X (X)	
MSP	T1-100%, T2-80%	N/A	17% of Red Ramp	100%	X	X	X	X	Underground
MDW	TG-80%, EG-60%	Yellow-100%, Red-70%	15% of TG	None	X (X)			X (X)	
PHX	99%	99%	Separate Garage	None	X (X)			X (X)	Elevators
PDX	LT-100%, ST-60-70%	70%	30% overall	None	X	X		(X)	Underground
RDU	85%	Term-85%, P&R-35%	None	None	X (X)			(X)	
SNA	100%	50%	11% overall	None	X			(X)	
SDF	1,2-100%, 3-90%, 4-30%	100%	None	None	X (X)			(X)	

(*continued on next page*)

TABLE A2
(*continued*)

Airport	Peak Parking Load Month	Peak Parking Load Days	Lowest Parking Load Month	Lowest Parking Load Days	Besides Patrons, who uses Structures				Ground Trans. Staging areas in Structure	Curbside Facilities Impacted by Construction
					Airport Employees	Tenants	Airline Personnel	Other users		
ATL					X	X	X		No	All
ORD	Oct.	Tues. - Wed.	Feb.	Sat.				None	No	Shuttles from hotels
DFW	February	Tues. - Thurs.		Fri. - Sun.	X	X	X	TSA	Yes	Buses, but no direct impact
DIA	Mar. - Oct.	Tues. - Thurs.	Jan. - Feb.	Sun. - Mon.				None	No	All
LAS	June - Aug.	Thurs. - Fri.	Jan. - Mar.	Tues. - Wed.	X	X	X	CBP	No	All
MSP	Feb. - Apr. & Sep. - Nov.	Tues. - Wed.	June - Aug.	Sat. - Sun.	X	X	X	Ground trans. Employees	Yes	Taxis, limos, shuttles, buses
MDW	Mar. - Aug.	Tues. - Wed.	Jan. - Feb.	Mon.	X	X		Security, TSA	No	None
PHX	May - June	Mon. - Thurs.				X	X	TSA	No	Roadway impact only
PDX	May & Oct.	Tues. - Wed.		Sat.	X	X	X	Security, TSA	No	Pickups, shuttles, taxis, valet
RDU	Mar., July, Oct.	Tues. - Wed.	Feb.	Sun				None	No	None
SNA	Steady (Summer)	Wed.	Jan. - Feb.	Sat. - Sun.	X	X	X	Anyone (must pay)	Yes	All
SDF	Oct., Mar., June, July	Wed. - Fri.	Dec. & May	Sat. & Tues.		X		Info booth volunteers	Yes, valet	None

TABLE A3
AIRPORT MAINTENANCE AND RESTORATION RESULTS

	CURRENT MAINTENANCE PROGRAM										
Airport	Annual Maintenance Budget	Type of Maintenance and Intervals Preformed: Floor Wash-downs	Sealant Replacements	Penetrating Sealer	Re-striping Stalls & Arrows	Minor Concrete Patching	Expansion Joint Repair	Traffic Topping Replacement	Other Procedures	Patron/Tenant complaints during maintenance	Most frequent complaint
ATL											
ORD	$2.5M	April-November: Each level scrubbed every 6 weeks on rotating basis. Everything pressure-washed in the spring	As needed	Every 5 years on rotating basis	As needed	As needed	Just replaced (lasted 4-5 years)	Used above habitable space		Patrons unable to park where they want / by wrong elevator	Having to park somewhere else when capacity is diminished
DFW		1 to 2 years intervals								There is a lack of parking spaces, patrons must walk through construction zones	Patrons need additional time, fear of missing flight
DIA	$4-$5M	Every 8 to 10 years or as needed	Every 8 to 10 years or as needed	Every 8 to 10 years or as needed	Every 8 to 10 years or as needed	Every 8 to 10 years or as needed	Every 8 to 10 years or as needed	Every 8 to 10 years or as needed	Weekly sweeping	Dust, noise, odors, fumes, car damage from towing, could not find relocated car after it was towed	Dust on the cars
LAS	Varies	Monthly pressure washing on a rotating basis for all curbs and a daily auto scrub is performed.			As needed	As needed	As needed			If citations are issued for interfering with a construction/maintenance area	Receiving a citation
MSP	$3.5-$4M	Floor power flushing/wash downs/machine scrubbers – Annually	Every 5 to 7 years	Every 7 to 10 years	Annually	Annually as inspections/failures occur	Every 10 to 12 years or as inspection shows failures	As needed based on inspections	Re-lamping every 2 years; overall inspection every 4 years	Almost none	Patrons saying they will miss flight because they could not park where they wanted
MDW	$500K	As needed	As needed	Every 5 years	As needed	As needed	As needed			Cars splashed with water from power washing	Dust on cars ($15 towards carwash for complaints)
PHX	$1M	Vacuum sweeping - weekly, Pressure washing (stalls - annually, drive aisles - semi-annually, entry/exit lanes - monthly)	As needed	Inspection monthly, repair if needed	As needed	As needed	Inspect monthly (T3 - 5 to 6 years needs replacing)			Towed cars when not moved in time (2 week notice usually given)	Towing, painting overspray
PDX	$45K	Every other year	Every 10 years	25 feet around perimeter of structure	Every other year	As needed, target cracks	Replaced in 2011	Membrane every 5 years		No serious complaints	Inconvenience of having to relocate
RDU	Small								Usually react when something breaks, fabric coated roof inspected annually	Dust and noise issues, altered pedestrian path for employees	Complaints about dust and dirty railings, patrons cannot find car
SNA	None	Parking spaces cleaned twice per year by hired contractor			As needed		Replaced once since construction (22 years)			Lack of covered parking, running late to flight because of construction	Got stuck in garage over 15 minutes, and had to pay $1 fee
SDF	$100-$150K	Hose wash-downs - decide if needed annually	Some replaced, more needed	As needed	As needed	As needed. Patching on houndies & slab spalls done	Roof replaced 2 years ago			Patrons wanting to park in blocked off spaces	Some patrons have car moved and cannot find it

(*continued on next page*)

TABLE A3
(*continued*)

	REPAIR, RESTORATION & REHABILITATION PROGRAMS						
Airport	Major Restoration in last 5 Years	Major Restoration in last 10 Years	Length of Construction Schedule	Construction Budget & Final Cost	Developed Operational Plan for Renovations	Longer term repairs, infrequent restoration, greater cost or shorter	Principal driver - budget, level of service, or asset protection
ATL	No	No	N/A	N/A	No		Combination of all 3
ORD	No	1995-1997 Renovation of parking garage	3 years phased	$65M	With entrance/exit ramp taken out, manual intervention needed	Maintenance should prevent repairs. Size and budget of the project is very important	Asset Protection is the most important
DFW	2012 Rebuilding of Terminal A parking structure A; Renovating Terminal B, Parking Structure C	No	9 months to 1 year	Unknown, came from Capital Budget	Details routing patrons to different parking garages thru dynamic signs	Longer term repairs, infrequent restoration	1. Level of Service 2. Budget 3. Asset Protection
DIA	1998-2009 Minimize water issues on all 6 older structures	1998-2009 Minimize water issues on all 6 older structures	11 years (9 phases)	$37,304,444	Yes	Shorter term, more frequent repairs	All 3 are extremely important
LAS	Exp. joint repair in Silver Garage, Taxi Curb & MSE Wall Refurbishment	No	Exp. joint approximately 3-5 months	N/A	No	Longer term repairs, infrequent restoration	Level of Service
MSP	No*	No	Maintenance schedule May 1 through Sept. 15	N/A	Yes	Shorter term, more frequent repairs	Landside promotes level of service and quality of work
MDW	No	Helices routing & resealing 2002	1 month	Approx. $200,000	Yes, wide enough drive lanes to keep half open at all times	Shorter term, more frequent repairs	All 3 are extremely important
PHX	Changing all lights to LED lights in T3	No	N/A	N/A	Not determined yet, need to determine how many spaces can be taken out	Longer term repairs, infrequent restoration	Rely more to minimize impact. 1. Level of Service 2. Budget
PDX	ST Garage helices, membrane replacement, and corrosion repair	No	1 month for helices	Membrane on top deck cost $1.5M in 2011	Closing off half of a level okay, provide 2 week notice or drop gates at helices, whole floor closure possible	Shorter term, more frequent repairs, smaller cost & easier to manage	1. Asset protecting (esp. as structure gets older) 2. Level of service
RDU	No	PG1 & PG2 traffic topping and exp. joint	1 summer	$300-$400K in 2008	Not until project comes up	No preference	Asset Protection, water intrusion usually biggest worry
SNA	Corbel repair on ramps in A2 & B2 due to cracking	No	2 months	About $300K, designer repaired free	No, directions given to contractor in scope of work	Shorter term, more frequent repairs	1. Asset protection, 2. Level of service, 3. budget
SDF	No	No	N/A	N/A	Ample time for cars to clear, good signage, and doing work during slow periods	Shorter, really based on budget, time of the year, and project size	N/A

*Capital maintenance has occurred. Entire levels are closed for the Ramp Rehab program for only a few weeks, at most. No concrete delaminations or other severe issues requiring scheduled or unscheduled closures of major parts of our ramps has occurred.

(*continued on next page*)

TABLE A3
(*continued*)

	IMPACT ON PARKING OPERATIONS DURING RESTORATION					IMPACT ON PARKING OPERATIONS DURING RESTORATION				
						Shifts Contractor can Work				
Airport	Major Operational Factors during Restoration	Any times that construction cannot proceed	Largest number of spaces that can be taken out	Number of entry/exit lanes that can be taken out at once	Can any ramps be totally closed off	Regular daytime	Evening	Overnight	Any or all shifts	Number of spaces that can be taken out of service for full duration of the job
ATL	Customer impact	No			Must not jeopardize public safety				X	Yes
ORD	Capacity & traffic control	Can be dictated by airlines, input from premier passengers	1500 to 2000	Up to 2 ramps on each level since there are 4 on each level	Yes			May not be allowed close to hotels	X	Stored in worksite only. Otherwise, offsite storage
DFW	Avoid peak parking demand, maintain level of service	Week of Thanksgiving & Christmas	2000 spaces, redirection provided at entry gates	None	No	X	X	X	X	Yes, violated vehicles will be towed
DIA	Limit area; protect vehicles, minimize dust and fumes, notification for relocated cars	Thanksgiving & other major holiday weeks	1000 spaces	2 lanes	Ramps closed during construction				X	Yes, must be minimized though
LAS	Hours of work, disruption to customers	Thanksgiving and Christmas holidays	Depends on location	Reduce to one entry/ exit lane for short durations, during off-peak hours/days	No, must have at least one drivable lane at all times	Last resort if needed	X	X		Yes, depending on location
MSP	Safety, signage, vehicle protection, noise levels, dust, parking reminders	Cold temperatures and rain	5000 during holiday weekend	1/2 of exit lanes, 2 of 5 entry lanes	Left partially open unless middle of the night				X	No, very limited inventory storage on site, no contractor parking
MDW	Clearing vehicles & rerouting traffic for sealer repair	Holidays	1000	Varies, all 7 exit lanes do not need to be open	Terminal garage – no Economy garage - yes	X	If reg not possible	Last resort		Yes, for garage construction or terminal rebuild
PHX	Phasing very important, Need alternate parking	November, Thanksgiving	100						X (February & March)	
PDX	Number of spaces, where to park people, how to get to the location	Christmas & New Year's time	Short term - 650 spaces (entire floor) Long term - half floor & inbound traffic	1 entry in short term (out of 3) and 1 entry in long term (out of 2, have staff ready)	No			X Maintenance	X (Repairs)	Long term - Dead space in level 2, short term - 16' by 16' corners for staging.
RDU	Pedestrian pathways	Very cautious during holidays		Inbound lanes	Inbound lanes				X	Yes
SNA	Safety for public, workers, personnel	Avoid Monday-Wednesday and Christmas Thanksgiving	Depends on revenue impact and type of job	About half of the entry/exit lanes on each floor	None unless overnight work			Unless noise is issue	X	Yes. A1 had 30 spaces for construction when garage C was being built
SDF	N/A	October	Entire floor closure	None, may be able to substitute 4th floor entrance as exit	Possibly 1 of the helical ramps				X	Store on 4th level since it is usually not full

(*continued on next page*)

TABLE A3
(*continued*)

	MAINTAINING SERVICES & USER SATISFACTION					
Airport	Work zones require comprehensive signage to guide users	Additional staff for directing traffic during const.	Free shuttle service from temp. parking	Incentives to use temp. parking	Require daily cleaning of work areas in view	Steps to segregate public from work areas
ATL	No	Yes, contracted parking staff	Free already	None	Yes	Bicycle fencing
ORD	Part of contractor's scope, but airport will provide when necessary	Supplied by the airport when necessary. (Already there Mon.-Wed.)	Currently have one	None	Yes	Contractor provides barriers
DFW	Yes[2]	Additional staff at entry gates, and affected garage	Free shuttle buses already available	Parking coupons, reduced fees	Yes	Areas will be closed off to public with 30 days notice
DIA	Yes, provided by the contractor	Try to do most traffic and customer management with signs to control costs.	Yes	Outlying surface lots lower price already	Not unless customer has access to work area	Fencing, walls of heavy construction plastic and other barricades
LAS	No	Yes, if it is needed	Yes if there was temporary parking	None	Contractors scope includes cleaning of the work area, inspectors enforce	Caution tape, A-frame signs, reader boards
MSP	Yes[2]	Yes, selected and trained by parking management contractor	Yes, light rail between terminals	$5 Caribou coffee coupons	Yes, part of contractor annual education	Drape visquine, concrete or water-filled barriers
MDW	Contractor provides, parking management approves	Yes	Yes	None	Yes	Barricades to Jersey walls with fencing
PHX						
PDX	Contractor & owner both (orange with black)	Yes, contractor puts signs up, staff moves signage as needed and directs traffic	Already available for economy parking	Current reduced rate	Daily unless area is completely fenced off	Temporary cones usually, temporary cyclone fence, orange mesh fences
RDU	Yes, way-finding consultant – outside signing contractor	not additional, but contractor will provide	Already have one	None	Yes, by contractor	Everything possible
SNA	Contractor required to provide signage and barriers	If needed, it is done through the contractor per the contract	Already provided free of charge	None	Yes	Barricades, caution tape and railings
SDF	In-house sign department produces professional signage	Not usually, avoid when possible	Already provided free of charge	None	Yes	Barricade, barrels, ropes and signs

[1] 30 days prior to schedule work, message will be posted to media, local dynamic signs at 4 different locations, then there are operational signs with notices at the entry gates, also dynamic signs at the doorway of each parking structure.
[2] This is provided through a parking management contractor. The airport approves all signs in form and text before they are created, pre-approve signs' location and site as well, and walk the site to be sure it is done well. If the signs need tweaking, the airport does it.

(*continued on next page*)

TABLE A3
(*continued*)

	COMMUNICATING AMONG PARTIES & CUSTOMERS												
	Ways to communicate construction activity to customers							Communicating with employees, tenants, vendors & security					
Airport	Radio	Signage	Newspaper	TV news coverage	Website	Electronic systems	Other	Emails	Website	Meetings	Memos	Newsletter	Social Media
ATL		X			X			X	X				
ORD	X	X (Electronic Roadway signs)			X	X	PARCS system to be installed	X	X	X			Not yet
DFW		X (dynamic signage)	X (Handouts)		X		Smartphone apps	X	X	X (Constr. Crews & vendors)			X
DIA		X (Posted 2 weeks prior)						X		X		X (Depends on target audience)	
LAS		X					Tenant Bulletins	X				X (Tenant bulletins)	
MSP		X			X		People & Emails	X	X	X	X	X	X
MDW	X	X				X		X		X	X		
PHX		X	X	X	X	X	Public information officers & social media	X (Hotline numbers)	X	X (Monthly tenant meetings)			X
PDX	X	X	X		X (capacity & dates)	X (Over roadway)	Press releases	X		X (Monthly)	X (Notices on bus shelters)		
RDU	X	X (Dynamic)			X			X	X	X (Tenants employee forums)	X (Impact notices)	X	X
SNA		X (Dynamic)	X		X			X	X	X	X		
SDF		X			X (Press releases)	X (Number of open spots)		X	X	X	X	X	

APPENDIX B

Case Examples

MINNEAPOLIS—ST. PAUL INTERNATIONAL AIRPORT

Minneapolis–St. Paul International Airport (MSP) parking structures at Terminal 1 and Terminal 2 have not required major restoration in the last 10 years. Airport parking management attributes this to a well-planned and disciplined capital maintenance program that invests between $2.5 and $4 million annually. To complete the work necessary in the time that Minnesota weather and parking demand allow, the program carefully schedules the closure of entire levels but for only a few weeks between May 1st and September 15th. This proactive, tightly controlled, and highly communicated schedule succeeds because it carefully matches those specific weeks of reduced customer demand and warmer temperatures with the work to be completed.

Specific lessons were learned and applied so this program continues to improve:

- The contracted project engineer is open to learning and incorporating the primary importance of customer service and the nuances of the MSP parking facilities and operations into the project. These concerns drive the specifications, the work, and the schedule required of the construction contractor. These concerns place specific restrictions on the number of levels out of service at any one time and that construction impacts in dust, noise, etc. to the public will be limited and controlled. This means some work will be scheduled at night or on weekends when fewer customers are impacted.
- When the contractor or engineer requests alteration to the approved schedule to complete more work by removing more spaces from service, the parking manager uses the prior year's parking demand records to approve, disapprove, or alter the request to meet the airport's customer service goals. The frequency of these requests led to a Spaces Allowed Out of Service Per Week of Work report the engineer now uses to develop next year's schedule of work and to address current year's contractor change requests. Use of this report has had a direct impact by reducing the inconvenience to the customer each year.
- Weekly construction meetings include the parking management contractor. This allows them to alert their staff to upcoming concerns and to meet with the airport parking manager to decide how best to address concerns in the upcoming weeks.
- Flaggers from the MSP parking management company control traffic rather than hired flaggers by the contractors who may well be on-site for the first time. This provides more consistent customer service and more accurate answers to customers' concerns as well as lower costs.

Planning construction logistics plays a major role in maintaining smooth operations. These practices include:

- In June the budget is set and establishing the work and schedule for next year begins. This provides sufficient time for budget updates (approved in November), allows the work to be clearly understood by the stakeholders, and makes it possible for the work to be scheduled when it least impacts customers. An early start also allows inclusion of lessons learned performing the work this summer and the identification or resolution of any new problems. Updates on required products, methods, and required timeframes for completion can be incorporated. We also update our customers' parking experience (how often and for how long we overflowed our parking structures) vs. the Spaces Out constraint from this year's schedule. We realize that we seek to manage but not eliminate construction impacts on the customer's parking experience.
- Signs at the entrance to each parking level inform customers of the specific date that this level will close 14 days in advance. Customers know they can park on this level if they plan to return from their trip and leave before that date. Signs are also posted where customers leave the Terminal into these parking levels. Remaining vehicles are carefully towed to another level or just moved out of harm's way on the same level. Once vehicles (actually very few) have been relocated, a sign at the parking level entrance from the Terminal informs customers (by their vehicle's license plate number) of their vehicle's location with an apology for any inconvenience.

In cases where an area closure necessitates rerouting traffic, additional attention must focus on timing and logistics. When a major artery, entrance, or exit must close, staff must carefully analyze traffic patterns and determine the best alternate routes. Depending on the duration of the closure, live flaggers may not be cost effective 24/7. Careful planning of temporary signage changes is essential, especially when there is live traffic moving through the areas while the new traffic routes are being established. Signs must be approved and ordered well in advance. The order of sign installation, equipment, and staffing must be well-planned. The "strike team" must be prepared to quickly and effectively change possibly dozens of overhead and eye-level signs on each level. Someone must inspect the work and drive through the areas wearing "the customers' eyes." And, finally, removal of the signs should be just as well-coordinated.

- Once construction activities are complete on a particular level, the schedule includes time for the airport's trades to compete their annual maintenance work before the area is opened for parking. This creates efficiencies and safety as they do not have to deal with vehicles or traffic and reduces their work time. Their work includes power washing to remove surface salts and oil drips, restriping the stalls, re-lamping, repairing drains, etc. A level may be reopened to the public with only a few parking spaces closed if needed for the trades to safely complete their work to better meet that week's parking demand. Agreement on the schedule in the fall, as to which parking levels will be available to the airport's trades staff next summer, allows time for them to schedule staff, order and receive supplies, and arrange equipment necessary to complete their work.

Budget tracking is the responsibility of the MSP project manager, who works with the contracted construction manager and the engineer. They work closely with the construction contractor

on a weekly basis to ensure submittals, field orders, and the like are moving through the approval processes and match with the budget.

Despite all the efforts, some decisions in the field made by the contractor or their subcontractors for their convenience occasionally impact parking customers. Some examples include:

- Rerouting traffic without gaining permission from airport parking manager
- Placing materials or equipment in unauthorized stalls or exit lanes
- Installing makeshift traffic routing signs not approved by the airport parking manager
- Contractors parking their vehicles in unauthorized areas or along the roadways.

The lesson is that the airport parking manager and the parking management company must provide constant supervision in the field, and identify and quickly correct the poor decisions of contractors and engineers before customers are affected. This is especially necessary as the construction contractor may change from year to year and lessons learned by last year's contractor may need to be retaught this year.

The schedule is the aspect of planning logistics most frequently tested. Once, a junior engineer approved the contractor to work in an area for a few days beyond the schedule. This delayed the reopening of a 500-space level for parking and customers had to be re-routed without notice to other parking areas. Another issue occurs when equipment or critical supplies arrive late. In this case, the team has to reassess the schedule in light of set priorities—customer service followed by completion of the necessary work. This has led to work being rescheduled to the end of the project or postponed until next year.

Another concern was when parking management assumes that contractors and partners (engineers, project managers, etc.) actually understand airport parking as well as parking management does. This led to customer impacts or lower quality of work being accepted by the engineer. Airport parking management must understand that contractors and engineers have different priorities, operational freedoms, and work assumptions when they work on non-airport parking projects. However, once the project engineer and the parking management company understand the airport's priorities, they can help avoid "schedule or scope creep" by the construction contractor before the customer's parking experience is impacted.

Stakeholders help develop the scope, budget, and initiation of needed work. These include MSP trades staff (plumbers for drainage, electricians for upgrading power loads, information technology for upgrades, etc.), other airport staff, police and fire responders, and public relations, as well as ground transportation staff (managers of taxis, shuttles, limos, and buses). With the scoping and scheduling starting early in the summer, stakeholders have time to supply their thoughts and ideas for the project and schedule.

DENVER INTERNATIONAL AIRPORT

Rewrite of ACRP—Case Study for Denver International Airport—by Bill Shirk—Nov. 7, 2012.

Beginning in 2000, Denver International Airport (DIA) undertook an 11-year, $37 million restoration program in six of its seven parking structures, making repairs and applying waterproofing methods to improve the precast concrete structures' corrosion resistance and to extend their useful lives.

To provide the required expertise, DIA hired a specialty consulting firm that concentrates on parking garage designs and repairs to plan the repair programs and then to monitor construction on a full-time basis. This continual oversight was essential to maintaining quality of the finished repairs. At DIA, the Airport Parking Administration department is responsible for the daily operation of the garages. The specialty consulting firm developed the recommendations of scope and budget for the anticipated repairs. Senior airport management reviewed the budget requests and made final determinations on the project funding. DIA Planning and Development and the specialty consulting firm managed the approved projects throughout the actual work phase.

In addition to the technical repair details, it was essential to plan the work to minimize disruptions to the overall DIA operations and to the customers. The following ideas were used to meet these requirements:

1. Notify the customers of impending work closure areas. The contracts required the contractors to post signage at roadway entrances and along walkways to the terminal at least two weeks before the construction closures would go into effect. The closure sizes were coordinated with the Parking Administration to limit the areas out of service and to provide sufficient space for the contractor to efficiently complete the work.
2. Provide contract requirements to hold the contractors responsible for minimizing disruptions. The contracts included penalties for generating noise, dust, or fumes, or in any other way disrupting or interrupting the operations of the airport.
3. Make the contractors responsible for towing cars that were still in the work zone after the two-week notice. The contractors were also responsible for posting signs to notify customers where cars were relocated.
4. Make the contractors responsible for customer complaints, including construction dust on cars and any other customer complaint resulting from the construction operations.

These processes were closely monitored by the DIA Planning and Development team.

CHICAGO O'HARE INTERNATIONAL AIRPORT

Chicago O'Hare International Airport underwent a three-year $65 million restoration project beginning in 1995 to repair a parking garage in poor condition. The scope consisted of replacement of the expansion joints and drainage troughs, making repairs to the post-tensioning system and ramp overlays, performing full and partial depth repairs to the elevated slabs, and installing a deck protection system consisting of a traffic-bearing membrane and joint sealants. In 2006, premature distress at the expansion joints forced the removal and replacement of 13,345 feet of expansion joints including headers.

Successful actions that helped maintain smooth parking operations throughout the initial restoration project included setting aside enough time for advanced planning, ensuring there was adequate labor to keep the project running smoothly, and hiring a third-party consultant to monitor the schedule and budget. As for the later expansion joint repair, successful

actions included an early pre-construction meeting among the general contractor, installation contractor, and the manufacturer to review all necessary quality-assurance measures; and use of a third-party field-testing firm to monitor all progress. Additional planning that kept operations running smoothly included an expansion joint workshop, during which everyone involved met with the manufacturer for a dry run of the project before it began. Repair implementation of expansion joint replacements was phased over two construction seasons.

Some issues that disrupted parking operations during the initial restoration included:

1. Concrete debris dropping. Some fell on the level below where concrete repair was taking place.
2. Maintaining revenue security. In some incidences, the contractors forgot to close the gates after entering and leaving.
3. Having two different contractors for on different levels. (One was much better and faster than the other.)
4. Specified expansion joint product. The specified expansion joint turned out to be poor and not durable, providing barely five years of good service instead of the 20 years they were supposed to last.

Many different people and companies were responsible in developing the scope, budget, and project initiation. The primary stakeholder was the city of Chicago. Other stakeholders included the airline companies, Standard Parking, which runs the parking garage, and the architects and construction managers.

APPENDIX C

List of Survey Participants

Code	Name of Airport	Hub Size	State	Concrete Institute Design Zone	No. of Parking Decks
ATL	Hartsfield–Jackson Atlanta International Airport	Large	GA	I	8
DFW	Dallas/Ft. Worth International Airport	Large	TX	I	14
DIA	Denver International Airport	Large	CO	III	7
LAS	McCarran International Airport	Large	NV	I	3
MDW	Chicago Midway International Airport	Large	IL	III	2
MSP	Minneapolis–St. Paul International Airport	Large	MN	III	6
ORD	Chicago O'Hare International Airport	Large	IL	III	1
PHX	Phoenix Sky Harbor International Airport	Large	AZ	I	5
PDX	Portland International Airport	Medium	OR	CC	2
RDU	Raleigh–Durham International Airport	Medium	NC	II	4
SDF	Louisville International Airport	Medium	KY	II	1
SNA	John Wayne Airport	Medium	CA	CC	4

APPENDIX D

Typical Structural Checklist for Parking Structures

ANNUAL STRUCTURAL CHECKLISTS

FORM F-5

ANNUAL STRUCTURAL CHECKLIST **INSPECTOR**

PARKING STRUCTURE NAME **DATE**

MAINTENANCE MANUAL AND PROGRAM

OWNER

CITY, STATE

FLOORS

_____ When was the last floor sealer application? (Typically applied every 3–5 years)

_____ Are there rips, tears, debonded areas, or signs of embrittlement in the traffic topping?

_____ Are there cracks in the floor slab? If yes, where are they located and how wide are they?

_____ Are there signs of leaking?

_____ Any spalls or delaminations? If yes, how big and where are they located?

_____ Has chloride ion content testing been performed this year?

BEAMS AND COLUMNS

_____ Are there cracks? If yes, are they vertical or horizontal and how wide?

_____ Are there any signs of leaking?

STAIR/ELEVATOR TOWERS

_____ Are there any signs of a leaking roof?

_____ Are there any cracks in the exterior brick?

_____ Are there any cracks in the mortar joints?

NOTES AND CORRECTIVE ACTION NEEDED:

JOINTS

_____ Are there any signs of leaking, loss of elasticity or separation from adjacent surfaces?

_____ Expansion joints

_____ Control joints

_____ Construction joints

_____ Tee-to-tee joints

ARCHITECTURAL SEALANTS

_____ Are there any signs of leaking, loss of elasticity or separation from adjacent surfaces?

_____ Between windows and doors

_____ In block masonry

_____ Exterior sealants

_____ Concrete walks, drives and curb landings

EXPOSED STEEL

_____ Is there any exposed steel? If yes, where is it located and is it rusted?

MASONRY

_____ Are there any cracks in the brick?

_____ Are there any cracks in the mortar?

_____ Are there any brick spalls? If yes, where are they located and how big are they?

NOTES AND CORRECTIVE ACTION NEEDED:

BEARING PADS

_____ Are bearing pads squashed, bulging, or out of place? If yes, where?

After answering the above questions, please consult a qualified engineer to discuss your answers.

NOTES AND CORRECTIVE ACTION NEEDED:

Source: Chrest et al. 2000 (*7*).

Abbreviations used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation