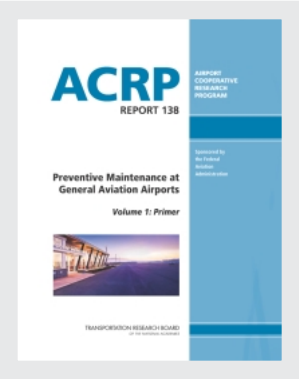

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 138

Preventive Maintenance at General Aviation Airports

Volume 1: Primer

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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 REPORT 138, VOLUME 1

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FOREWORD

By Marci A. Greenberger
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ACRP Report 138: Preventive Maintenance at General Aviation Airports is published as a two-volume set. Volume 1 is a primer for airport governing- and policy-board members on the importance and value of a preventive maintenance (PM) program. Volume 2 is a guidebook for airport managers, maintenance managers, and all line personnel on how to plan, prioritize, and conduct preventive maintenance for physical infrastructure assets.

This Volume 1 Primer begins by discussing the value of airports to communities and the national airspace system. It reviews the various infrastructure assets at airports and outlines the value of planning and prioritizing preventive maintenance into the budgeting process and the impacts to operations if an airport fails to conduct preventive maintenance. It also identifies basic principles for establishing and implementing a preventive maintenance program.

General aviation airports of all sizes are an integral part of the National Aviation System. Many of these airports have aging facilities, changing facility demands to accommodate the changes in the general aviation industry, and diminishing revenue sources. These trends coupled with limited staff and budgets have made it difficult to properly maintain the facilities beyond responding to immediate needs. Airport management responds well to those needs, but these efforts leave little time for true maintenance planning.

Preventive maintenance programs can be effective at ensuring that physical assets operate reliably and efficiently. However, preventive maintenance is not always funded. Delta Airport Consultants, Inc., as part of ACRP Project 10-18, conducted research on the benefits and value of an airport preventive maintenance program, as well on the typical physical infrastructure assets at airports and the considerations for developing a preventive maintenance program for those assets. Airport policy- and governing-board members will find the primer informative on the need and the value that a preventive maintenance program provides. Airport management and their staff will find that the guidebook illustrates how to set up a preventive maintenance program and provides specific guidance for specific assets. The primer and guidebook will be useful for general aviation airports of all sizes.

CONTENTS

Note: Photographs, figures, and tables in this report may 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.

CHAPTER 1

Introduction

1.1 Background

General aviation (GA) airports play an important role in the nation's aviation system. They provide access by air and serve the aviation needs of local communities. They have a significant economic impact on their community, region, and state. However, it is costly to properly operate, maintain, and develop an airport. Also, many airports have aging facilities, changing demands, and few revenue sources. Unfortunately, airport preventive maintenance (PM) is often neglected and given little to no priority when establishing local budgets and schedules. A sound maintenance program is critical for extending the life of airport facilities and to keep the airport as safe and efficient as possible. A lack of PM can result in premature failure of infrastructure and additional costs that would not otherwise have existed.

This primer provides basic information about airport PM programs. The companion guidebook (Volume 2 of this report) provides hands-on information to help with implementation of a PM program. These documents were developed using the knowledge and experience of the authoring team along with a review of literature, industry outreach, and on-site visits and interviews involving a diverse group of airports and state aviation agencies from around the country. Chapter 6 of this primer provides an overall summary of key points. Appendix A contains a list of the airports and state aviation organizations that provided information to help with development of the primer and guidebook.

1.2 Purpose of the Primer

The purpose of this primer is to help airport governing officials, policy makers, airport management and staff, and state aviation officials understand the importance of a PM program for airports and gain an understanding of what a good program includes. This primer provides:

- Basic information about the value of a general aviation airport;
- Information about the complexities of an airport and the many types of infrastructure systems needed to meet the needs of airport users;
- An overview of PM, its importance, the entities involved, and the basic principles that airports should follow;
- Information about the key aspects of a PM program, such as its elements, staffing, budget, and how it relates to other strategic plans for the airport.

1.3 How to Use the Primer

The primer is primarily directed toward airport governing officials and policy makers who are responsible for approving airport budgets, staffing levels, and strategic plans for their airport. Readers are encouraged to use the primer to consider the importance and value of their airport

in relation to the who, what, why, and value of PM. The companion guidebook primarily targets airport management and staff and, in addition to further enforcing the purpose of the primer, provides guidance on the where, when, and how of PM programs.

The primer's organization flows from a general discussion of the value of general aviation airports and types of infrastructure systems to a discussion about preventive maintenance programs. Key questions that airport officials and policy makers might ask and where answers may be found in the primer are shown in Figure 1.1. In addition, the bibliography in Appendix B provides a list of useful references.

Each airport is unique. Therefore, this primer and companion guidebook provide considerations for preventive maintenance programs. The actual program and activities that occur at an airport differ significantly based on the complexity and age of an airport's infrastructure and the available resources. Although the primer and guidebook cannot specifically address the unique needs of each airport, they will help the reader better understand the important elements of a PM program.

The intended audiences and how they may use this primer are:

- ***Airport owners and policy makers*** such as board members, elected officials, economic development staff, and community leaders need a good understanding of general aviation, general

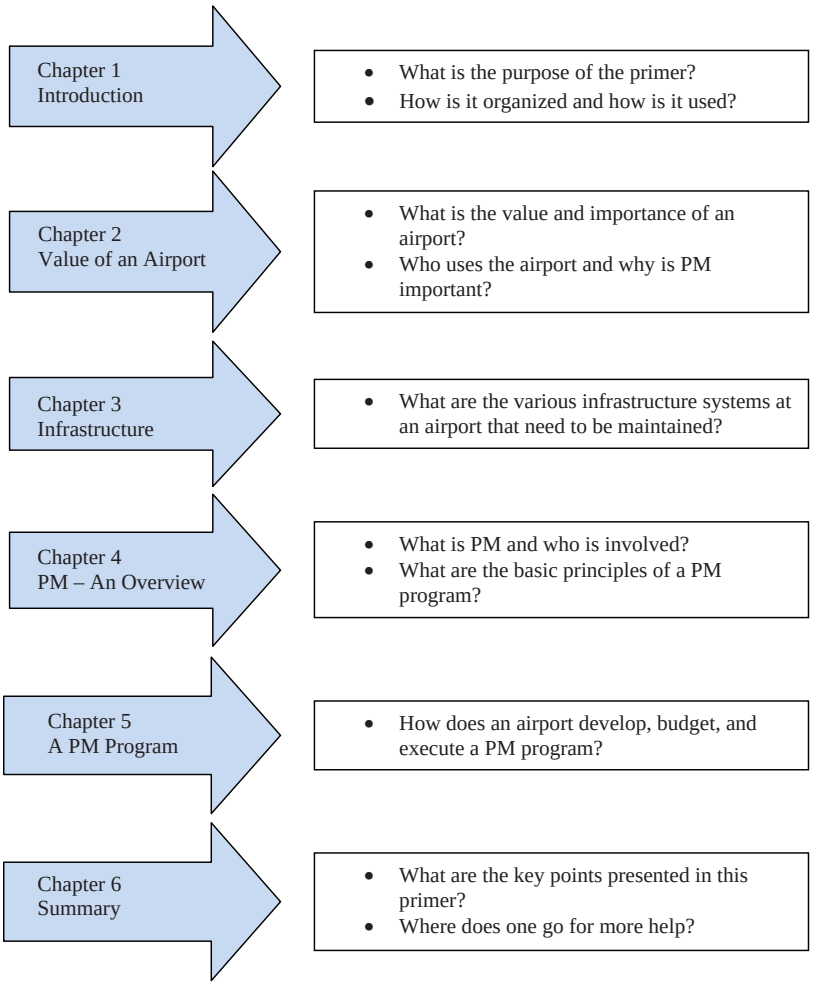


Figure 1.1. Organization of the primer.

aviation airport services, and facilities that provide those services. This knowledge will in turn help them plan budgets, adopt community visions, recognize funding opportunities, and understand the importance of preventive maintenance. This audience will primarily benefit from Chapters 2 through 5.

- ***Airport management and staff*** are generally interested in development of the overall PM program. Their focus is typically on identifying requirements, establishing a good program, and implementing it on a daily basis. This audience will primarily benefit from Chapters 4 and 5 as well as the companion guidebook.
- ***Airport tenants*** such as fixed-base operators (FBOs) lease areas or facilities provided by the airport, but some develop their own facilities or participate in the airport owner's PM program. This audience will benefit from Chapters 4 and 5 of the primer as well as the companion guidebook.
- ***Local/state/federal agencies*** may benefit from all chapters depending on the staff's role with airports and PM.
- ***Airport consultants*** are normally familiar with general aviation airports and the principles that make up a good PM program. This audience will primarily benefit from Chapters 4 and 5.

This primer and the companion guidebook supplement other guidance that is available, such as Federal Aviation Administration (FAA) Advisory Circulars (ACs) and orders, state aviation agency guidelines, and maintenance manuals for specific equipment or vehicles. Many of these publications are listed in Appendix B: Bibliography at the end of this primer.

CHAPTER 2

The Value of an Airport

2.1 Introduction

Airport governing officials and policy makers understand the value of their airport and, thus, appreciate the need to maintain and preserve the life of its infrastructure. The value of an airport can be significant to a community because it provides access to the national airspace system and serves the needs of businesses, the flying public, emergency and medical personnel, aerial firefighters, agricultural concerns, search and rescue organizations, law enforcement personnel, and other users. An airport provides considerable direct and indirect value to a community by generating jobs, services, and tax revenue.

2.2 Airport Users

All airports provide value by serving a wide range of users. The FAA's report *General Aviation Airports: A National Asset* (2012) summarizes the types of aeronautical functions serving the public's interest (see Figure 2.1).

Airport uses include:

- **Emergency Preparedness and Response.** Many general aviation airports are used for aeromedical flights for quick transporting of patients that need specialized medical care. Airports often serve as a base for local, state, or national law enforcement and national security during times of emergencies. Some airports provide an alternative to an intended destination when there are unexpected emergencies or bad weather. The nation's system of general aviation airports serve as staging areas to support relief efforts whenever needed (e.g., tornado recovery efforts).
- **Critical Community Access.** When scheduled air service is not available or convenient, businesses and individuals can charter air-taxi aircraft that operate from general aviation airports. Also, general aviation airports may be the only means of transport in remote areas.
- **General Aviation with Specific Functions.** There are several types of general aviation users with specific functions that benefit from airports. The FAA indicates that about 23% of private flying in the United States is done by business persons flying in piston, turboprop, or jet aircraft. Most of the private flight instruction takes place at general aviation airports. These airports also serve private flying in the areas of practicing flying skills, personal or family travel, enjoyment, and personal business.
- **Commercial, Individual, and Economic Activities.** General aviation airports serve many important commercial, industrial, and economic activities. These include agricultural support, aerial surveying and observation, delivery and air cargo services, utility inspection, and oil and mineral exploration and surveys.
- **Destination and Special Functions.** General aviation airports are needed for use by charters and private pilots during special occasions such as major sporting events, concerts, and races.

Emergency Preparedness and Response	▪ Aeromedical Flights ▪ Law Enforcement/National Security/Border Security ▪ Emergency Response ▪ Aerial Fire Fighting Support ▪ Emergency Diversionary Airport ▪ Disaster Relief and Search and Rescue ▪ Critical Federal Functions	
Critical Community Access	▪ Remote Population/Island Access ▪ Air Taxi/Charter Services ▪ Essential Scheduled Air Service Cargo	
Other Aviation Specific Functions	▪ Self-Piloted Business Flights ▪ Corporate ▪ Flight Instruction ▪ Personal Flying ▪ Charter Passenger Services ▪ Aircraft/Avionics Manufacturing/Maintenance ▪ Aircraft Storage ▪ Aerospace Engineering/Research	
Commercial, Industrial, and Economic Activities	▪ Agricultural Support ▪ Aerial Surveying and Observation ▪ Low-Orbit Space Launch and Landing ▪ Oil and Mineral Exploration/Survey ▪ Utility/Pipeline Control and Inspection ▪ Business Executive Flight Service ▪ Manufacturing and Distribution ▪ Express Delivery Service ▪ Air Cargo	
Destination and Special Events	▪ Tourism and Access to Special Events ▪ Intermodal Connections (rail/ship) ▪ Special Aeronautical (skydiving/airshows)	

Figure 2.1. Types of aeronautical functions serving public interest.
***Source: FAA*, General Aviation Airports: A National Asset**

Airports also enable access to areas not easily accessible for recreation, including remote and mountainous areas and islands.

The national airspace system includes approximately 2,800 public-use airports that are designated by the FAA as in the nation's interest to be included in the National Plan of Integrated Airport Systems (NPIAS). The FAA further identifies several principles of the NPIAS based on law and reflected in FAA programs, regulations, and policies. The NPIAS holds that airports should be:

- Safe and efficient, located at optimum sites, and developed and maintained to appropriate standards;
- Flexible and expandable, able to meet increased demand, and able to accommodate new aircraft types;
- Permanent, with assurance that they will remain open for aeronautical use over the long term; and
- Compatible with surrounding communities, maintaining a balance between the needs of aviation and the requirements of residents in neighboring areas (FAA, National Plan of Integrated Airport Systems, 2015–2019).

2.3 Airport Economic Impact

Local general aviation airports provide economic benefits that exceed the funding spent on operating and maintaining the facilities. Organizations such as the National Business Aviation Association (NBAA) and Aircraft Owners and Pilots Association (AOPA) publicly convey this

message. The NBAA reported in 2010 that business aviation contributed $150 billion to U.S. economic output and employed more than 1.2 million people. AOPA publicizes the types of economic impact created by general aviation airports. These are direct impacts associated with the providers of aviation services at the airport, indirect impacts associated with users of the airport services, and indirect impacts because of the airport's existence (e.g., jobs, payroll, and employer expenditures).

Many local and state governments have undertaken economic impact studies for their airports. These studies help with strategic economic investment decisions, evaluation of airport expansion alternatives, and informed decisions about land use and commercial projects in the vicinity of the airport. They also support public relations programs for educating policy makers, airport users, and the general public about the economic value of the airport.

As one state example, Georgia indicated in its 2011 Georgia Statewide Economic Impact Study that the total economic contribution of Georgia's 95 public-use general aviation airports is the sum of the on-airport businesses, the spending of visitors, and the additional activity of the recirculation of spending of on-airport businesses and visitors. These general aviation airports contribute significantly to the state's economy, supporting over 10,000 jobs, $354 million in payroll, and $1.2 billion in state economic impact (Georgia Department of Transportation and CDM Smith, 2011).

2.4 Cost of an Airport

The infrastructure of an airport, like other public works, can be very expensive. An airport's cost includes the cost of land, infrastructure (pavement, buildings, and other facilities), and the cost for ensuring that navigable airspace around the airport is clear. Each airport is unique, and the cost to construct it depends on its location, terrain, and size of the infrastructure. A typical one-runway general aviation airport could cost from $20 million to $100 million to build. It simply does not make good business sense to have to replace expensive airport facilities because of a lack of preventive maintenance. Airport owners can maximize the useful life of existing infrastructure through a proper PM program. Chapter 3 provides an overview of the types of airport infrastructure and the general maintenance considerations for each.

CHAPTER 3

Airport Infrastructure

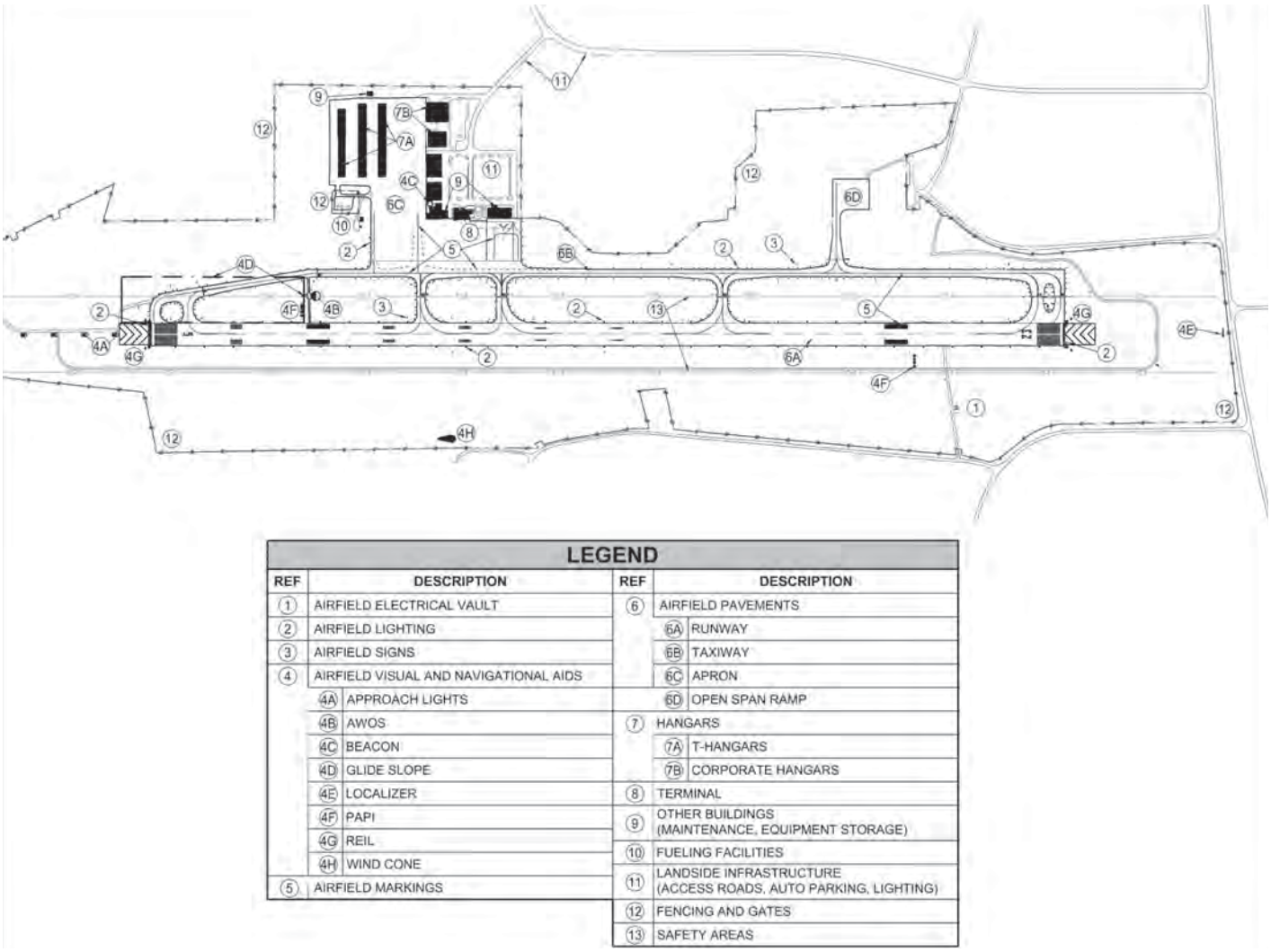
3.1 Introduction

There is a saying in the aviation community that goes, "If you have seen one airport, you have seen ONE airport." This is intended to emphasize the uniqueness of each airport. Airports can, and do, vary significantly in terms of the amount of activity that takes place at the airport and the infrastructure that is required to support that activity. The amount of infrastructure may vary greatly between airports; however, the type of infrastructure from one airport to another will usually be similar. For example, the type of signs used on an airfield to direct pilots and aircraft will be relatively consistent from one airport to another regardless of the size or complexity of the airport. The same holds true for many other types of airport infrastructure.

The infrastructure at an airport is normally spoken of in two categories: airside infrastructure and landside infrastructure. The airside infrastructure accommodates the movement of aircraft around the airport and includes such things as aircraft parking aprons, taxiways, airfield lights and signs, navigational and visual aids, and runways. The landside infrastructure accommodates the movement of ground-based vehicles and passengers and includes such things as access roads, parking lots, garages, aviation– and non-aviation–related businesses, support buildings, and terminal buildings.

Figure 3.1 depicts some of the infrastructure systems, both airside and landside, that may exist at an airport. These and other systems will be discussed briefly in this chapter. These systems are:

- Airfield electrical vault,
- Airfield lighting,
- Airfield signs,
- Airfield visual and navigational aids,
- Airfield pavements,
- Airfield markings,
- Hangars,
- Terminals and administrative/office buildings,
- Maintenance and storage buildings,
- Fueling facilities,
- Deicing facilities,
- Landside infrastructure,
- Airport-owned utilities,
- Obstructions to imaginary surfaces,
- Fencing and gates,
- Drainage,
- Turf and safety areas,
- Maintenance equipment, and
- Airport vehicles.



LEGEND			
REF	DESCRIPTION	REF	DESCRIPTION
1	AIRFIELD ELECTRICAL VAULT	6	AIRFIELD PAVEMENTS
2	AIRFIELD LIGHTING	6A	RUNWAY
3	AIRFIELD SIGNS	6B	TAXIWAY
4	AIRFIELD VISUAL AND NAVIGATIONAL AIDS	6C	APRON
4A	APPROACH LIGHTS	6D	OPEN SPAN RAMP
4B	AWOS	7	HANGARS
4C	BEACON	7A	T-HANGARS
4D	GLIDE SLOPE	7B	CORPORATE HANGARS
4E	LOCALIZER	8	TERMINAL
4F	PAPI	9	OTHER BUILDINGS (MAINTENANCE, EQUIPMENT STORAGE)
4G	REIL	10	FUELING FACILITIES
4H	WIND CONE	11	LANDSIDE INFRASTRUCTURE (ACCESS ROADS, AUTO PARKING, LIGHTING)
5	AIRFIELD MARKINGS	12	FENCING AND GATES
		13	SAFETY AREAS

Figure 3.1. Airport infrastructure systems. Source: Delta Airport Consultants, Inc. Notes: AWOS = automated weather observing systems, PAPI = precision approach path indicator, REIL = runway-end identifier light.

3.2 Types of Infrastructure Systems

In order to provide the reader with a basic understanding of the infrastructure systems at airports, each of the systems in the previous list will be briefly described, including the purpose of the system, the components that make up the system, and some basic maintenance practices. An airport may not have one or more of the infrastructure systems described here or may have a system that looks slightly different from the one pictured. The purpose is to introduce the reader to the system and provide a basic knowledge of what the system does and what maintenance may be required to keep the system operating properly. A more detailed description of the recommended maintenance practices is contained in the guidebook that accompanies this primer and is intended for the use of airport management and maintenance personnel.

Airfield Electrical Vault

The airfield electrical vault (see Figure 3.2) houses the equipment necessary to power the airfield electrical components, including runway and taxiway lights, signs, and visual and navigation

Figure 3.2. Airfield electrical vault. Source: Delta Airport Consultants, Inc.

aids. Building construction typically consists of precast concrete, cement blocks, or prefabricated steel. Older vaults may be of wood-frame construction. The electrical vault may also consist of a separate room in another building, such as the terminal or a maintenance building. The vault may be air conditioned or heated to help stabilize the internal temperature throughout the year. Maintenance of the vault generally consists of periodic inspections of the overall condition of the building, routine painting, and maintenance of the air conditioning and heating systems. Maintenance of the electrical equipment in the vault is discussed in the sections related to the relevant airfield electrical systems.

Airfield Lighting

Runway and taxiway lights (see Figure 3.3) are used to designate the boundaries of the runways and taxiways at the airfield. The lights may be either mounted on posts of various lengths or may be installed flush with the pavement, depending on where the lights need to be located. The color of the light indicates its purpose; for example, blue lights designate taxiways. Each light is connected to an individual transformer located underground that reduces the main-line power to the voltage and amperage required by the light. Maintenance of the lights includes the replacement of bulbs, cleaning of glass domes, clearing grass and weeds from around the lights, and testing the cable feeding power to the lights. Testing of the

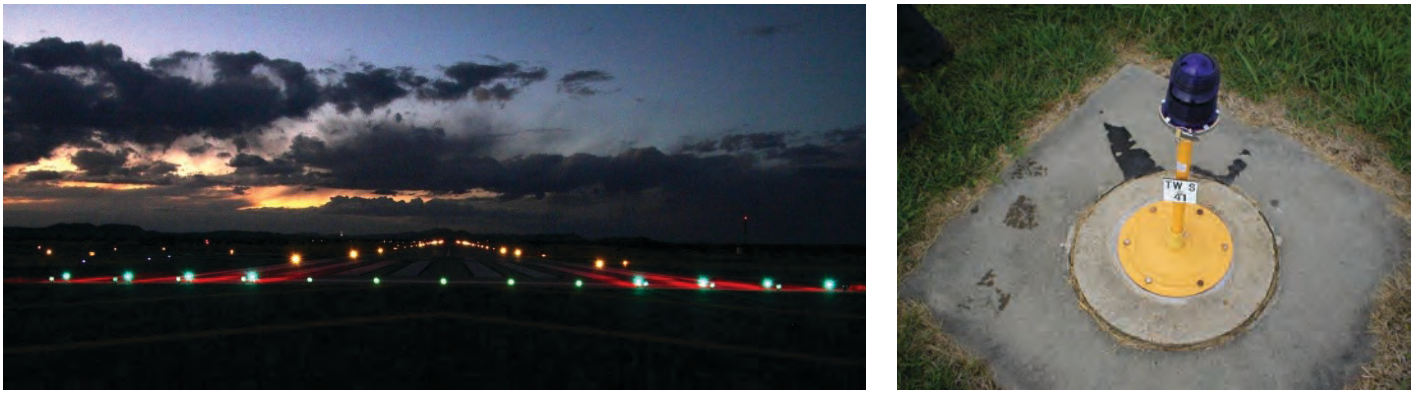


Figure 3.3. Airfield lighting. Source: Delta Airport Consultants, Inc.

electrical equipment located in the electrical vault is normally accomplished at the time the electrical cables to the lights are tested.

Airfield Signs

Airfield signs are used to indicate to pilots where they are located on the airfield and give directions to runways, taxiways, and other areas of the airport. The sign depicted in Figure 3.4 indicates that the pilot is on Taxiway C and is at the hold line waiting to enter or cross Runway 3-21. As with runway and taxiway lights, the colors of the sign panels convey specific meanings to the pilot. The power to the signs is supplied by individual transformers located underground, similar to the transformers used for runway and taxiway lights. Maintenance of the signs includes clearing the area around the signs of high grass and weeds, cleaning of the plastic sign faces, bulb replacement, and testing of the electrical cables and transformers supplying power to the signs.

Airfield Visual and Navigational Aids

Airfield visual and navigation aids (see Figure 3.5) include the airport rotating beacon, approach lighting systems, runway-end identifier lights (REILs), and visual glide path indicators such as precision approach path indicators (PAPIs) and visual approach slope indicators (VASIs). All of these systems are intended to aid the pilot in finding the airport, locating the runway, and making a safe approach to the runway. Required maintenance actions are dependent on the type of system but generally involve the clearing of high grass and weeds from around the system, bulb replacement, testing and maintenance of the electrical wiring, cleaning of any lenses, any calibration required for the system, and preservation and repainting of the metal structures supporting the navigational aids. Some airports have automated weather systems such as automated weather observing systems (AWOS) or automated surface observing systems (ASOS), which are typically maintained through specialized contracts and, therefore, are not covered in this report.

Airfield Pavements

Airfield pavements (see Figure 3.6) include all runways, taxiways, taxi lanes, and aircraft parking aprons. These pavements will be constructed of either asphalt or concrete. It is critically

Figure 3.4. Airfield sign. Source: Delta Airport Consultants, Inc.

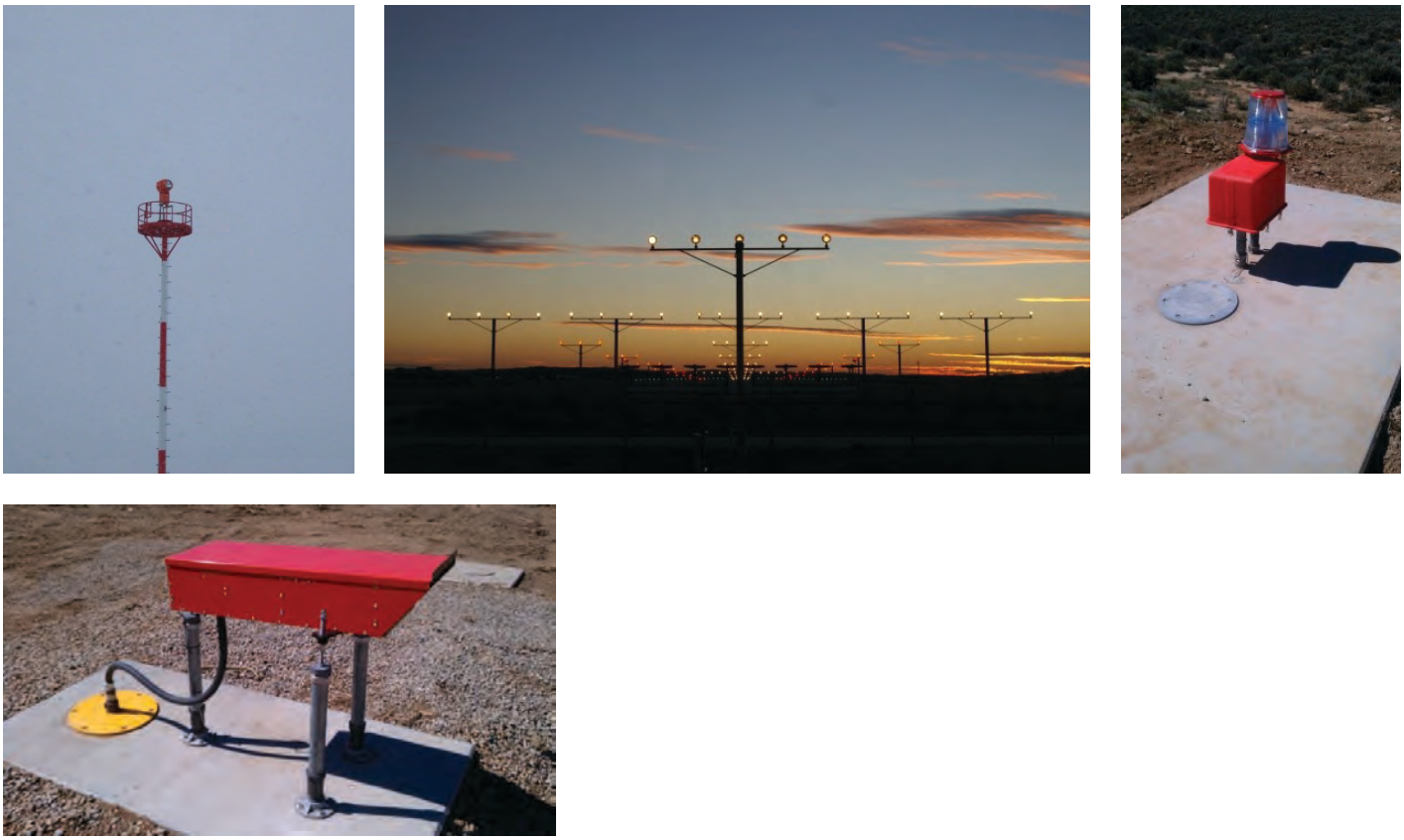


Figure 3.5. Airfield visual and navigation aids. Source: Delta Airport Consultants, Inc.

important to the safety of aircraft that these pavements be maintained in good condition. Unlike automobiles, most aircraft do not easily accommodate even relatively minor flaws in pavement surfaces. Any damage or deterioration of these pavements could result in severe damage to aircraft engines and propellers and could cause injury to personnel from loose debris thrown by a spinning propeller. There are many types of pavement distress and preventive maintenance treatments that are discussed in more detail in the guidebook in Volume 2 for airport managers

Figure 3.6. Example of airfield pavements. Source: Delta Airport Consultants, Inc.

and maintenance personnel. Pavement maintenance generally consists of periodic sweeping of the pavement, sealing of cracks, and various types of surface sealing to slow or counteract the effects of environmental conditions. In more severe cases, milling and overlay of the surface with new pavement may be required.

Airfield Markings

Airfield marking (see Figure 3.7) consists of the painted lines, signs, and designations that appear on the pavements throughout the airport. Their effectiveness (visibility during daylight and darkness) is vital to safe navigation, although they are generally observed only peripherally. Airfield markings are the principal visual aid at general aviation airports, unlike larger airports where signs and lights provide reliable navigation from gate areas to runways. Effective visibility of airfield markings provides situational awareness, distance recognition, and enhanced safety. In general, markings that appear on runways are white, and markings on taxiways are yellow. One notable exception is surface-painted holding-position signs, which are painted on taxiways at the entrance to a runway and consist of white numbers on a red background. The type of markings on a runway is dependent on whether the runway has an instrument approach procedure to guide pilots to the runway during periods of reduced visibility and whether the instrument approach is a precision or non-precision approach. Waterborne paint and glass beads are used at the majority of airports in the United States when pavement markings are installed on runways, taxiways, and aprons. When the materials are applied well, markings can remain effective for a year or more, depending on the airport's environment and its operations. However, pavement markings deteriorate gradually. Preventive maintenance for airfield markings involves periodic, objective assessment of the condition of the markings based on specific attributes that contribute to marking effectiveness and cleaning or repainting the markings when conditions warrant.

Hangars

Aircraft hangars (see Figure 3.8) provide storage for aircraft to protect them from the environment and provide increased security. In addition, hangars are also used as aircraft maintenance

Figure 3.7. Airfield markings. Source: Delta Airport Consultants, Inc.

(a) (b)

(c) (d)

Figure 3.8. Hangar types: (a) shade, (b) T with simple door, (c) T with bi-fold door, and (d) box. Source: Delta Airport Consultants, Inc.

facilities. While hangars come in all sizes and shapes, they generally fall into three categories: shade hangars, T-hangars, and box hangars. Shade hangars consist of a framework with a roof, but no sides or doors. They are intended to help protect aircraft from the effects of the sun, rain, and hail. T-hangars are fully enclosed hangars that connect together in a long row. Each hangar is shaped like a "T" and interlocks with the adjacent hangar. This building style conserves space and is generally only used for the storage of smaller aircraft. Box hangars (also referred to as corporate hangars or open-span hangars) are square or rectangular hangars that generally stand alone and can be constructed to accommodate any size of aircraft. In many cases, these hangars are used to house multiple aircraft in the same hangar. Maintenance of a hangar generally consists of maintaining the structural integrity of the building (walls, roof, etc.), maintaining the doors, which can be quite large and complex and may be electrically or hydraulically operated, and maintaining any utility systems in the building. Larger, more complex hangars may also have heating, ventilation, and air conditioning (HVAC) systems, offices, and restrooms. T-hangars are typically not designed with long-term maintenance in mind and require much attention. Poorly maintained hangars can result in displacing tenants and potentially losing revenue. Also, it is difficult to get government grants to replace hangars.

Terminals and Administrative/Office Buildings

Terminals and administrative-type buildings (see Figure 3.9) at a general aviation airport can range in size from a small, utilitarian building with only a small lobby or common area and restrooms to a large, complex building housing offices, conference rooms, large lobbies, pilot rest areas and flight planning rooms, FBO facilities, rental car facilities, and so forth. The larger and more complex the building is, the more infrastructure systems there are that need to be maintained. In addition to the normal structural items that require preventive maintenance, such as roofs, doors, and windows, periodic maintenance may also be required on various utility systems, such as those for electricity, plumbing, HVAC, sprinklers, security, landscape irrigation, and, possibly, emergency generators. In some cases, airport maintenance personnel may be able to properly perform preventive maintenance on these systems; however, it may be necessary for the airport to negotiate contracts with local companies for required system maintenance that is beyond the capability of the airport staff.

Maintenance and Storage Buildings

Maintenance and equipment storage buildings (see Figure 3.10) will vary in size and complexity depending on the intended use of the building. They may be similar in function and design to a simple aircraft hangar or may incorporate offices and workrooms that require plumbing, electrical, and HVAC systems similar to those of an office building. In addition, maintenance buildings may also have vehicle lifts, overhead cranes, or other maintenance equipment installed that have specialized power requirements. There may also be the need for an area to store hazardous or flammable materials or the need for a fire suppression system. Maintenance of these buildings will be similar to a comparably equipped hangar or administrative building.

Fueling Facilities

Fueling facilities (see Figure 3.11) vary greatly from airport to airport. The size and makeup of the facility is dependent on the amount and type of fuel sold. The fuel tanks may be either above ground or underground and may be configured with credit card readers and hose reels so as to allow pilots to self-fuel their aircraft. The most common sizes of tanks being used at general aviation airports are 10,000- and 12,000-gallon tanks, but much larger tanks may be installed if

Figure 3.9. Terminals and administrative/office buildings. Source: Delta Airport Consultants, Inc.

Figure 3.10. Maintenance (left) *and storage* (right) *buildings. Source: Delta Airport Consultants, Inc.*

the amount of fuel being sold warrants it. Maintenance requirements will be specific to the type of system and manufacturer but generally consist of inspecting the integrity of the tanks and piping, sumping the tanks to remove water and contaminants, replacing fuel filters, lubricating the pump assemblies, inspecting the containment areas, and pressure testing hoses and fuel nozzles. Fueling facilities typically must be licensed by municipalities, and federal law requires a stormwater pollution prevention plan (SWPPP) and spill, prevention, control, and countermeasure plan (SPCC).

Deicing Facilities

Deicing of aircraft is performed as part of winter operations at many airports across the country. Deicing facilities provide an area where pilots can have ice and snow removed from their aircraft prior to taxiing to the runway for takeoff. The deicing chemicals mix with precipitation and may be collected by the airport's stormwater collection system. Depending on the amount of deicing done at the airport each year, the deicing facility may need to monitor the stormwater concentration for compliance with the applicable discharge permits for the airport or collect the

Figure 3.11. Fueling facility. Source: Delta Airport Consultants, Inc.

deicing fluids and ice and snow that are removed from the aircraft and provide for their proper disposal. *ACRP Report 72: Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials* provides a process for identifying and selecting methods to monitor stormwater that is subject to runoff containing deicing materials. In most cases, the maintenance of the deicing facility consists of normal pavement maintenance and the maintenance of the stormwater drainage system, which will be discussed later in the chapter.

Landside Infrastructure

Landside infrastructure (see Figure 3.12) consists of those facilities that are used to provide access to the airport by the general public. This includes access roads, automobile parking lots, parking lot access control systems, and lighting systems. The paved areas (roads and parking lots) will face the same circumstances and have similar maintenance requirements as the airfield pavements discussed earlier. The same is true for the markings painted on the roads and parking lots—they will need to be maintained in much the same fashion as the airfield markings. Due to the priority placed on airfield pavements by the FAA and many state aviation agencies, it is not unusual to see access road and parking lot maintenance deferred due to a lack of available maintenance funding. While the priority of airfield pavements is understandable, the repair or replacement of access roads and parking lots may be no less costly, and preventive maintenance of these pavements should not be ignored. If entrance to the parking lots is controlled through some type of electric gates, then they will need to be inspected and maintained in accordance with the manufacturer's operating and maintenance manuals. Road and parking lot lighting systems are much simpler and straightforward than airfield lighting systems. In most cases, maintenance of these lighting systems consists of inspecting the light poles for damage from vehicles and replacement of the lightbulbs and any photocell sensors when they have failed. However, due to the height of the light poles, it will most likely be necessary to use a bucket truck to replace the bulbs. Therefore, the airport may need to enlist the aid of the municipality's public works department or hire a local electrical contractor to perform bulb replacement.

Airport-Owned Utilities

In some circumstances it may be necessary for the airport to own the utilities at the airport and serve as the vendor of those utilities to airport tenants. This may include utilities such as water when the airport owns the well supplying water to the airport, water storage tank (see Figure 3.13),

Figure 3.12. Landside area of the airport. Source: Delta Airport Consultants, Inc.

Figure 3.13. Airport water storage tank.
Source: Delta Airport Consultants, Inc.

sanitary sewer lines or septic systems, electric power if it is produced from a power generating system on the airport, or a fiber-optic cable system for Internet connectivity. In any case, the airport takes on the responsibility of a utility company and must provide uninterrupted service to airport tenants. Some utilities, such as water systems, are more maintenance intensive than others and may require detailed recordkeeping showing that the airport is meeting the regulatory requirements for that particular utility. If the airport staff are properly trained in the maintenance of the system, the airport may be able to perform all of the required maintenance. If not, it may be necessary for the airport to enter into a contract with another company to provide the required maintenance to the system.

Obstructions to Imaginary Surfaces

The FAA has designated specific areas surrounding airports that are to be kept free of obstructions in order to enhance the safety of aircraft flying into and out of the airport. These areas are referred to as "imaginary surfaces" and are based on 14 Code of Federal Regulations (CFR) Part 77. Most of these surfaces begin at ground level and gradually slope up and away from the airport's runways at various rates depending on the designation of the imaginary surface. It is the responsibility of the airport owner to keep these surfaces clear of obstructions. The most common obstructions are trees, towers, and buildings in the vicinity of the airport. In those cases where the obstruction cannot be removed, for example a building on property that the airport does not own, the FAA strongly encourages the airport to provide obstruction lighting

Figure 3.14. Trees obstructing transitional area of a runway. Source: Delta Airport Consultants, Inc.

on the building to make it more visible to pilots at night or in reduced visibility conditions. The airport should maintain the property it owns in a manner that precludes shrubs and trees from growing to a height where they would become obstructions. The airport is encouraged to enter into agreements with adjacent landowners to remove obstructions on the landowner's property or light the obstruction in accordance with FAA recommendations. Municipalities should adopt a zoning ordinance to protect the airport. Airport obstructions that are hazards can adversely affect the runway length or restrict instrument operations (see Figure 3.14).

Fencing and Gates

Airport fencing generally serves two purposes—to prevent wildlife from entering the airport and becoming a hazard to aircraft and to secure the airport from unauthorized entry by persons or vehicles. The type and size of fencing used will vary according to its purpose. The most common types are chain-link fencing for security purposes and wildlife fencing to control the entry of larger animals. Frequently, barbed wire will be installed on the top of chain-link fencing to prevent people from climbing over the fence. Gates (see Figure 3.15) are normally provided at

Figure 3.15. Airport fencing and gates. Source: Delta Airport Consultants, Inc.

strategic locations to allow pedestrian or vehicular entry to the airport. Various security devices and opening systems are used to provide access to authorized persons and automatically open and close the gates. Electrically operated gates are most commonly used for vehicular access. Common maintenance practices include the inspection of the fences for damage or evidence of animals burrowing under the fence, lubrication of gate fittings, and lubrication and maintenance of electrical opening devices.

Drainage

Airports need to provide adequate drainage for large amounts of land to ensure that the pavements remain free of standing water and that no flooding occurs during heavy rain events. These drainage systems (see Figure 3.16) could be as simple as ditches and culverts draining the water off the airport property or as complex as underground storm drainage systems with detention ponds and outlets designed to release water at a predetermined rate. In addition, the drainage systems need to take into consideration the security requirements of the airport and not provide a means of access for animals or unauthorized personnel. Drainage systems must provide for a free flow of water to prevent ponding that could attract wildlife such as birds and small mammals. Maintenance requirements include the cleaning or mowing of drainage ditches, cleaning of inlets and outlets of culverts and stormwater systems, and maintenance of security devices to prevent unauthorized access to the airport. It is poor practice to overlook maintenance of drainage systems until they are clogged.

Turf and Safety Areas

Turf areas (see Figure 3.17) include any area of an airport upon which grass or some form of vegetation (other than trees and shrubs) is intentionally grown. In some cases, the turf may be irrigated to maintain the health of the turf and encourage growth. Turf areas may be carefully landscaped for the sake of appearance, such as around terminal or administrative buildings or along the airport access road, or may simply be permitted to grow in a more natural state, such as in safety areas or more remote areas of the airport. The type of vegetation planted must be

Figure 3.16. Drainage. Source: Delta Airport Consultants, Inc.

Figure 3.17. Turf area. Source: Delta Airport Consultants, Inc.

carefully selected so as to avoid varieties that produce seeds or any type of berry that will attract birds or small mammals. In all cases the height of the turf must be controlled by cutting or the application of growth inhibitors to discourage wildlife from entering the airport and establishing unwanted and potentially harmful colonies that could threaten the safety of aircraft. In addition, turf areas should be periodically inspected for the presence of burrowing animals that may attract larger predators onto airport property. The removal or eradication of certain types of burrowing animals may require a permit from state or federal wildlife agencies. Runway and taxiway safety areas should be maintained per FAA standards to protect the airspace and provide for aircraft that may overshoot/undershoot the pavement.

Maintenance Equipment

Airports use a variety of maintenance equipment (see Figure 3.18) to ensure that the airport remains operational and that the airport grounds are properly maintained to reduce wildlife attractants and enhance the safety of aircraft operating at the airport. This equipment may

Figure 3.18. Example of maintenance equipment. Source: Delta Airport Consultants, Inc.

include mowers, tractors, snowplows, snowblowers, backhoes, front-end loaders, and various smaller pieces of equipment used to maintain the landscaping. The maintenance of this equipment is specific to the piece of equipment and the manufacturer. Airport personnel should refer to the operations and maintenance manuals provided with the equipment to determine the appropriate maintenance actions to be performed and the maintenance schedule to follow. Personnel should be trained to operate in the complex airfield environment before being allowed to work independently.

Airport Vehicles

Airport vehicles include any cars, pickup trucks, all-terrain vehicles, and gas or electric carts that the airport may use for general transportation and light maintenance duties. As with the maintenance equipment, maintenance of these vehicles is specific to the vehicle and manufacturer, and airport personnel should follow the recommendations found in the vehicle's operations and maintenance manuals.

CHAPTER 4

Preventive Maintenance—An Overview

4.1 Introduction

Major facilities such as large manufacturing plants with a considerable amount and diversity of expensive equipment have formal maintenance programs and require a wide variety of types of maintenance, including preventive maintenance. General aviation airports generally do not have this same degree of focus on preventive maintenance due to a lack of awareness of what it involves and resource limitations. Therefore, it is important that airport policy makers and airport management officials have an appreciation of what preventive maintenance is, its importance, and how to go about developing and implementing a program at their airport.

Previous chapters in this primer discussed the value of a general aviation airport and gave an overview of the types of infrastructure at an airport. This chapter provides an overview of preventive maintenance for general aviation airports. It will answer questions such as:

- What is preventive maintenance and how does it relate to other types of maintenance?
- Why is preventive maintenance important and what is its value?
- What entities are involved with preventive maintenance?
- How does preventive maintenance relate to other airport plans and programs?

Chapter 5 will provide information about the development and implementation of a preventive maintenance program for airports. The companion guidebook will provide more detailed information and tools to help airport staff execute a program.

4.2 What Is Preventive Maintenance?

Most airports perform some type of maintenance on their facilities. Generally, the conditions of runways and airfield lighting systems are monitored every day by someone. If there is loose pavement on the runway, a light is not working, or a hangar door will not open, someone quickly addresses the problem. However, few airports have comprehensive preventive maintenance programs that include the regular assessment of the condition of infrastructure systems and scheduled maintenance of the many components of each airfield system.

The maintenance of general aviation airports is frequently divided into the following types:

- **Operational.** There are certain aspects of operating an airport that require maintenance activities due to weather, environmental conditions, and electrical/mechanical manufacturer's calibration of equipment. Snow and foreign objects must sometimes be removed from pavements. Lighting systems and approach aids for pilots must be calibrated. These are examples of operational requirements that require maintenance activities and may have an impact on the condition of infrastructure. These types of operational activities are generally driven by

regulatory and airfield safety requirements and are discussed in detail in sources such as FAA Advisory Circulars. Operational maintenance will not be a subject of this primer.

- **Reactive.** Reactive maintenance is basically characterized by an attitude of use it until it breaks or fix it when it breaks. A perceived advantage to this type of maintenance is that manpower and capital costs are not incurred until something actually breaks. The reality is that many general aviation airports are primarily in a reactive mode and are spending more dollars to repair equipment than they would be spending with a preventive maintenance approach. While waiting for something to break (e.g., an HVAC unit), the life of the equipment is shortened, resulting in earlier replacement. This results in an increased capital cost in the long run. Also, some facilities do not break in a traditional sense, and their outright failure can have a significant impact on an airport's mission. For example, joints in a runway pavement that are not kept sealed can result in water seeping into the pavement base structure, eventually causing serious pavement failure. This might require expensive rehabilitation or replacement of pavement systems. Simply reacting to this type of failure is not acceptable to the airport user or the airport's budget. Reactive maintenance is poor customer service and can result in damage to aircraft. Airports cannot staff or plan for reactive maintenance. Multiple system failures will reduce staff availability, affect services provided to tenants and customers, reduce revenue, and may even require closure of the airport.
- **Preventive.** Preventive maintenance can be defined as those actions performed to detect, preclude, or mitigate the degradation of an infrastructure system or its components. Preventive maintenance involves routine scheduled activities intended to keep a system performing at its best and has the goals of preventing the system's breakdown and extending its useful life. Preventive maintenance has several advantages over a reactive program. By performing preventive maintenance on a facility as envisioned when it was designed, the full design life of the facility may be realized. Preventive maintenance (e.g., lubrication, filter changes, sealing pavement joints) will generally help equipment run more efficiently and will ensure that infrastructure functions more safely and efficiently. This results in reduced costs and improved user satisfaction. Airports can plan and assign staff appropriately by applying scheduled preventive maintenance.
- **Predictive.** Predictive maintenance is an approach that involves testing and monitoring of equipment and facilities to detect symptoms that are out of specification and, thus, predicting potential failures. This approach is especially useful for vehicles and equipment. Some airports use a mix of preventive maintenance and predictive maintenance standards to ensure minimal impact on the operational capability of the airport. For purposes of this primer and its companion guidebook, preventive maintenance will include certain aspects of predictive maintenance.

4.3 Why Is Preventive Maintenance Important?

As indicated previously, one of the purposes of PM is to extend the life of a facility and avoid incurring capital replacement costs prematurely. This allows capital funds to be available for other projects such as improvements or expansion rather than required rehabilitations or replacements. For this reason and many others, it makes good sense for airports to adopt a PM program. These reasons are discussed in the following and include safety, economics, reduction in energy usage, system longevity, legal/regulatory issues, environmental impacts, and community marketing.

Safety. Airport maintenance directly contributes to keeping airports and their facilities safe for users. Pilots expect pavements to drain well and expect clear approach paths, legible pavement markings, and reliable airfield lighting systems. Preventive maintenance helps ensure that

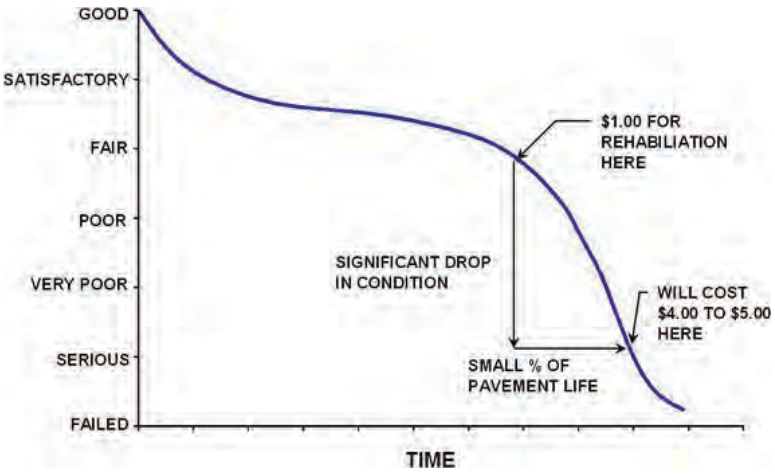


Figure 4.1. Typical pavement life cycle. Source: FAA Central Region, Guidance—Airport Obligations: Pavement Maintenance.

those systems used by pilots are functioning properly. Similarly, well-maintained fueling facilities and airport vehicles help improve safety for their users.

Economics. Preventive maintenance extends the life of facilities and avoids costly and early replacement or rehabilitation. Preventive maintenance may result in the identification of the need for timely rehabilitation before a system fails or before more costly rehabilitation is needed. An example of this is with pavement rehabilitation. Pavement performance and the economic impact of no preventive maintenance or waiting too long for rehabilitation are shown in Figure 4.1.

Another example of how a poorly maintained facility can adversely affect an airport's financial well-being is a hangar that is rusted so badly that aircraft cannot be stored in it, resulting in lost hangar rental revenue (See Figure 4.2).

The other reasons discussed here for preventive maintenance have an economic effect too. An aircraft or personal accident related to poor airport maintenance is not only tragic but can be costly to the airport owner. Increased energy usage caused by poorly maintained electrical systems is also costly. An airport that is so poorly maintained that it drives away a corporation that wishes to base an operation there results in an adverse economic impact on the community from loss of jobs and tax revenue.

Figure 4.2. Rusted hangar not usable for aircraft storage. Source: Delta Airport Consultants, Inc.

It is difficult to quantify the specific monetary value of preventive maintenance for all infrastructure. The type of maintenance, the nature of the infrastructure, and various components of each system vary widely (e.g., roof, HVAC, motors, door hinges, pavement joints, drainage swales). However, the value of preventive maintenance is generally intuitive. For example, pavements typically last their design life of 20 to 30 years if properly maintained. Proper maintenance may include surface treatments every few years, which over the design life might total $1 million, followed by a major rehabilitation or reconstruction at the end of the life, which could cost $2 million to $5 million for a general aviation airport runway. If the surface treatments are not done over the life of the pavement, a large rehabilitation or reconstruction would likely be needed at 10 to 15 years. So, over the course of the life of the runway, the additional cost would be $2 million to $5 million for the premature failure of the pavement caused by the lack of preventive maintenance. A roof can also be used to demonstrate the value of maintenance. The cost of maintaining a roof is often much less than letting a roof prematurely fail, causing interior building damage and possible adverse impacts on the customer. This is particularly true in the earlier years of a roof's life, but late in a roof's life it may be more cost-beneficial to replace the roof.

Reduction in Energy Usage. Poorly maintained electrical and mechanical systems lead to increased use of energy. Airfield lighting systems with aging cable and loss of energy drive electrical bills up. This can be managed through an effective preventive maintenance program. Similarly, poorly maintained HVAC units or weatherproofing in a general aviation terminal building will increase energy costs. These excess energy costs are ongoing and can become significant over time.

System Longevity. The life of many airport infrastructure systems can be extended with proper preventive maintenance. Examples of PM in this area are pavement crack sealing, servicing HVAC equipment, regular oil changes for airport vehicles, checking and replacing airfield lighting isolated transformers, greasing hangar door components, and keeping drainage swales free of debris so pavements can drain properly.

Legal/Regulatory Issues. There are legal, regulatory, and contractual reasons for preventive maintenance. Airport owners wish to reduce their liability and risks, and good preventive maintenance of facilities can help in this regard. Tenants with leases of airport land or hangars expect well-maintained airport facilities, and often the lease itself addresses the airport owner's responsibility. State and federal capital improvement grants include contractual obligations that require airport owners to keep the airport safe, operational, and well-maintained. FAA grants specifically require airports to have a pavement preventive maintenance program. FAA grant assurances become airport obligations when airports accept federal funds for airport development. Grant obligations require airport improvements to be maintained for their design life, typically 20 years. Failure to comply with grant assurances can significantly affect an airport's ability to receive future federal funds.

Environmental Impacts. Some airport infrastructure can adversely affect the environment if not well-maintained. Examples include drainage systems that start backing up and allow poor-quality runoff to environmentally sensitive areas. Fuel leakage from poorly maintained fueling facilities will harm the environment. Most communities and states have environmental regulations that directly affect aspects of an airport's preventive maintenance requirements.

Community Marketing. An airport is often the front door to a community. If it is well-maintained and attractive in appearance, it conveys a message that the community protects its investments and cares about those who use its facilities. Businesses deliberating about where to base themselves not only look at location and the ability of the airport to serve their needs but also consider the condition of the airport.

4.4 What Entities Are Involved with Preventive Maintenance?

Preventive maintenance is not simply a program or responsibility placed on the shoulders of the airport manager to handle alone. Other entities help with direction, resources, and knowledge. Preventive maintenance is the joint responsibility of the airport owner (e.g., city/county), policy-making board, airport manager, and airport maintenance staff. Although airport management typically makes recommendations or requests certain resources, the airport owner and policy-making board normally approve the budget and other resources for a preventive maintenance program. Airport management and staff then execute the program.

Airports owned by a city or county typically have access to non-airport resources for some maintenance activities. These activities include motor vehicle fleet maintenance, use of public works staff to help maintain HVAC or buildings, and routine maintenance such as lawn mowing and cleaning ditches. Airport staff typically focus on those tasks related to airport-unique systems such as airfield lighting. Use of municipal staff may not always be the best option for the airport. Other departments often charge for services, may have higher non-airport priorities, and may not provide the same level of service as airport staff.

State departments of transportation and aviation offices may be able to help with some maintenance activities. Some states have robust programs to help airports; others are unable to do much other than provide guidance. A strong state/airport partnership can help significantly with an airport maintenance program. These partnerships include a state funding program, advisory help, and an active state presence by state officials through an inspection program. Following is a list of some of the activities that states may offer to help general aviation airports with their maintenance programs.

- State airport inspections.
- Grant programs that include eligible maintenance work.
- Development of a formal pavement management plan with specific goals and funding to improve pavement condition.
- Supporting airport efforts to gain FAA funding for work such as pavement and lighting rehabilitation.
- Providing airports with a fixed amount of funds each year to use for the maintenance of facilities.
- State purchase of crack-sealing equipment for airports to use.
- State-sponsored training for airport staff. Examples include pavement maintenance and stormwater management.
- Statewide contracts for activities such as airfield marking, pavement joint sealing, and airfield electrical repairs. Doing this on a statewide basis helps to reduce the cost for individual airports.
- Combining the maintenance work of several airports under a single FAA grant coordinated and sponsored by the state. An example is rehabilitation of rotating beacons at several airports in the state.
- State aviation office coordination with other state agencies for the use of equipment to perform maintenance activities at airports.

The FAA Airport Improvement Program is limited in what it can fund for airport maintenance. The work that is eligible for funding depends on current congressional authorization and is normally limited in available funding. Projects such as needed pavement and lighting rehabilitation may also be eligible. Airports are encouraged to work with both their FAA and state aviation offices to determine how they may get help.

Tenants and airport users can be important sources of information about the condition of facilities. A tenant that rents an airport-owned hangar should be encouraged to let airport management know when some aspect of the hangar needs attention—for example, bearings on a door that are becoming noisy. However, airport management still needs to make periodic inspections of the hangar. Airports should have a process whereby pilots can report conditions to the airport through the fixed-base operator servicing them.

Consultants help airports with engineering design and preparation of plans and specifications for the more complex maintenance work. Consultants can also provide help to airports in setting up an airport maintenance program.

4.5 Strategic Planning

The primary goals of airports include to (1) provide airport users and tenants with the facilities they need, (2) keep the airport open and safe, (3) operate the airport in an economically efficient manner, and (4) make the airport an asset to the local community. These goals are reflected in the airport's strategic plans and programs, all of which have an influence on the airport's preventive maintenance decisions.

Airport master plans and airport layout plans provide the short- and long-term development plans for the airport. These plans can help decision makers determine what facilities need to be maintained. For example, if the plan is to construct a new terminal building in 2 years, perhaps minimal preventive maintenance would need to be done on the existing terminal building. Master planning should reflect considerations for additional capacity needs of the airport and whether it makes sense to maintain a facility if it will soon need to be removed to build another facility in its place. As another example, if an aircraft apron needs a surface treatment but will also soon need additional pavement strength with an overlay, it may be wise to not do the surface treatment and wait for the overlay.

Some airports adopt a business plan that may include non-aeronautical uses of airport surplus property such as an industrial park. These plans can influence decisions about who will maintain certain infrastructure such as access roads. An example of how a business plan might affect an airport's preventive maintenance program is a 5-year plan to build an airport restaurant adjacent to the terminal area parking lot. This would likely strengthen the need to keep the parking lot well-maintained so as to preserve its life for future use by both the airport and restaurant. Airport business plans include information about expected revenues from leases, tie-downs, and hangar rentals. Another example of how this plan might influence a maintenance program is the use of excess apron. If an airport has a large unused World War II surplus aircraft parking apron and no likelihood of its use, there is little need to incur preventive maintenance costs for it.

An airport capital improvement plan identifies an airport's plan for future development projects and typically includes a funding breakdown for local, state, and federal contributions. This plan would provide information about the airport's future financial challenges that will create competition with airport operational and maintenance costs. Airport maintenance staff should participate in the development of an airport's capital improvement plan. The plan should reflect life-cycle cost considerations (see Section 5.5 of this primer).

An airport's wildlife management plan may indicate the need for frequent cleaning of drainage ditches to avoid the ponding of water and attraction of birds. This plan would indicate the need to increase funding for this activity in the airport's preventive maintenance program. Another maintenance need for wildlife management plans would be to inspect and repair openings in or beneath the fencing.

Airports should do strategic planning when developing their annual budgets for preventive maintenance. This would include consideration of what the previously discussed plans indicate about the future use of infrastructure. Also, life-cycle considerations would help indicate the need for preventive maintenance. For example, a good seal coat might help extend the life of an aging pavement for a few years, thus postponing the need for an extensive rehabilitation.

Strategic planning may also include an analysis of resources needed for the operation and maintenance of the airport. This may include assessment of the benefits of hiring dedicated staff versus relying on part-time help from other departments. Dedicated staff often take much greater pride in the airport. Public works or utility departments often take on airports as an added or peripheral responsibility.

CHAPTER 5

An Airport Preventive Maintenance Program

5.1 Introduction

Previous chapters provided the reader information about airports, their infrastructure systems, and PM in general. Chapter 5 provides a road map for the development and implementation of a preventive maintenance program for an airport. For airports with minimal or no preventive maintenance programs, suggested steps to develop a preventive maintenance program are discussed in this primer and include those in Figure 5.1.

Throughout development and execution of a preventive maintenance program, important stakeholders such as maintenance staff, policy makers, tenants, and users should be educated and involved as appropriate. Key policy makers need to adopt the program.

5.2 Principles of a Preventive Maintenance Program

There are certain principles that help guide the development of an airport's preventive maintenance program. These principles provide direction to an airport that has no program and help airports evaluate and improve their existing programs.

1. The preventive maintenance program should be planned, developed, and executed with a focus on the very reasons for having such a program. These reasons were discussed in Chapter 4 and include keeping the airport as safe as possible, preserving and increasing system longevity as economically as possible, meeting legal and regulatory requirements, mitigating negative environmental impacts, and embracing the notion that the airport is the front door to the community.
2. Maintenance objectives need to be fully integrated with the airport's overall objectives, mission, and plans. In other words, PM cannot be done independently or in a vacuum without consideration for the operational needs of the airport or the airport's capital improvement plans. For example, a decision to reseal runway pavement joints should factor in future plans for major runway rehabilitation as well as the need to keep the runway open to users.
3. Maintenance objectives and standards should be established for each facility. These standards should include both a periodic condition assessment and regular maintenance activities with schedules, checklists, tracking, and recordkeeping.
4. Appropriate resources should be committed to perform the preventive maintenance. This includes funding, time, personnel, equipment, tools, and materials. Maintenance staff and departments should be well-organized, and all preventive maintenance activities and follow-up needs should be reported and tracked. Staff should be appropriately trained and fully understand their responsibilities. This includes training related to job safety and hands-on maintenance skills.

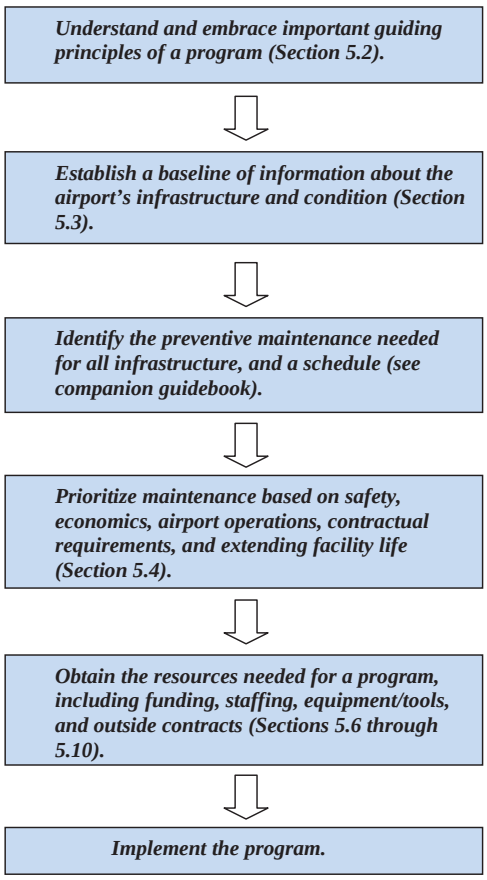


Figure 5.1. Steps to develop or improve a preventive maintenance program.

5. Airport management should include maintenance personnel in the early stages of decision making when purchasing major equipment or designing new infrastructure. Maintenance personnel can help ensure that systems are designed and constructed to facilitate effective maintenance, recurring maintenance costs are minimized, and facility life is as long as it can reasonably be.
6. The PM program should include those activities and resources necessary for the airport to comply with local, state, and federal regulations. For example, there are environmental regulations, fuel storage regulations, airport operation regulations for 14 CFR Part 139 certificated airports, federal labor laws, local permits, and many other local, state, and federal requirements that need to be met.

5.3 Facility Condition Assessment

When establishing a new PM program for an airport, the facilities should first be inventoried and their condition assessed. Airport management needs to be familiar with the airport's infrastructure systems, their components, condition, and expected life before failure. There are well-established criteria for assessing and documenting the condition of pavements, but to-date there has been little formal guidance for other types of infrastructure systems. The guidebook that accompanies this primer provides detailed information about how to assess the condition of infrastructure systems. Once a PM program is established, a facility condition assessment should

be a regular activity. For example, building roofs should be inspected not only at the beginning of a new PM program, but twice a year, looking for blistering, plugged drains, and damage from adverse weather.

In Chapter 3, a brief description was given of 19 infrastructure systems that may exist at airports. The condition of each of these systems should be assessed when establishing a new PM program. In some cases the assessment may be as simple as a visual inspection of the system (e.g., airfield markings). In other cases, such as with terminal buildings, the assessment will be much more complex and may involve the assistance of contractor personnel to evaluate the condition of HVAC, electrical, and plumbing systems. The guidebook provides a description of the components in each of these infrastructure systems and provides inspection checklists that may be used to assist in the evaluation of these systems. However, assets such as HVAC systems, roofs, buildings, and pavements may require the help of professionals to assess their condition.

Airport management may wish to focus the initial assessment efforts to establish a preventive maintenance program on the critical assets. These are the assets that, if they failed, would have a significant impact on safety at the airport or the airport's ability to serve users. Each airport will have to determine its own critical assets, but they typically include the primary runway system, the major taxiway(s) system, the parking apron, the terminal building, and access roads.

5.4 Prioritizing Preventive Maintenance

The cost of preventive maintenance and major rehabilitation of systems often exceeds available funding. Airport management and policy makers should use an objective process to help set priorities for maintenance activities and projects. To make cost-effective decisions between full replacement and continued maintenance of facilities such as HVAC systems in buildings, managers can use tools like a life-cycle cost consideration. Also, prioritization should reflect considerations such as:

- **Safety.** Daily inspections and maintenance should ensure that the airport infrastructure is safe for pilots and other airport users. This should be a top priority.
- **Operations.** There should be a focus on the most critical assets first. For example, work on a major runway should have a higher priority than work on an infrequently used taxiway or apron.
- **Economics.** Evaluate the cost that may be incurred if PM is delayed. For example, an overflowing ditch may be causing damage to adjacent pavements, so delaying ditch maintenance may result in an increased cost to repair pavement or edge lighting damage.
- **Contractual Obligation.** Leases with airport users typically have requirements that the airport owner will properly maintain facilities owned by the airport. For example, an aircraft owner fully expects to be able to open the hangar door. Also, the state/federal grant obligations requiring that pavement and other facilities must be maintained need to be taken seriously. Future funding for airport projects may be denied if routine PM of existing facilities is ignored, regardless of the reason.
- **Accessibility.** The main access road and the appropriate amount of automobile parking need to be properly maintained so they remain usable.
- **Other.** There are other considerations that airport management might use to help prioritize preventive maintenance. For example, an airport master plan may indicate that the airport has excess aircraft parking apron. Some of this apron may be old surplus apron. The proper decision might be to abandon maintenance actions on the unused apron areas while the airport focuses on other higher priorities.

5.5 Life-Cycle Considerations

Airport infrastructure and the individual components have life expectations that depend on how well they are maintained. A motor on an automated gate will fail if not maintained in a certain manner. Fan belts that show signs of fraying can easily be predicted to fail in the near future. Pavements with unsealed cracks will fail before similar pavements with sealed cracks. At some point, all facilities will reach the end of their economic lives, even those that are well-maintained. One key to an effective PM program is to know when that life span is expected to be reached and to understand if and when specific PM activities can reasonably extend that life or if major rehabilitation or replacement is the better option. For example, underground electrical cable and transformers for an airfield edge lighting system typically last up to 20 years. If the system is 15 years old or older, and frequent failures of sections of the system are happening, it is likely time to plan for wholesale system rehabilitation. Continuous repair of transformers and replacement of burned-out bulbs in lieu of system rehabilitation may not be cost-effective. See Section 4.3 of this primer for additional discussion about the economic benefits of preventive maintenance.

An annual review of the condition of each element of airport infrastructure is recommended, along with development of plans for timely replacement of deficient systems. These plans should be incorporated into budgets and capital improvement plans.

Life-cycle considerations are important when trying to decide whether to maintain, repair, or replace infrastructure. This is especially the case with vehicles, HVAC systems, roofs, and pavements. Questions that airports may wish to consider when deciding whether to continue to maintain or replace infrastructure include the following:

- Is the infrastructure or component near or beyond its expected life?
- Do the facility's reliability and consequences of its failure pose an unacceptable risk?
- Will the continued maintenance costs and repair/rehabilitation costs exceed the cost of replacement?
- Does the facility's performance have a track record of being unacceptable, and will corrective maintenance measures lead to acceptable performance?
- Is additional facility capability or capacity needed, and will replacement of the system provide that?

Key elements to be considered in decision making are not always capital costs. Customer service, user requirements, safety, and the consequences of failure all should be considered when deciding whether to continue with preventive maintenance or replace a system or component.

5.6 Budgeting

Airports need to prepare annual budgets that include the PM program. The budget covers staffing, materials, tools and equipment, spare parts, and any significant local costs for capital projects related to PM (e.g., a new drainage pipe). The annual assessment of the condition of facilities and the periodic PM for infrastructure will provide information to help establish the budget requirements. When entities such as the state or FAA are able to help fund eligible projects, the local share needs to be covered in the budget.

The amount of infrastructure an airport has, the age of facilities, and staffing levels affect the required budget for PM. Airports vary widely in the amount of funding they dedicate to PM. The airport interviews conducted in the development of this report found that these airports dedicated from 6% to 40% of their budget to maintenance. Airports in colder climates and

airports that were financially self-sufficient tended to dedicate more funding to PM than did other airports.

During the course of the airport interviews, a commonly heard statement was "We just don't have enough money to perform the maintenance that needs to be done." This statement is a corollary to the phrase "There's never enough time to do it right, but there's always enough time to do it over." Ignoring or delaying PM indefinitely will never save the airport money in the long run. Poorly maintained equipment and infrastructure will fail sooner and more often than properly maintained equipment. Frequently, the cost of the ultimate repairs is several times more than the cost would have been to perform the PM. Budgeting for and performing PM is an area where the airport simply cannot afford to be shortsighted. There are a number of states with funding programs specifically designated for maintenance at airports. Airports should be aware of these types of funding sources in their state and take advantage of them to the fullest extent possible.

5.7 Organizational Structure and Staffing

How should an airport be organized and staffed to perform preventive maintenance? There is no single answer to this question. Many small general aviation airports handle all airport operations and maintenance with one or two people. Sometimes the airport manager does it all. Large and very busy general aviation airports with several hundred based aircraft in major metropolitan areas tend to have large staffs handling maintenance and operational requirements such as snow removal. Some airports are also able to rely on other resources, such as the city department of public works. However, non-airport department staffs may have other priorities that may affect the level of service provided to the airport.

Whatever staff handle the PM program, they need to be properly trained and competent to perform the job(s). Some airports are able to have specialists that can focus on basic airfield electrical systems, high-voltage systems, vehicle maintenance, building systems such as HVAC and roofs, and turf/drainage. Other airports have the same person do all of this. Regardless, the staff need to be properly trained, have the appropriate work licenses, and fully understand the requirements of working at an airport (i.e., where they can and cannot go on the airfield). Airport management needs to be prepared for the times when key staff retire, depart for other positions, or are simply unable to go to work at critical times to perform PM. Formal checklists, good recordkeeping, and some redundancy in staff capabilities can help in this regard.

5.8 Using Contracts and Other Agencies

Airports sometimes are required or have the option to contract with outside entities to perform routine preventive maintenance work that may be beyond the capabilities of the airport staff. Examples of these activities are HVAC service, herbicide application, equipment/vehicle maintenance, servicing of motorized gates, formal pavement condition assessments, and high-voltage electrical work. In those cases where the airport is owned by a municipality, the airport sponsor might consider including the airport in any applicable contracts that are being let by the municipality. Examples are areas such as HVAC maintenance and vehicle maintenance. Outside contractors are often used for highly specialized navigational facilities such as automated weather observing systems.

In addition, the resources of other agencies may be available to assist the airport with its PM needs. City public works departments were previously mentioned as a possible resource for

assistance. In some cases, the state aviation division may provide resources for airports to use in the performance of their PM. At least one state has purchased crack-sealing equipment that is available to any airport in the state to use. The state provides training on how to use the equipment, and the airport is responsible for purchasing the crack-sealing material. This has resulted in considerable savings and a significant improvement in the maintenance of pavements at airports throughout the state.

5.9 Work Orders and Recordkeeping

Once a PM program has been developed, staff and budget are in place, and schedules of activities and priorities are established, the program is implemented. An important part of implementing a PM program is to use an effective work-order system to keep track of and schedule activities. This system can also be used for follow-up work that is identified from periodic inspections.

Work order and recordkeeping systems range from a simple paper filing system that contains daily, weekly, monthly, and annual inspection forms to a fully automated system such as a computerized maintenance management system (CMMS). There are various commercial vendors that offer CMMS products for airports. The actual system used at the airport will depend on the complexity of the airport and the availability of resources for maintaining the recordkeeping system. If this system is automated, costs can more easily be tracked and trends monitored, and management can easily monitor progress. Also, automation helps with retention of records and preventing knowledge loss due to change in personnel. Regardless of whether a work order system is automated, there is still significant benefit from being able to track schedules and completion of work through even a manual system. As long as the system provides a means to schedule inspections and PM, records the results of the inspections, and can be used to track maintenance and spot trends, it can be an effective tool in a PM program.

Work orders are forms that are used to identify maintenance work (PM or repair work) that needs to be accomplished and record what action was taken to correct the situation, who performed the work and when, and whether any further action is required. They are frequently used in situations where the person who schedules the work or identified the problem is not the person who will perform the actual maintenance. The person completing the work writes what action was taken on the form and returns the form to be filed. Work orders are extremely useful in verifying that PM has been performed and in tracking maintenance actions and spotting maintenance trends.

Recordkeeping systems should include checklists and inspection forms for the airport and each infrastructure system. These checklists should identify the components for inspection and the PM activities that need to be performed. Upon completion of the inspections or completion of a maintenance action, the checklist or work order should be filed in some manner. This may be as simple as placing it in a three-ring binder or filing it in a folder according to the type of equipment worked on or the month in which the maintenance was performed. Automated maintenance records provide a readily available and searchable history of work activities and help with sharing of knowledge from routine inspections or the compilation of maintenance information for reports.

Regardless of the type of recordkeeping system used, recordkeeping is a valuable tool in a PM program. When used properly, it can assist in discovering maintenance trends, formulating future maintenance plans, and justifying the need for maintenance funding.

5.10 Tools and Equipment

A good PM program includes provision of the appropriate tools and equipment needed to effectively perform the maintenance. While the specific type of required tools and equipment will vary from airport to airport depending on the complexity and amount of infrastructure and the climate, general requirements include:

- Hand tools,
- Mowers,
- Weed trimmers,
- Snow removal equipment,
- Maintenance vehicles,
- Maintenance equipment storage, and
- Personal safety equipment for maintenance personnel.

In addition to tools and equipment, airports should maintain an inventory of spare parts for replacement of those items that are normally required as a result of actual or anticipated failure. Examples are airfield lightbulbs, isolation transformers for light fixtures, and fan belts.

CHAPTER 6

Summary

6.1 Key Points

The purpose of this primer is to help airport governing officials, policy makers, airport management and staff, and state aviation officials understand the importance of a preventive maintenance program for airports and gain understanding of what a good program includes.

Airport governing officials and policy makers need to understand the value of their airport and, thus, appreciate the need to maintain and preserve the life of the airport's infrastructure. The value of an airport can be significant to a community because it provides access to the national airspace system and serves the needs of business, the flying public, emergency and medical personnel, aerial firefighters, agricultural concerns, search and rescue organizations, law enforcement personnel, and other users. An airport contributes direct and indirect value to a community by generating jobs, services, and tax revenue.

Although airports are of considerable value to communities, they are expensive to build. A new basic general aviation airport typically costs several million dollars. Replacing failed infrastructure is also costly. Infrastructure at airports includes airfield pavement, runway/taxiway edge lighting, airfield signs, visual and navigational aids, airfield markings, hangars, terminal and administrative buildings, maintenance and storage buildings, fueling facilities, deicing facilities, airport-owned utilities, turf and safety areas, fencing and gates, drainage systems, maintenance equipment, airport vehicles, and landside infrastructure such as automobile parking, access control, roads, and lighting.

Preventive maintenance can be defined as those actions performed to detect, preclude, or mitigate the degradation of an infrastructure system or its components. These actions involve routine scheduled activities intended to keep a system performing at its best, with goals of preventing its breakdown and extending its useful life. Preventive maintenance has several advantages over those of a reactive program. By performing preventive maintenance on a facility as envisioned when it was designed, the full design life of the facility may be realized, thereby saving money.

Preventive maintenance (e.g., lubrication, filter changes, sealing pavement joints) will generally help equipment run more efficiently and will ensure that infrastructure functions more safely and efficiently. This results in reduced costs, improved airport safety, reduced energy consumption, improved longevity of facilities, and compliance with legal/regulatory requirements, and helps the airport owner better market the community.

Suggested steps for developing or improving an airport preventive maintenance program are:

1. Understand and embrace important guiding principles.
2. Establish a baseline of information about the airport's infrastructure and condition.
3. Identify the preventive maintenance needed for each infrastructure system.

4. Prioritize maintenance based on airfield safety, economics, operations, contractual requirements, and extension of the life of each facility.
5. Obtain resources (funding, staffing, equipment/tools, and outside contracts). Ensure that staff are properly trained.
6. Implement the program, using appropriate checklists, work orders, recordkeeping, and the necessary equipment/tools.
7. Keep program up-to-date.

6.2 Where to Go for Help

Preventive maintenance is not simply a program or responsibility placed on the shoulders of the airport manager to handle alone. Other entities help with direction, resources, and knowledge. Preventive maintenance is the joint responsibility of the airport owner (e.g., city/county), the policy-making board, airport manager, and airport maintenance staff. Other city/county agencies can help with resources and expertise. Many state aviation agencies can help with both expertise and grants. Although eligibility is limited, FAA grants can help with some maintenance and rehabilitation of infrastructure. Also, vendors, manufacturers, and airport consultants are good sources of information.

The companion guidebook can help airport management and staff develop and implement a preventive maintenance program. Included on the CD-ROM that accompanies this report are detailed checklists for the preventive maintenance of airport infrastructure systems and a PowerPoint presentation that covers the key points of both the primer and guidebook.

Other sources of information about preventive maintenance programs, inspection practices, and safety include other airports that have good preventive maintenance programs, insurance companies, local hospitals, schools, and large companies. These entities often have expertise in maintenance practices and can help an airport set up or improve their preventive maintenance program. Manufacturers of airport facilities or components (e.g., vehicles, HVAC systems, electrical equipment, approach aids) are excellent sources of information. Airports that do not already have manuals for their equipment should contact the manufacturer to obtain them.

Appendix B provides a bibliography related to airport preventive maintenance.

APPENDIX A

Airports/States Providing Assistance

The following airports provided information and staff interviews that helped in the production of this document:

Ada Municipal – Ada, OK
Bismarck Municipal – Bismarck, ND
Bowman Field – Louisville, KY
Columbus Municipal – Columbus, IN
Dawson Community – Glendive, MT
DeKalb-Peachtree – Atlanta, GA
Dillant-Hopkins – Keene, NH
Double Eagle II – Albuquerque, NM
Greely-Weld County – Greeley, CO
Lincoln – Lincoln, NE
Meacham International – Fort Worth, TX
Monroe Municipal – Monroe, WI
Morristown Municipal – Morristown, NJ
North Las Vegas – Las Vegas, NV
Olympia Regional – Olympia, WA
Rio Vista Municipal – Rio Vista, CA
Southern Illinois – Carbondale, IL
Sumter – Sumter, SC
Venice Municipal – Venice, FL

State aviation agencies from the following states provided information and interviews that helped in the production of this document:

Arizona
California
Colorado
Florida
Iowa
Maine
Michigan
Mississippi
New York
North Dakota
South Carolina
Texas
Virginia
Washington

APPENDIX B

Bibliography

This appendix identifies valuable sources of information about the maintenance of specific airport systems and airport maintenance programs. The bibliography includes all publications cited in the report.

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FAA Advisory Circular 150/5210-24, Airport Foreign Object Debris (FOD) Management, issued September 30, 2010.
FAA Advisory Circular 150/5220-10E, Guide Specification for Aircraft Rescue and Fire Fighting (ARFF) Vehicles, issued June 1, 2011.
FAA Advisory Circular 150/5220-20A, Airport Snow and Ice Control Equipment, issued September 24, 2014.
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Abbreviations and acronyms 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

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