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DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP RESEARCH REPORT 188

Using Existing Airport Management Systems to Manage Climate Risk

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AIRPORT COOPERATIVE RESEARCH PROGRAM

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Airport stakeholders also contributed to the research by providing feedback on the direction and content of the handbook during a series of webinars and site visits. Webinar participants included representatives from the City of Phoenix Airport Department, the City and County of Denver, Atlanta Department of Aviation, Lee County Port Authority, Columbus Regional Airport Authority, Allegheny County Airport Authority, and Massachusetts Port Authority. Site visits were held at Southwest Florida International Airport, Denver International Airport, Logan International Airport, Pittsburgh International Airport, and Seattle—Tacoma International Airport.

FOREWORD

By Theresia H. Schatz
Staff Officer
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ACRP Research Report 188 is a handbook to help airport planners, management, airport operations staff, and others who need to integrate current and projected climate change-related risks into airport management systems and planning. The goal is to enable airports of all sizes, types, and geographic locations to reduce their vulnerability to current and projected impacts of climate change, including extreme weather events, and to minimize long-term costs to their facilities and operations. This handbook provides a detailed guide for integration, as well as a self-assessment tool for determining the applicable systems for climate-related decision-making within the airport. The accompanying quick start guide helps airports get started on the most critical portions of the handbook.

Airports manage risk—including risks related to climate and weather—under various programs and decision-making processes, such as enterprise risk management, safety management, and emergency management. Additional processes such as asset management, capital planning, and others also manage risk by making sure resources are allocated, and assets designed and maintained, to reduce an airport's vulnerability to certain stressors.

Assumptions about climate and weather are built into most airport management systems. Budget planning, for example, involves assumptions about how much infrastructure maintenance or replacement is needed to counteract effects of climate and weather. Emergency management and irregular operations planning involves assumptions about events that might disrupt operations.

Expectations for future climate and weather conditions are usually based on historical records. However, climate change means that past events are not indicative of future events. If climate change is not taken into account, expensive infrastructure could be inadequately designed for future needs, the airport could be underprepared for extreme weather events and associated service disruptions, and other financial and operational planning efforts might not be optimized.

Rather than considering climate change as a completely new and separate risk to address, airports can integrate the concept of climate change into their existing decision-making processes to ensure that climate risks are adequately managed. Approaching climate change in this way allows airports to make more informed decisions about appropriate investments to mitigate risks over time. However, there are no universal best practices or existing guidelines on how to do so. Without an integrative resource for airports, climate risks can be viewed as an abstract and unquantifiable, with missed opportunities as a result. Airports also may not be aware of the full range of climate risk factors warranting inclusion in airports' multihazard risk management processes.

To help overcome this barrier, ACRP is releasing *ACRP Research Report 188: Using Existing Airport Management Systems to Manage Climate Risk*, which is a handbook that helps airports understand the need to address climate change and demonstrates how climate change can be factored into their existing decision-making processes. The handbook includes a self-assessment tool for determining applicable management systems for climate-related decision-making within the airport, a detailed guide for integrating climate risks into seven key management systems, and strategies for building support across the airport. The seven management systems addressed are strategic planning, master planning, enterprise risk management, safety management, capital planning, asset management, and emergency management.

Under ACRP Project 02-74, research was conducted by ICF (led by Principal Investigator Beth Rodehorst), Gresham Smith & Partners, and Faith Group, LLC. Initial insights into the state of practice and key management systems for climate risk management were obtained through a literature review and webinars with airport stakeholders. The handbook was based on this initial research and then tested and vetted through several airport focus groups and site visits. An accompanying quick start guide [Appendix E and online, found by searching the TRB website (www.TRB.org) for *ACRP Research Report 188: Using Existing Airport Management Systems to Manage Climate Risk*] covers the most critical portions of the handbook; airports may choose to use the quick start guide as a starting point and then refer to the handbook for more detailed information as needed. A Microsoft® PowerPoint presentation as an overview of the project is also available online at the same site.

KEY TERMS

Adaptation. Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, for example, anticipatory and reactive, private and public, and autonomous and planned. Adaptation increases resilience to future impacts. Adaptation puts an understanding of hazard and risk first and considers impacts, costs, and acceptance in addition to return on investment [Airport Cooperative Research Program (ACRP) 2015a]. This research report uses the term *climate risk management* to refer to adaptation.

Adaptive management. A systematic approach to managing uncertainty that promotes flexible decision-making as information evolves. Adaptive management emphasizes learning while doing (ACRP 2015a and U.S. Department of Interior 2009).

Airport management system. Function or formalized airport process for managing aspects of the business. In this handbook, these systems or processes are described using the plan–do–check–act model used to manage processes and systems (International Organization for Standardization 2015).

Climate entry point. Existing step in a management system that provides an opportunity to manage climate risks.

Climate hazard (or climate change hazard). Changes due to or directly related to changing climate. Examples include sea level rise, increased global and regional temperatures, and shifts in precipitation patterns. Also known as a *climate stressor* (ACRP 2015a).

Climate risk (or climate change risk). The potential losses associated with individual or multiple climate hazards, defined in terms of expected probability and frequency, exposure, and consequences (ACRP 2015a).

Climate risk management. Methods to minimize, monitor, and control climate risks, such as through avoiding, accepting, removing, reducing, sharing, and retaining the risk (ISO 2009).

Extreme weather event. An event that is rare at a particular place and time of year. Definitions of *rare* vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. By definition, the characteristics of what is called *extreme weather* may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to anthropogenic climate change, as there is always a finite chance that the event in question might have occurred naturally. When a pattern of extreme weather persists for some time, such as a season, that pattern may be classified as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought, heavy rainfall over a season) (ACRP 2015a).

Resilience. The ability of a system to bounce back after experiencing a shock or stress. Resilient systems are usually characterized by flexibility and persistence (ACRP 2015a). Resilience may be an outcome of climate risk management activities.

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 Who Should Use This Handbook?

- Do you manage airport infrastructure or services?
- Does weather affect the infrastructure or services that you manage?
- Does weather influence your airport's ability to operate?
- Do you wish to reduce the financial, operational, and safety risks at your airport?

If you answered "yes" to any of these questions, this handbook is for you. Even if your airport has not experienced extreme weather events in recent years, it is important to understand how the climate may change in your area and what the associated vulnerabilities and risks are to maintaining your day-to-day operations.

Specifically, this handbook is for executives, managers, and staff responsible for minimizing disruptions to airport services, maintaining or repairing infrastructure, managing investments in infrastructure, and planning other long-term or strategic activities. If you fit in one of these categories, this handbook will help you to identify your risks associated with changing local climate conditions and appropriate strategies to manage those risks.

Users of this handbook may include

- Department or system managers (e.g., capital planning, asset management) who are ideally positioned to identify strategies for integrating climate risk management into the systems that they manage;
- Climate risk management champions (i.e., individuals or teams) who lead your airport by coordinating information collection and sharing efforts across departments, tenants, and external stakeholders; and
- Airport executives who prioritize and guide how your airport addresses and prepares to mitigate climate risks as part of existing management systems and who guide management in identifying opportunities for collaboration across the airport.

Benefits of Addressing Climate Risks at Airports

- **Save on maintenance costs** for pavement repair, drainage system maintenance, and other weather-related costs.
- **Improve safety and security** for staff and passengers.
- **Avoid being caught unprepared** for an extreme weather event.
- **Avoid underestimating infrastructure sizing requirements.**
- **Maintain compliance** with environmental, safety, and other regulations.
- **Improve reliability and customer service.**
- **Maintain continuity of operations** during an unplanned or emergency event.
- **Improve ability to recover** from an extreme event.

1.2 Why Should I Use This Handbook?

Assumptions about climate and weather are built into decisions made throughout most airport management systems. The infrastructure is designed and built to withstand a specific range of climate conditions (e.g., a specific temperature or amount of

2 Using Existing Airport Management Systems to Manage Climate Risk

Examples of Climate Change Impacts on Airports

- Shifting averages and temperature extremes may cause a variety of impacts:
  - Pavement deterioration may affect maintenance and capital expenditures (e.g., replacement after 10 years instead of 15 years).
  - Increased frequency of extreme heat conditions may affect worker safety and delay summertime construction schedules.
  - Changes in weather-based tourism (e.g., skiing) may affect demand.
  - Adjustments to employee safety measures because of heat or cold stress may negatively affect productivity.
- Frequent heavy precipitation events may stress drainage infrastructure, reduce useful life expectancies of infrastructure, and cause flooding and damage.
- The rise in the sea level may extend the reach of storm surge and threaten critical infrastructure.
- Changes in winter weather patterns may lead to adjustments in winter operations and equipment needs.
- Water scarcity and drought may affect facility development and operational costs, particularly in southwestern regions.

rainfall). For example, the selection of pavement mix and other materials is based on assumptions about local temperatures, and drainage systems are designed on the basis of assumptions about local precipitation patterns. Airport management systems often use similar methods. Budget planning, for instance, involves assumptions about how much infrastructure maintenance or replacement is needed to counteract the effects of climate and weather. Emergency management and irregular operations planning involves assumptions about events that might disrupt operations.

The expectations for climate and weather conditions are usually based on historical records. However, climate change means that past events are not indicative of future events. If climate change is not taken into account, the design of expensive infrastructure could be inadequate for future needs, the airport could be underprepared for extreme weather events and associated service disruptions, and other financial and operational planning efforts might not be optimized.

Because climate change is often thought of as something in the future, some people may think that there is no need to take action today. This position may seem bolstered by the discussion of scientists and media about how the climate will be different in 2050 or 2100—decades ahead. However, it is important to remember the following:

- Infrastructure is costly to build and is often expected to last for decades. It can also be difficult and expensive to replace. For example, a drainage system that was not sufficiently sized for future rainfall patterns may lead to increasingly frequent flooding. It is often easier and more cost-effective to plan and design with those challenges in mind.
- Climate change is a gradual phenomenon that occurs over decades, rather than abruptly changing in one year. Although a report might project a climate in terms of what 2050 may look like, changes in the weather are already under way and may introduce risks to the climate on a much shorter timescale than expected.
- Climate represents averages of an area's weather. A given year may be hotter or colder, or wetter or drier, than average. Despite projections of the climate around 2050, annual variations mean that more extreme weather events could be experienced far earlier.

Won't My Business-as-Usual Processes Take Care of My Climate Risks?

Some business-as-usual processes, such as annual engineering assessments and capital improvement planning exercises, can help you to stay on top of trends and impacts as they occur at your airport. These processes are best suited to manage risks that change gradually.

However, these existing processes may not be sufficient when changes are happening quickly or when the potential impacts would be severe: both situations can be true of climate risks. In addition, there may be opportunities to be more proactive about preventing climate impacts in the first place by understanding where climate trends may be headed. Existing processes are often not designed to indicate that long-lived infrastructure should be designed to accommodate these trends.

This handbook will help you identify opportunities to be proactive about preventing impacts.

Airports may experience climate changes both in the short term and the long term. Different sets of actions may be needed to address those risks. There are many ways to manage your airport's climate risk proactively—and not all involve costly changes to existing infrastructure. Understanding how the future may change enables you to make cost-effective decisions in the short term about adjusting to infrastructure design, planning for extreme events, and improving maintenance and repair practices. Planning for climate change is an opportunity to make smart, long-term decisions now that will save money later, minimize service disruption, and keep your employees, passengers, and community safe.

What About Uncertainty?

Uncertainty in future climate risk is a common challenge for airports and other entities. Although the direction of change may be certain, the exact level of change is less so. This situation can be particularly challenging for engineering because you need to pick a specific value to design and build to. Uncertainty in choosing this value is sometimes used as a reason for not taking action.

However, it is important to remember that uncertainty is not unique to climate data—most data sets and models have underlying uncertainties and assumptions. For example, major capital investment decisions are already based on uncertain assumptions such as future passenger volume and use when building or expanding airports. Climate change uncertainty is one more uncertainty to manage but should not prohibit action.

The Massachusetts Port Authority (Massport) (Boston) is an example of an entity that has taken actions to account for uncertainty. After assessing flood models of its assets, Massport published its *Floodproofing Design Guide,* which set a design flood elevation for new and existing infrastructure. The standard is based on a 500-year event plus 3 feet of freeboard, which serves as an additional safety factor against flooding or wave action. Massport has already begun floodproofing its most critical assets.

Finally, even if your airport is not coastal or is not currently experiencing issues with flooding or extreme weather, it is valuable to consider how climate risks will change both regionally and locally and whether small adjustments to your airport's decision-making processes would increase your long-term resilience to climate risks.

Figure 1 illustrates how the handbook can be useful to both a highly vulnerable airport and a less vulnerable airport.

Regardless of location, past weather experiences are not indicative of the future. Use this guidebook to make a fully informed decision regarding when and how to address your airport's potential climate risks.

Airport Management Systems Addressed in This Handbook

1. Strategic planning
2. Master planning
3. Enterprise risk management
4. Safety management
5. Capital planning
6. Asset management
7. Emergency management

1.3 What Is the Purpose of This Handbook?

This handbook provides a practical approach to account for climate risks at an airport using a two-step process. The process, which includes the completion of a self-assessment and the ongoing planning and implementation of one of seven common management systems identified in this handbook, is repeatable and scalable. Specifically, the handbook will help you to identify climate resources and basic climate entry points within common airport management systems to inform decisions better on investing, planning, and design. The intended outcome is a more resilient airport that can avoid many impacts of climate change.

1.4 What Does the Handbook Cover?

The handbook is structured into two main stages: self-assessment (i.e., understanding risks) and integration (i.e., managing risks). See Figure 2.

Chapter 2 provides guidance on conducting a self-assessment to identify how the climate is projected to change locally and which existing management systems at your airport might be best suited to use first to address those changes.

Table 1 describes the seven common airport management systems into which climate risks can be easily integrated.

These and other airport management systems are interrelated, and outputs from one system can inform other systems. For example, a priority project identified as part of your master plan update could be an input for developing the next iteration of your capital plan. Figure 3 illustrates some of these relationships.

Chapter 3 provides strategies to communicate, coordinate, and build support around climate risk management.

Chapter 4 provides strategies to account for climate risks in selected management systems. A management system at your airport may vary in the number and types of steps typically followed in comparison with those presented in this handbook. However, in an effort to provide guidance across the airport industry and meet the needs of airports of various sizes and governing structures, a comprehensive, formal description of each included management system is presented.

Figure 1. Usefulness of handbook to airports with a range of climate risks.

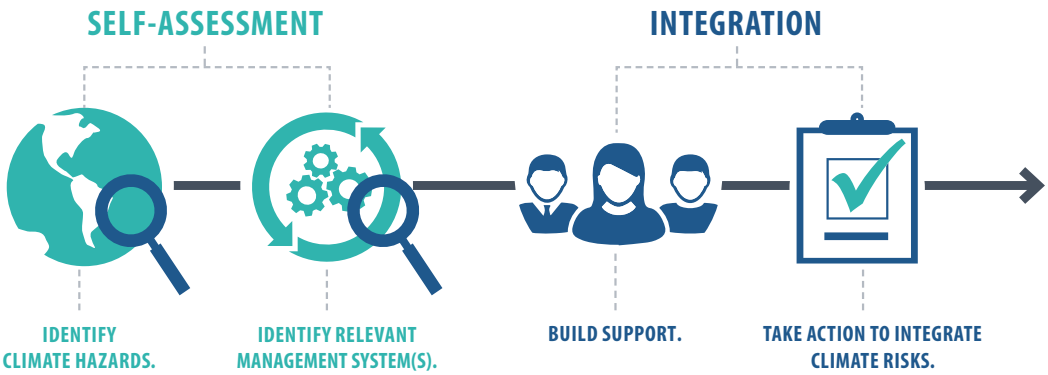


Figure 2. Handbook overall approach.

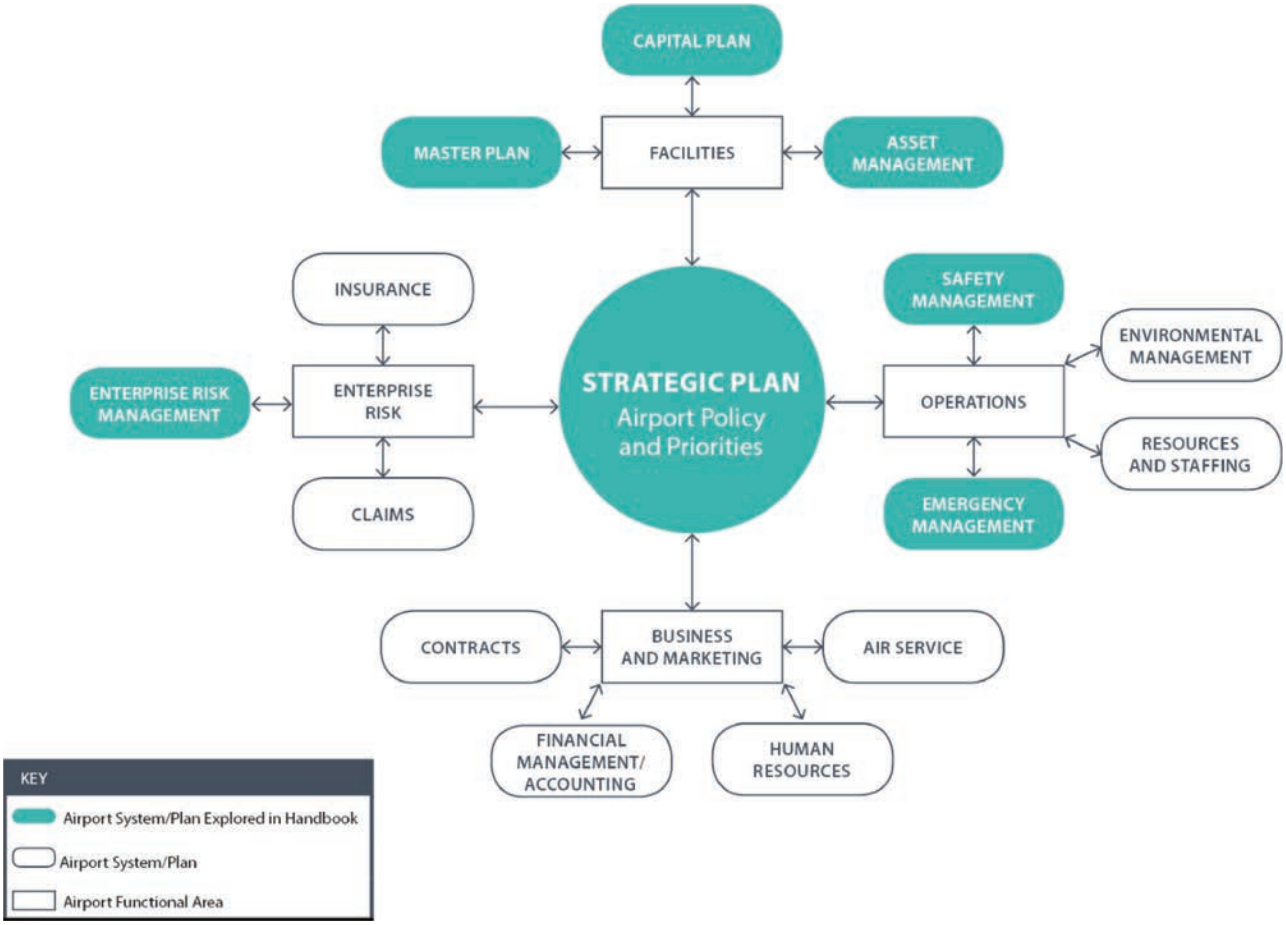
The chapter describes how and where to account for climate risks in each management system. The chapter also includes a section on adaptive management strategies that can occur within or across management systems.

Chapter 5 presents the next steps to assist with advancing climate risk management from planning to actual implementation.

Accompanying this handbook is a quick start guide (Appendix E and online), which provides an easy entry into the handbook content. The quick start guide presents the key actions needed to start managing climate risks. You may choose to follow the quick start guide when taking your initial planning steps and refer to this more detailed handbook as needed. Other users may wish to use this handbook from start to finish.

Table 1. Airport management systems for integrating climate risks.

Management System	Description
Strategic planning	Strategic planning defines an airport's long-term strategy and direction and guides airport planning and management processes.
Master planning	Master planning addresses infrastructure to meet forecasted service levels.
Enterprise risk management	An enterprise risk management system is the encompassing management mechanism at an airport that holistically addresses the organization's risks.
Safety management	A safety management system identifies the safety performance indicators that address the main hazards and incidents at an airport. Hazards may include personal injury, accidents/incidents resulting from equipment, or organizational practices and environment (e.g., terminal, parking garages).
Capital planning	Capital planning covers longer-term investments in infrastructure, equipment, and so forth.
Asset management	Asset management accounts for the status of existing assets and infrastructure to maintain operations, and manages measures to repair, rehabilitate, or replace aging or poor condition assets.
Emergency management	Emergency management covers responses to emergency situations, including severe weather-related emergencies. Although the planning horizon is short, this management system would benefit from some sort of trigger or process to ensure that future emergency management plans include new hazards due to a changing climate.



Note: Airport functional areas, systems, and plans are representative and may vary by airport.

Figure 3. Interrelationship of common airport management systems.

CHAPTER 2

Conduct Self-Assessment of Relevant Climate Hazards and Management Systems

This self-assessment is intended to help you, an airport system manager or climate risk management champion, identify the hazards most relevant for your airport and determine how to start integrating climate change considerations into your airport's management systems. This process will involve first gathering and compiling information on expected climate hazards in your location and then identifying possible impacts to your airport. Choosing the priority management systems for integrating climate change considerations depends on two key factors:

1. The nature of climate risks at your airport and
2. The management systems in place at your airport.

This self-assessment walks you through the process of understanding the nature of climate risks at your airport and identifying the most appropriate management systems in light of those risks. You will determine what your local system looks like and what hazards climate change introduces. This is a similar process to the 5M model used in aviation (FAA 2012; see text box in Section 4.4.2). There are numerous resources available to help you to do this, including a step-by-step Airport Cooperative Research Program (ACRP) tool, explained below.

Fill out the accompanying worksheet, located in Appendix A, to follow along in the self-assessment. If your airport has already conducted a climate risk assessment, proceed to Section 2.3.

2.1 What Are My Relevant Climate Hazards?

All airports are exposed to climate hazards, such as high temperatures, heavy precipitation and flooding, snow storms, ice storms, drought, wildfires, sea level rise, and hurricanes. Examples of such hazards and their associated risks are shown in Table 2 and are organized by the following categories: physical risks, operational and business risks, and safety and security risks.

The first step in this assessment is to determine which hazards may increase in severity or frequency in your area, and whether your airport may experience any new hazards. In the next step, you rank and prioritize the climate hazards and risks that are most relevant to your airport. During that process, refer to Table 2 for examples of the types of risks your airport might face.

Information on what climate hazards to expect in your location is available from numerous sources—so many, in fact, that many airports find it overwhelming. The following steps are intended to simplify the process.

Table 2. Examples of climate hazards and risks.

Climate Hazard	Physical Risks	Operational and Business Risks	Safety and Security Risks
High temperatures	• Reduced operational lifespan of airport pavements • Pavement buckling and loss of non-concrete pavement integrity • Increased stress on air conditioning systems	• Greater demand and increased costs for cooling • Limits to aircraft operations due to insufficient runway lengths	• Higher risk of heat-related health issues for workers • Increased risk of fuel ignition (flashpoint of aviation fuel at 100°F) • Changes in vector-borne and contagious diseases, increasing risk of disease spread through air travel
Heavy precipitation and flooding	• Flooding and associated damage to facilities (e.g., buildings, drainage systems, navigational aids) • Foundation heave[a]	• Flight delays during severe rain events • Higher risk of power outages during severe storms • Higher costs of flood mitigation	• Outbreak of contagious diseases due to extended flooding conditions favorable for vector population growth[a]
Snowstorms	• Damage to navigational aids and other equipment	• Limited airport access • Operational disruptions • Need for deicing	• Safety risk to workers
Ice storms	• Damage to navigational aids and other equipment	• Limited airport access • Operational disruptions • Need for deicing	• Safety risk to workers
Droughts	• Pavement or foundation damage from soil contraction, subsidence[a]	• Reduced throughput capacity[a] • Change in tourism and seasonal enplanements[a] • Increased water demand for landscaping	• Reduced water availability[a]
Wildfires	• Destruction of assets	• Reduced visibility • Access restrictions	• Reduced visibility • Impaired air quality and associated health risks for outdoor workers
Sea level rise	• Inundation of low-lying airfield buildings and other structures • Flooding of runways and other airfield areas from storm drain overflows • Salt water damage (e.g., corrosion) to aircraft and equipment	• Limited airport access • Operational disruptions • Additional inspections and maintenance	• Safety risk to passengers and workers • Damaged electrical systems
Hurricanes (including wind and storm surge)	• Inundation of runways, airfield areas, access roads, and facilities • Salt water damage (e.g., corrosion) to aircraft and equipment • Damage to navigational aids and other equipment	• Flight cancellations and delays • Fuel supply and storage disruptions • Limited airport access	• Safety risk to passengers and workers • Impaired water quality and associated health risks from overwhelmed storm water systems

Source: U.S. Department of Transportation 2014 unless otherwise noted.
[a]ACRP 2015b.

Use this information to fill out columns A and B of the self-assessment worksheet (Appendix A).

1. If you have little previous exposure to the topic of climate change and the associated impacts, **review the National Climate Assessment (NCA)** section for your region for a high-level overview of key messages related to expected climate changes and their impacts in the region. The NCA, updated every four years, provides comprehensive national research findings on specific climate impacts and regions. If you already have some familiarity with this type of information, proceed to the next step.

   For example, the 2014 NCA includes the following key climate hazards for the Midwest (Pryor et al. 2014):
   - Extreme heat. This will manifest in terms of more days above 95 degrees and more cooling degree days, meaning more energy needed for cooling (see NCA Figure 18.2).
   - Heavy precipitation and flooding. The heaviest rainfall events have intensified in the past century, and "this tendency toward more intense precipitation events is projected to continue" (see NCA Figure 18.6, shown in Figure 4).
2. Check whether there have been other climate change assessments in your location. For example, check with your state agencies, city government, and local university for existing studies. Also check with other airport leaders to determine whether personnel have researched or have begun addressing climate risks. You may be able to use this existing information to reduce work and to ensure coordination and consistency with other local efforts. In addition, these assessments may provide more information on climate hazards and the expected timing and severity of impacts beyond what the ACRP Airport Climate Risk Operational Screening (ACROS) tool (see Step 3) can provide.

   For example, the City of Philadelphia conducted an analysis to identify detailed climate change projections for the city, which may be useful for the airport (ICF 2014). In addition, the San Diego County Regional Airport Authority participated in a regional climate change assessment effort to assess the risks that sea level rise posed to airport operations (ACRP 2012a).
3. **Use the ACRP Airport Climate Risk Operational Screening (ACROS) Tool** to gather detailed projections of climate hazards and their impacts on your airport. Without going through the full tool to evaluate climate risks, you can use the ACROS tool to gather climate projections quickly for your airport (this task can take less than 10 minutes):

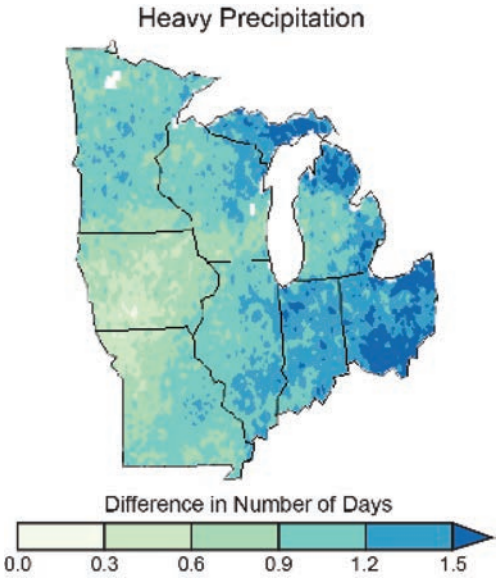


Figure 4. Example from NCA.

Open the ACROS tool, enter your airport code, and get projections for multiple climate hazards for your airport.

View the results either
1. In the tool directly (see Figure 5) or
2. In a report (even if you have not finished the rest of the tool's risk assessment): click the "Reports" button at the bottom of the left-hand pane to generate a summary table of the climate hazard projections (see Figure 6).

4. **If your airport is coastal**, look for information on whether any parts of your airport or its access roads could be affected by sea level rise. Check the following sources of information:
   - **Locally specific studies.** Many coastal areas have existing sea level rise mapping studies that take into account local land elevations, vertical land movement rates, expected sea level change rates in the area, and local coastal processes. Check with your state or local government offices and nearby universities for existing sea level rise assessments.
   - **National Oceanic and Atmospheric Administration (NOAA).** If no locally specific studies are available, the NOAA Sea Level Rise Viewer is a tool to visualize community-level impacts from coastal flooding or sea level rise (see Figure 7) (NOAA 2017a).
5. If you would like additional information, see the climate data resources in Appendix D.

Terminology Clarification: Climate Hazards Versus Climate Vectors

The ACROS tool uses slightly different terminology from this handbook. The ACROS tool identifies *climate vectors*, which are similar to climate hazards but are more specific and directly related to airport operations.

Through the ACROS tool development process, airport subject matter experts identified climate hazards that would impact airport operations and worked with atmospheric scientists to identify specific climate metrics that could be analyzed. For example, high temperatures were identified as a *hazard* to multiple assets and operations. Specific climate *vectors* developed to assess this hazard included days per year when air temperature exceeded 90°F (hot days) and 100°F (very hot days) (ACRP 2015a).

The table below maps the climate hazards in this handbook to the ACROS climate vectors:

Climate Hazard	ACROS Climate Vectors
High temperatures	Hot days, very hot days, hot nights, humid days, cooling days, cooling degree days, heating days, heating degree days
Heavy precipitation and flooding	Heavy rains (1 day), heavy rains (5 days), storm days
Snowstorms	Snow days
Ice storms	Freezing days, frost days
Droughts	Dry days
Wildfires	None
Sea level rise	Sea level rise, sea level rise–base flood elevation
Hurricanes	None

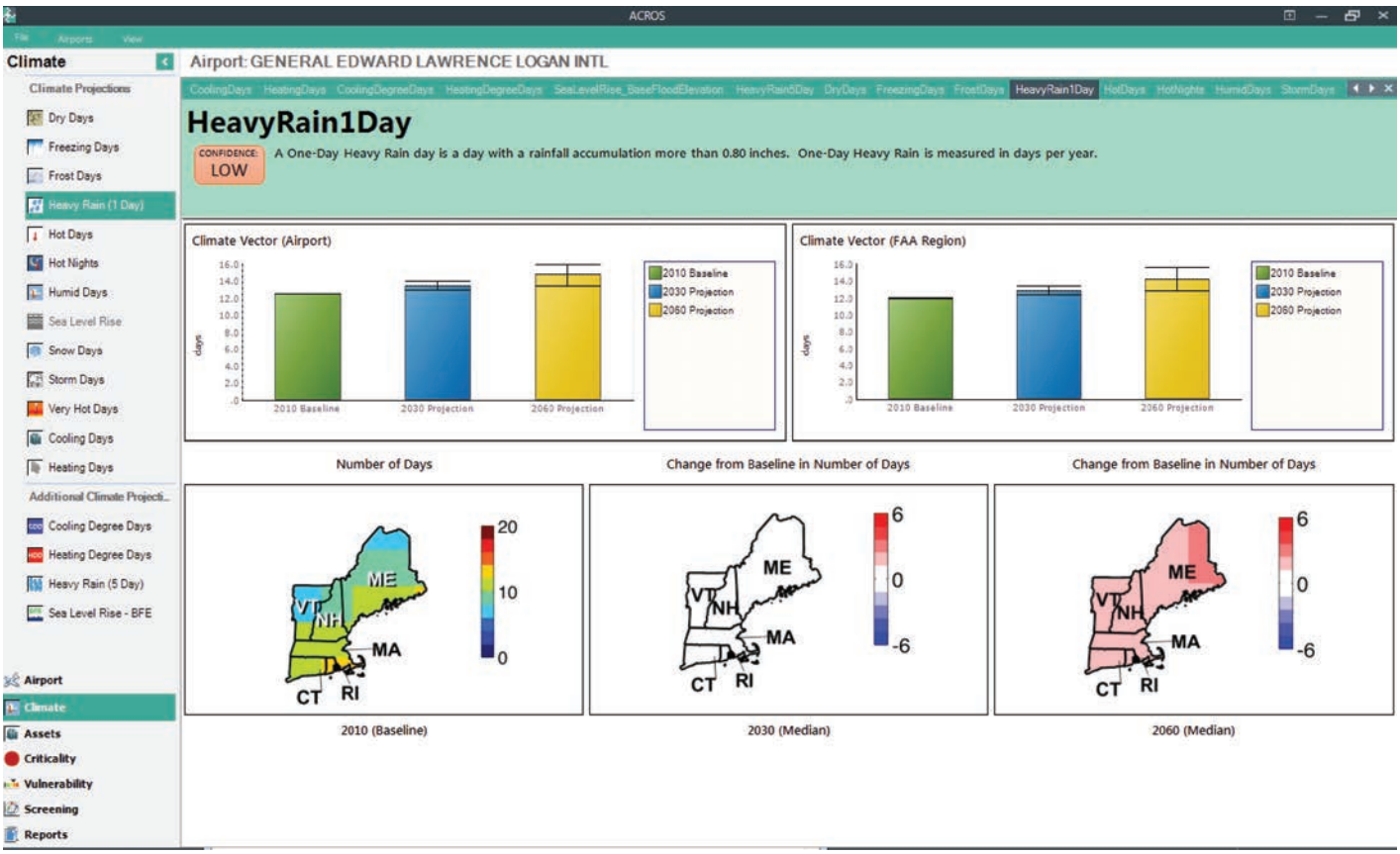


Figure 5. Examples of climate hazard projections from the ACROS tool (shown for BOS), viewed in the tool.

2.2 What Are My Expected Climate Risks?

Next, translate the information about climate hazards into climate risks that are relevant for your airport.

Table 2 provides examples of the types of hazards and risks to consider. The degree of risk to your airport depends on the magnitude of change for each climate hazard, the sensitivity of airport infrastructure and operations to those changes, and the preparedness of your airport. This step leads you through the process of ranking and prioritizing climate risks.

If your airport has already conducted a climate risk assessment, proceed to Section 2.3.

Use this information to fill out Columns C, D, and E of the self-assessment worksheet (Appendix A).

The risk assessment step can be as detailed as desired and should be revisited over time as new information becomes available, because climate science is changing rapidly. For one pathway, follow the steps below:

- If you are not ready to spend time on a more detailed risk assessment, work with others at your airport to complete this self-assessment based on **personal judgment** to understand which management systems may be most applicable to managing the types of climate risk at your airport.
  - You may also find it helpful to use the **default results from the ACROS tool** (see Figure 8). In addition to providing climate projections, the ACROS tool provides a structured process for conducting a risk screening and answering the question of what is most at risk to projected climate change within the entire airport (ACRP 2015a). Ideally, you will spend

Section I: Climate

Summary of climate data changes

Summary of Historical Record and Projected Changes (Days/Year)								
Climate Vector	Units	2013	2030			2060		
		Baseline	25th Percentile	Median	75th Percentile	25th Percentile	Median	75th Percentile
HotDays	days per year	0.7	1.5	3.5	9.4	3.7	8.7	22.4
VeryHotDays	days per year	0	0	0.2	0.7	0	0.8	3.3
FreezingDays	days per year	26.8	20	21.8	23.9	9.9	14.4	19.6
FrostDays	days per year	90.6	78.4	81.4	83.5	60.2	67.6	72.9
HotNights	days per year	16	26.1	30.9	38.5	41.2	53.2	72.2
HumidDays	days per year	19.6	27.8	33.6	39.9	40.2	54.7	70.4
SnowDays	days per year	6.6	5.6	5.7	6	4.1	4.3	4.9
StormDays	days per year	34.7	34.7	36.4	37.8	34.6	38.9	42.5
HeavyRain1Day	days per year	12.6	13	13.5	14	13.5	14.8	16
DryDays	days per year	14.5	14.5	14.8	15.4	14.4	15.2	16.6
SeaLevelRise	days per year	0	0	0	0	0	0	0
CoolingDays	days per year	55.7	68.1	68.8	71.8	86.7	88.5	95.9
HeatingDays	days per year	253	240.7	242	242.7	222.2	225.4	227.2

Summary of Historical Record and Projected Changes (Various Unit)								
Climate Vector	Units	2013	2030			2060		
		Baseline	25th Percentile	Median	75th Percentile	25th Percentile	Median	75th Percentile
CoolingDegreeDays	yearly accumulation	206	280.9	323	355.4	393.3	498.4	579.6
HeatingDegreeDays	yearly accumulation	3404.8	3049.2	3163.6	3216.4	2515.7	2801.8	2933.8
HeavyRain5Day	inches	3.4	3.4	3.5	3.6	3.5	3.8	4
SeaLevelRise_BaseFloodElevation	feet	10	10	10	11	10	12	13

Figure 6. Examples of climate hazard projections from the ACROS tool (shown for BOS), viewed in the report.

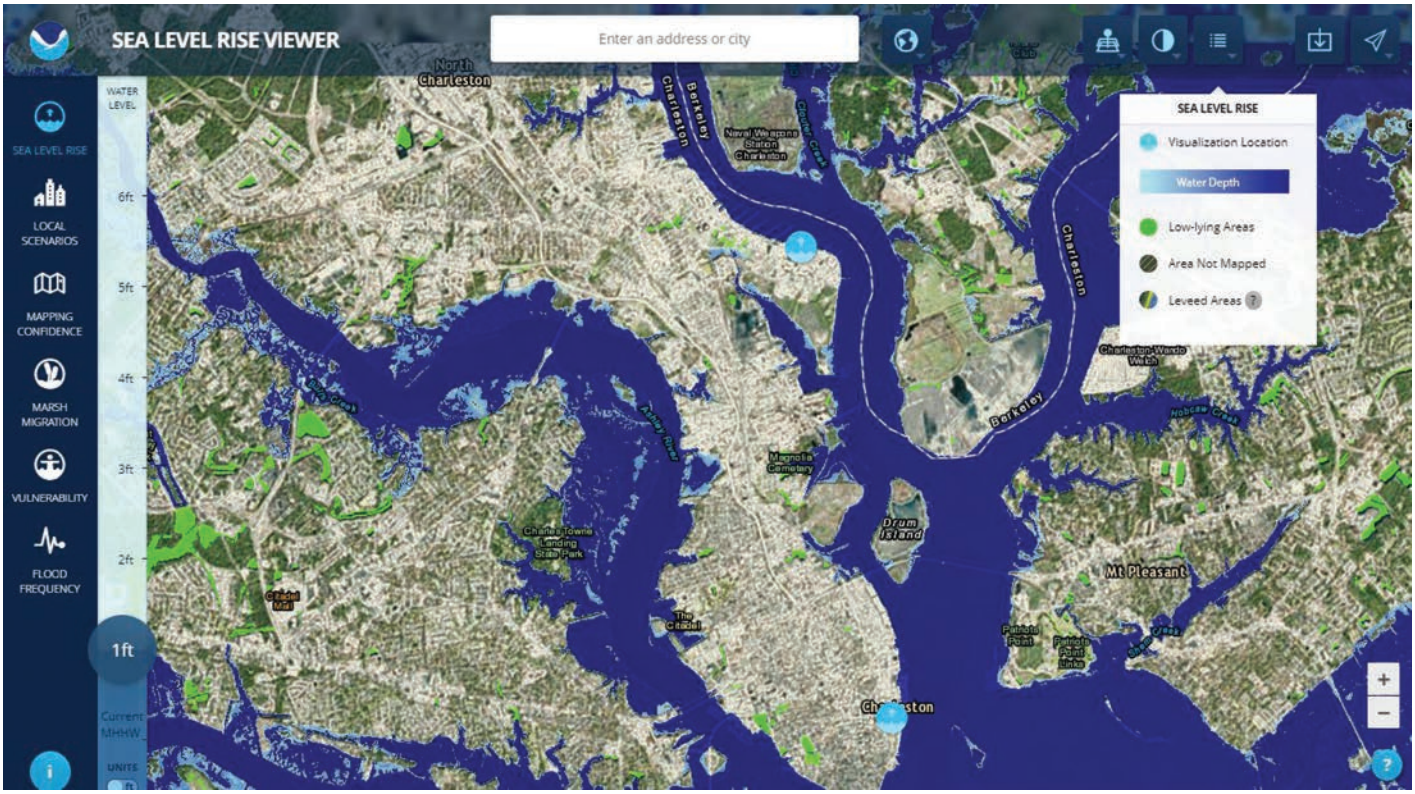


Figure 7. Screenshot of the NOAA sea level rise viewer.

Section II: Risk (2030)

OVERALL RISK	SERVICE:					ASSET/OPERATION:
	Commercial Passenger Terminal Facilities					Commercial Passenger Terminal Facilities
	Impact Risk	*Criticality*	*Vulnerability*	*Climate Vectors*	*Impacts*	*Adaptation Options*
		3	2	HumidDays CoolingDays	Failure of Building Envelope (Roofing Materials, External Seals) and / Or Mold Vulnerability	• Improve Building Envelope (Fenestration, Roofing Materials, Cladding Material, Vapor Barriers / Retarders, etc.)
		3	2	HotDays HotNights HumidDays	Increased HVAC Demand and Duration	• Design for Incremental Change (e.g. Modular Systems) • Perform Energy Modeling • Improve Building Envelope • Replace Equipment According to Climate Zone
		3	2	HumidDays HeavyRain1Day	Building Moisture Damage; Mold	• Schedule More Frequent Inspections • Improve Building Envelope (Fenestration, Roofing Materials, Cladding Material, Vapor Barriers / Retarders, etc.)
		3	2	HotDays	Roofing Material and Exterior Seals (Roof and Walls) Degradation	• Upgrade Roof with High Heat and Reflective Products
		3	2	StormDays HeavyRain1Day HotDays	Decreased Food Resources	• Develop Adaptations in Cooperation with Regional Planners • Incorporate Adaptations in Master Plan
		3	2	StormDays HeavyRain1Day HotDays	Outbreak of Contagious Diseases	• Develop Biological, Chemical and Personal Protective Strategies
		3	2	StormDays	Internal Facility Damage Due to Driving Rain	• Improve Building Envelope • Improve Drainage Infrastructure
		3	2	StormDays HeavyRain1Day	External Facility Damage Due to Driving Rain	• Improve Building Envelope (Incorporate Flood-Resistant Structural Elements) • Install Flood Barriers • Elevate Critical Equipment • Elevate Structure

Figure 8. Example of risk assessment from ACROS (default results for BOS shown).

time rating the criticality (importance) and vulnerability of your airport's assets to the hazards and reviewing the results to ensure that they are appropriate for your airport.

- For a more detailed assessment, invest time to complete the **ACROS tool** fully and involve staff from multiple departments to assess and to prioritize risks.

At the end, the ACROS tool provides a prioritized list of climate risks, as shown in Figure 8. The red, yellow, and blue icons for impact risk represent high, medium, and low risk, respectively.

If additional information would be helpful for assessing your airport's vulnerability, a variety of sources of this information are available to the public, as described in Appendix D.

Use this information to fill out Columns C, D, and E of the self-assessment worksheet (Appendix A).

Table 3 shows the self-assessment worksheet populated with the use of the default results for Boston's Logan Airport (BOS) from Figure 8. As you review the ACROS risks for your airport, categorize the impacts as physical, business and operational, or safety and security to populate the worksheet. These three categories will help align the risks to related management systems.

The results from ACROS should be reviewed critically to ensure that they align with the experiences and knowledge of airport stakeholders. If the results do not include hazards that you think are vital, you can modify the results, with ACROS as a starting point.

Table 3. Example of completed self-assessment worksheet.

Populated for BOS based on default ACROS tool results.

A **Expected Hazards**	B **Expected Timing**	C **Physical Risks**	D **Business and Operational Risks**	E **Safety and Security Risks**
☑ High temperatures	**2030s:** 1.5–9.4 hot days **2060s:** 3.7–22.4 hot days by 2060	**High.** Failure of building envelope **Moderate.** Loss of pavement integrity **Low** Reduced vegetation and increased erosion	**High.** Increased HVAC demand and duration **High.** Reduced throughput capacity **Low.** Increase in number of endangered species	**Low.** Potential for drawing in smoke through outdoor air handling systems
☑ Heavy precipitation and flooding	**2030s:** Increase in 1-day heavy rain event from 12.6 to 13–14 inches **2060s:** Increase to 14.4–16.6 inches	**High.** Building moisture damage; mold **Moderate.** Pavement heave **Low.** External facility damage due to flooding	**High.** Reduced throughput capacity **Moderate.** Change in tourism and seasonal enplanements **Low.** Reduced level of service	**Moderate.** Outbreak of contagious disease **Low.** Decreased food resources
☐ Snowstorms	**2030s:** 5.6–6.0 snow days **2060s:** 4.1–4.9 snow days	None identified	None identified	None identified
☐ Ice storms	*Not measured directly* **2030s:** 20.0–23.9 freezing days **2060s:** 9.9–19.6 freezing days	None identified	None identified	None identified
☐ Drought	**2030s:** 14.5–15.4 dry days **2060s:** 14.4–16.6 dry days	None identified	None identified	None identified
☐ Wildfires	Not provided	Not provided	Not provided	Not provided
☑ Sea level rise (SLR)	*From local study (City of Boston 2016):* **2030s:** 4–8 inches SLR **2050s:** 7 inches–1.5 feet SLR **2070s:** 1.3–3.1 feet SLR	None identified in ACROS (this would be a place to supplement ACROS with additional information)	None identified in ACROS (this would be a place to supplement ACROS with additional information)	None identified in ACROS (this would be a place to supplement ACROS with additional information)
☐ Hurricanes	Not analyzed	None identified	None identified	None identified
☐ Other: _____	Not applicable	Not applicable	Not applicable	Not applicable
☐ Other: _____	Not applicable	Not applicable	Not applicable	Not applicable
Summary				
Highest risk rating (e.g., high, moderate, low)		High	High	Moderate

Note: The risks in this table are not presented in priority order. Risks will need to be prioritized by each airport.

If you are not using the ACROS tool, attempt to apply qualitative risk ratings (i.e., high, medium, and low) to the risks that you have identified. These ratings may be based on a separate analysis or personal judgment and can be refined over time as new information becomes available or as more detail is needed. For now, applying these ratings helps to prioritize which management systems are the best fit to manage your climate risks.

2.3 Which Management Systems Should I Use to Manage My Climate Risks?

Although all management systems could ultimately be used to manage climate risk, you may prefer to choose just one or two to focus on during the early stages of the process. Then you could move on to other management systems and integrate climate considerations in a phased and gradual way across your airport. To choose where to address climate risk first, consider the following questions.

1. **Which management systems address priority risks?**

   Some management systems will be more relevant than others for managing different types and levels of risk. Here are some examples:

   – **Strategic planning** is well suited to manage multidiscipline, potentially existential risks to the airport, such as the risk of long-term inundation from sea level rise and the potential for significant changes in passenger or other use demand.
   – **Master planning** is well suited to manage long-term infrastructure risks that can impact forecasted service levels, such as those from extreme temperatures, sea level rise, and flooding.
   – **Enterprise risk management** is well suited to holistically address risk identification, planning, and response coordination across the airport, such as those addressing airport service reliability.
   – **Safety management** is well suited to manage safety-related risks, such as extreme heat and the health effects on workers.
   – **Capital planning** is well suited to address infrastructure management and investment through a multiyear systematic approach that ensures basic safety, security, and operational efficiency and maximizes economic potential.
   – **Asset management** is well suited to manage the status of existing assets and infrastructure, as well as risks related to changes in operations and maintenance costs.
   – **Emergency management** is well suited to manage risks from operational changes due to extreme events (e.g., new risk of wildfires and ice storms).

   Furthermore, consider the severity of climate risks at the airport and which management systems can address those risks. Higher risks may warrant more management systems or more cross-cutting management systems. Examples follow:

   – Certain systems, such as asset management and emergency management, may be appropriate even for low risks and can be used with minimal modifications to stay on top of your existing climate risks and monitor them over time.
   – The higher the risk, the more management systems may be appropriate to manage them. For instance, if you have high physical risks, it may be appropriate not only to manage them through asset management, but also to incorporate into capital planning and master planning.
   – If climate change poses fundamental risks to the airport, consider identifying this risk in cross-cutting management systems such as strategic and master planning, which can then influence other applicable systems.

	PHYSICAL RISKS	BUSINESS AND OPERATIONAL RISKS	SAFETY AND SECURITY RISKS
LOWER RISK	Asset Management	Asset Management	Emergency Management
	Asset Management + Capital Planning	Asset Management + Enterprise Risk Management	Emergency Management
HIGHER RISK	Asset Management + Capital Planning + Master Planning	Asset Management + Enterprise Risk Management + Strategic Planning	Emergency Management + Safety Management

Figure 9. Example of match between management systems and levels of risk.

Figure 9 provides an example of how these concepts might be applied in practice to match an airport's risks to the appropriate management systems to start with. For example, an airport with low physical risks and high business and operational risks may want to start with asset management, enterprise risk management, and strategic planning.

2. **How does the time horizon of the management system correspond to projected climate risks?**

   Also consider the time horizon of each management system—including the *planning horizon* (e.g., the internal development cycle) and the *implementation horizon* (i.e., the lifetime of decisions set forth in the plan). For example, your capital plan may have a planning horizon of 5 years with an annual update, but the priorities set forth in the plan, such as plans for expansion or new infrastructure developments, will have implications over many decades. If climate risks are expected within this *implementation horizon* of your management system, it may be necessary to account for these risks (Figure 10).

3. **When will the management system be updated next?**

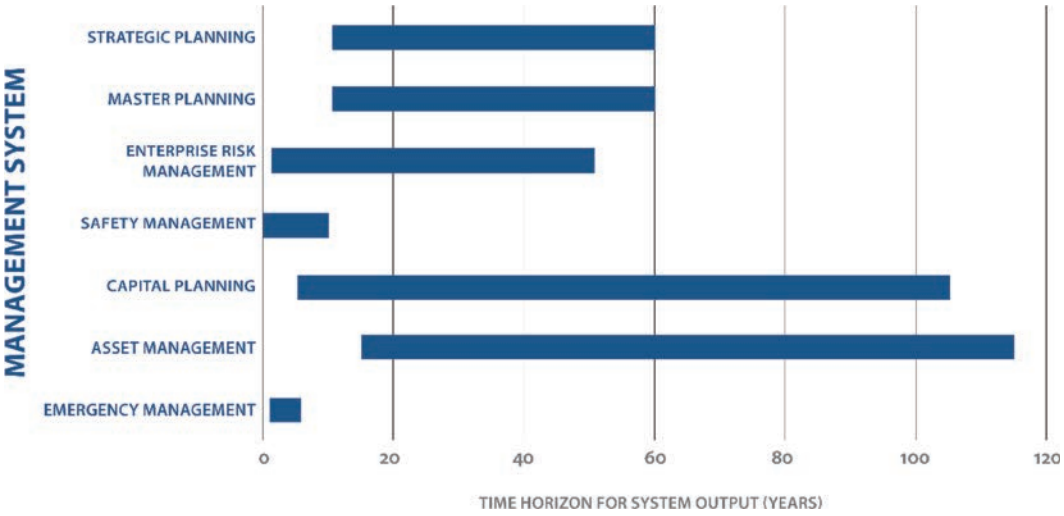


Figure 10. Typical implementation horizons for airport management systems.

Update Schedule

Finally, it is pragmatic to incorporate climate risks into airport management systems as a part of their usual update schedule. Identify the management systems that are due for updates and determine which would be most relevant, given the considerations discussed in this section.

Another option may be to account for climate risks during the next strategic plan update, because it establishes the major programmatic, policy, and management goals of the organization and is the management mechanism that other planning analyses align with and support. Ultimately, the preferred approach is at your discretion.

Example Starting Points

Even if your airport does not know the risks or has determined that it faces low risks, there are still actions that all airports could take that require minimal up-front work and can increase the airport's ability to manage risks over time. With starting points such as the following examples, you can manage and understand your climate risks over time, even if risks are low or unknown today:

- **Use asset management (or other) systems to monitor climate risks over time.** How often are drainage systems failing? Are pavements meeting their expected useful life? This assessment can improve your understanding and management of risks. See details in the sections about asset management strategies (Section 4.6) and cross-cutting adaptive management strategies (Section 4.8).
- **Consider climate change in the design of new infrastructure**. If your airport is making major, long-lasting capital expenditures, take the opportunity to ensure that the infrastructure will fulfill its intended useful life. That desired result requires planning for the expected weather conditions the infrastructure may experience over its lifetime. See details in the section on capital planning strategies (Section 4.5).
- **Learn from extreme weather events**. As extreme weather events occur, learn from them to improve emergency management and other planning efforts continuously. See details in the section on emergency management strategies (Section 4.7).

The next two chapters provide details on how to build support and use each of these systems, and others, to manage your climate risks.

CHAPTER 3

Build Support

Before you can identify, develop, and propose climate change integration strategies at your airport, you may need to build support. For some airports, managing climate risks may be new and will require diverse staff participation, collaboration, and financial support.

Approaches for gaining support can be top-down or bottom-up. A top-down approach is a change that comes from upper management, often acting as a directive for lower-level actions or decisions. Actions or decisions by a lower-level group or individual that create change come from bottom-up approaches. The following strategies can help you to build the support you need to manage climate risks.

3.1 Identify a Champion

Climate risk management initiatives may be most successful when a specific individual or team generates support for the effort. This champion, or champions, will drive climate change integration throughout and across your airport so that the function is considered in each management system planning cycle. The role of a champion is not to do all the work single-handedly, but to gather the support that is needed, foster collaboration, and sustain momentum for the effort.

In many cases, climate champion is not a formal job title but rather an unofficial role that a person adopts in addition to other duties.

3.2 Define Roles and Responsibilities

You can set up your group of climate risk management champions for success by maintaining clear, individual responsibilities as your needs and efforts progress. This clarification avoids any confusion that might arise from such a delegation of responsibilities. Actions that can help this effort include the following:

- **Establish goals and objectives.** Ensure that your team's goals, needs, and objectives are aligned before assigning individual tasks and actions. Revisit these goals and objectives throughout your climate change integration efforts to measure progress or to change these goals and objectives if needed.
- **Create specific responsibilities and roles of individuals and groups**. Once your goals are aligned, assign specific tasks, responsibilities, and roles for individuals or groups on your team. Take into account each individual's existing roles and responsibilities within the airport: some team members may be suited to a top-down or bottom-up approach for integrating climate change. For example, individuals involved in management system planning could ensure that climate change is visited at each planning meeting. In a top-down approach, team

members could incorporate an element of climate change education as part of airport-wide mandatory training exercises.

- **Set out timelines**. Once roles and responsibilities are set, attach your goals, objectives, and individual tasks to a timeline. Regularly monitor your progress and allocate resources to needed efforts.

3.3 Make the Case to Executive Management

Making the case for climate risk management to airport executives or senior management will help inform airport priorities, influence the amount of effort that individual departments will expend on climate risk management, and contribute to a coordinated approach to climate risk management at the airport.

You may find success in engaging your upper management about the risks and costs associated with climate change. Showing how climate risk management can save money, improve service reliability, and decrease workplace hazards is recommended. This handbook provides a template for making the case to executive management (see Appendix B).

When appealing to upper-level management, incorporate airport-wide strategic objectives and goals. The example template in Appendix A can support these efforts. Also see Section 3.5, which can help in developing methods for communicating the relationship between climate change and your airport's strategic objectives.

3.4 Build Support across Airport Departments

You can create a heightened awareness of climate risks by internal engagement and education. Examples of these activities include distributing a one-page summary of climate risks to staff across departments and hosting optional workshops and seminars where airport personnel can learn and discuss climate hazards and risks that you have identified in your self-assessment. Treat these events as introductory outreach efforts to solicit feedback and garner interest. You may find that you are not the only person at your airport actively seeking to integrate climate risks; other teams may have already begun efforts. You can use these engagement activities to identify those personnel, share experiences, and potentially begin collaborating.

If possible, commission internal exploratory efforts that foster collaboration to create climate change awareness. For example, the chief executive officer of the Jacksonville Aviation Authority tasked an internal group to work across management systems to determine airport climate risks and created awareness through collaboration (ACRP 2012a).

3.5 Coordinate with External Stakeholders

Airlines, other commercial airport tenants, fixed base operators, and concessions are dependent on airports for business continuity, regardless of climate or other conditions (ACRP 2013). Risk management exercises at your airport—including climate risk management—should involve these stakeholders in appropriate ways (ACRP 2013). For example, identify the stakeholders and decide whether and how they should be involved in your risk management processes. At a minimum, include these stakeholders in communication efforts to ensure that they are aware of the airport's planning.

Coordinating and collaborating with external stakeholders allows airports to address indirect climate risks. Indirect climate risks can affect your airport even if you cannot directly mitigate them. Examples of indirect risks may include disruptions to airport energy and water supply systems, disruptions to vulnerable transportation infrastructure providing airport access (e.g.,

local highway pavement failure), and delays or disruptions to other airport supply chains. Airport planners could share data or lessons learned in mitigating climate risks with external stakeholders who have greater control over these indirect risks.

3.6 Communicate Effectively

Keeping your message simple, focused, positive, and solution-based will help you to create empowerment and support. Use these additional steps to help your communication efforts:

- **Focus on climate risks and not the causes.**
  The science behind the forces that create climate change can be challenging to communicate and sometimes can create tension. Focusing instead on the risks, and those risks specific to your airport and region, can help simplify this message. Relying on clear historic examples and recent climate trends may help others grasp these risks. Sometimes stakeholders are more receptive to discussing severe weather or variable weather patterns, as the threats and risks from these events are often more relatable than climate change.
- **Acknowledge the uncertainty in climate projections.**
  Uncertainty in future climate values is a common challenge for airports and other entities. In many projections, the **direction of change is certain,** and scientists can often provide a minimum amount of expected change, but the exact amount of change is uncertain. Acknowledging the uncertainty in your communications could help open the conversation. The text box on page 3 provides additional information about acknowledging and working with uncertainty.
- **Keep the message positive.**
  Sometimes the vastness and the severity of climate risks can be overwhelming. While underscoring risks can motivate people to take action, a message that is too doom and gloom can have the opposite effect. Too negative a message can give the wrong impression that nothing can be done or may even push people into denial that the risks can possibly be true.
  A better approach is to focus your message on what people *can* do to mitigate climate risks and improve your airport's performance, whether as an individual or a team. Research shows that communication about climate change is most successful when hazards and risks are paired with solutions that connect with us on a personal level and empower the audience to engage further (ecoAmerica 2014). When people feel empowered to address a risk, they are more likely to act. Therefore, you do not necessarily want to dwell on extreme, worst-case scenarios, but rather outline realistic risks and then explain how it is in the airport's control to reduce those risks.
- **Focus on why this matters to the audience at hand.**
  While keeping your core points and objectives the same, you can tailor your message when targeting different audiences. For example, planners involved in emergency management will want to focus on the risks and hazards associated with severe weather events, while asset management personnel will be more interested in the impact on infrastructure maintenance and rehabilitation needs.
- **Tie communication efforts to airport-wide objectives.**
  Airport-wide objectives provide a driving motivator for action. Link your climate risk management objectives to the airport-wide mission, vision, values, objectives, and goals as described in the airport's strategic plan or other document. The example template in Appendix B (also available online) can help these efforts.
- **Develop and disseminate intuitional knowledge of risks.**
  Consider using your results from the self-assessment to create a summary of airport-specific climate risks that can be used throughout the airport. For example, you could simplify and summarize your output from Table 3. This summary could assist other airport managers to begin thinking through potential impacts to their own management systems, and expedite your climate risk integration efforts.

CHAPTER 4

Take Action to Integrate Climate Risks

Thus far, the handbook has helped you to identify climate hazards, climate-related risks to your airport, and the management systems now in place that are best suited to address these risks. This chapter provides you with strategies for using existing management systems to manage those climate risks.

Other Management Systems

This handbook focuses on common management systems with the greatest opportunities for mitigating climate risks. However, you may find that your airport has management systems related to climate risks not addressed in this handbook.

For example, changes in precipitation may impair your control of runoff pollutants (e.g., glycol from deicing), affecting your environmental management system. You could apply similar strategies to those presented in this handbook to manage climate risks through environmental management systems or others not covered explicitly.

To help you with those management systems, see Section 4.8 for cross-cutting strategies that may be applicable for many management systems.

This chapter includes

- Specific strategies for addressing climate risk through the following management systems:
  - Strategic planning (Section 4.1),
  - Master planning (Section 4.2),
  - Enterprise risk management (Section 4.3),
  - Safety management (Section 4.4),
  - Capital planning (Section 4.5),
  - Asset management (Section 4.6), and
  - Emergency management (Section 4.7) and
- Cross-cutting adaptive management strategies that apply across multiple management systems (Section 4.8).

Airports may have varying levels of interest in climate risk management. Therefore, the handbook provides integration strategies in a recommended priority order, so that each airport can successively build on its efforts over time.

For each of the management system sections (Sections 4.1–4.7), the handbook summarizes the basic steps of that system, identifies the best opportunities (i.e., entry points) for integrating climate risk, and provides details on specific strategies that your airport can use to take advantage of each of these entry points.

4.1 Strategic Planning Strategies

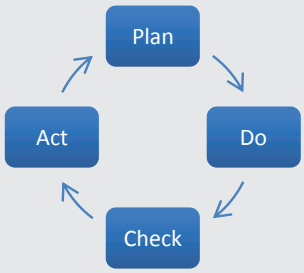
Strategic planning is a process that airports use to define their vision for the future and formulate a road map for achieving that vision (ACRP 2009). Strategic planning outlines the long-term direction of the airport and often lays the foundation for other planning and management systems.

Strategic planning, therefore, can be used to help an airport define its long-term vision and strategy related to managing its climate risks. As noted in Section 2.3, this function is most likely to be

Overview of Management System Flowcharts

This handbook provides a flowchart for each of the seven management systems (e.g., Figure 11). Each flowchart has three main components:

1. **Overview of the main steps of a system.** This is the base layer of each flowchart, and it organizes the main steps of each system into the International Organization for Standardization (ISO) Plan-Do-Check-Act framework (ISO 2015). This four-step framework, defined below, is intended to help you align the flowchart steps with your own planning process, even if you do not have a formal management system or do not follow the steps exactly as outlined.



Plan	Define scope and objectives. Collect and analyze data. Identify risks/problems. Develop a plan to solve problems/meet objectives.
Do	Implement plan.
Check	Verify plan meets objectives by monitoring and measuring.
Act	Improve process effectiveness based on findings. Integrate with future decision-making.

2. **Climate entry points.** In the boxes, the flowcharts identify suggested climate entry points to integrate climate risk into your planning processes. The climate entry points are listed alphabetically in recommended priority order. Depending on your planning process and capacity to address climate integration, some entry points may be more relevant than others. The remainder of each section details how to take advantage of each possible entry point.
3. **Climate integration actions.** The flowcharts provide integration actions associated with each entry point. Your airport can take these actions at that step to integrate climate risk into the management system.

Example: Managing Climate Risk Through Strategic Planning

An airport's air service demand and revenues are highly dependent on ski-related tourism.

The airport realizes that climate change may increase uncertainty in ski-related tourism—warmer temperatures can affect snowpack not just in the airport's own market, but in other competing markets. Depending on the year and the location of the snowfall, winter demand could vary considerably.

Therefore, the airport uses strategic planning to create local partnerships with ski resorts, the chamber of commerce, and public officials to diversify tourism offerings and ensure continued service demands and local economic health.

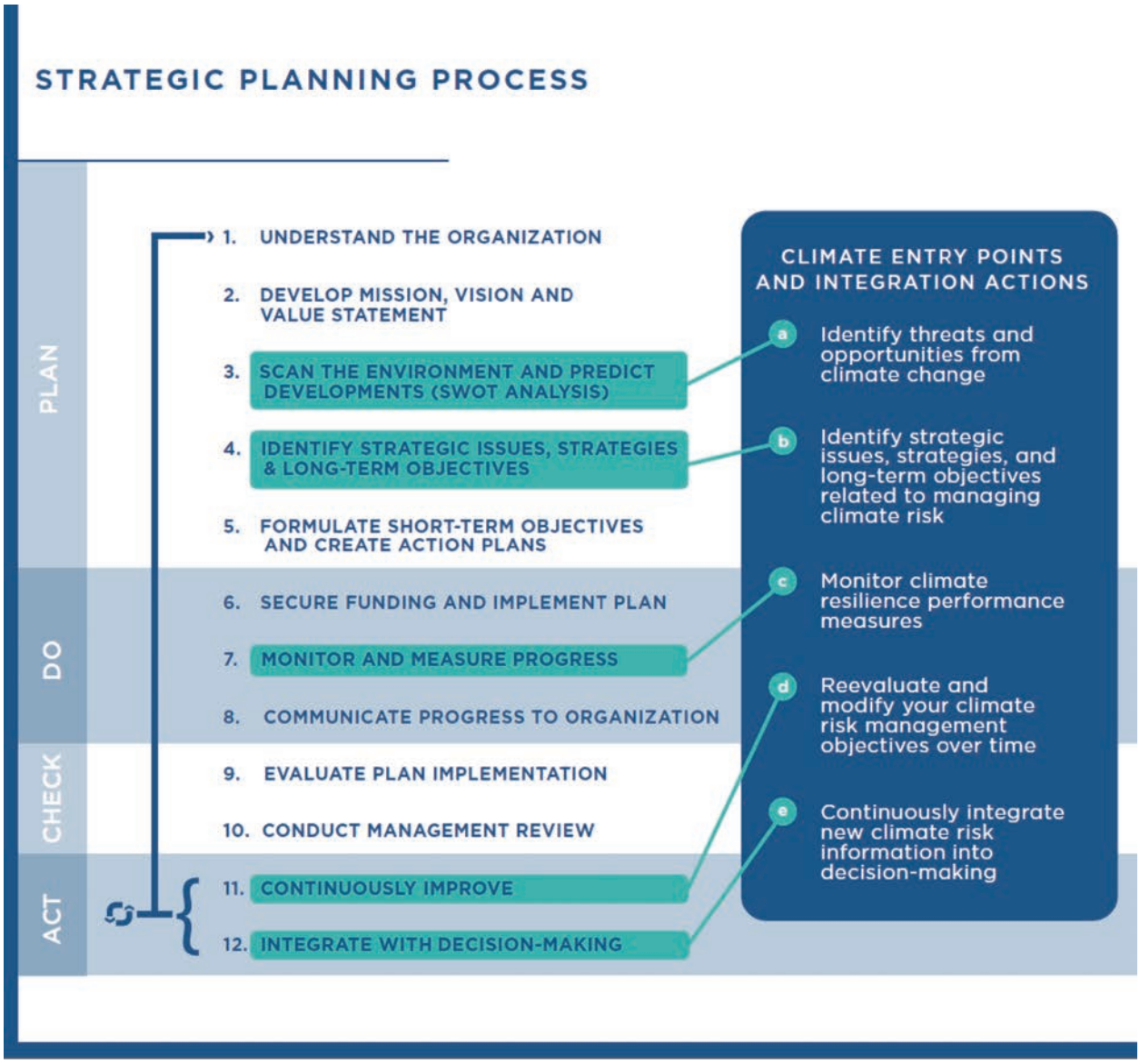


Figure 11. Strategic planning system overlaid with climate entry points and integration actions.

Links to Other Management Systems

Airport management systems are inter-related. For example,

Strategic planning **informs**
- – Capital planning and
- – Department/tactical level planning and

Strategic planning **is informed by**
- – Aviation forecasts and facility requirements,
- – Capital planning, and
- – Department/tactical level planning.

applicable when airports face severe risks, such as a low-lying coastal airport dealing with flooding and property loss from sea level rise and an airport with significant climate-related air service demand (e.g., for skiing). Such airports can use strategic planning to review these climate risks in context with other threats and opportunities and articulate a vision that allows the airport to thrive despite these risks. As with other elements of the strategic plan, this vision and specific objectives can flow down through all other airport management systems in a top-down approach to address climate risks.

Examples of mitigating climate risk through strategic planning follow:

- Identifying airport-wide hazards that threaten operations or expansion plans,

- Setting a climate risk management objective to limit service disruptions from a specific climate hazard, and
- Creating metrics to monitor operational performance during extreme weather events over time.

4.1.1 Climate Risk Management Overview

There are five entry points for integrating climate risk management within the strategic planning process, as shown in Figure 11. Not all entry points are necessary for any climate risk management to occur, but airports can build on each entry point to successively increase the level to which they manage climate risks.

In recommended priority order, the entry points are

a. Scan the environment and predict developments (SWOT analysis);
b. Identify strategic issues, strategies, and long-term objectives;
c. Monitor and measure progress;
d. Continuously improve; and
e. Integrate with decision-making.

The next section explains how your airport can take advantage of each entry point for integrating climate risk.

4.1.2 Climate Risk Management Steps

A. Scan the environment and predict developments [analysis of strengths, weaknesses, opportunities, and threats (SWOT): identify threats and opportunities from climate change

In this planning step, airports typically compile and assess all relevant information for current and future impacts to operations and service levels. This step offers a key opportunity to identify threats and opportunities from climate change and to evaluate those threats and opportunities alongside others.

For example, in 2010 San Diego International Airport collaborated with the local government effort to identify vulnerabilities to sea level rise. The effort found that portions of the airfield were vulnerable to flooding and inundation, impacting the airport's expansion plans for new terminals. As a result, the airport began to incorporate sea level rise scenarios into strategic planning efforts to reduce current and future vulnerabilities (ACRP 2012a).

Follow the same process to complete the analysis of strengths, weaknesses, opportunities, and threats (SWOT) for other threats and opportunities. As needed, draw from climate risk information collected during the self-assessment on the expected timing and type of impacts or conduct a more detailed analysis if needed. Consider the following:

- **Evaluate hazards identified in self-assessment.** In the SWOT analysis, you should carefully consider how the climate hazards identified in the self-assessment may impact current and future planning efforts.
- **Prioritize climate risks to existing planning and operations.** You may have identified several climate risks in the self-assessment, with some posing greater threats than others in the short term. For example, your airport may already be experiencing increased disruptions from more frequent and more severe storms. You may want to prioritize this short-term climate risk over others that are more relevant in the long term, such as changes in service levels associated with warmer temperatures.

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B. Identify strategic issues, strategies, and long-term objectives: identify strategic issues, strategies, and long-term objectives related to managing climate risk

Once you've completed the SWOT analysis, evaluate all threats and opportunities (including those related to climate change) to identify strategic issues, strategies, and long-term objectives. This step is the essence of articulating climate-related priorities within the strategic plan, as needed. These priorities or objectives could be high level (e.g., reduce risks from extreme weather) or more specific about managing a specific risk, such as uncertain passenger levels. Your objectives need not be exclusively climate specific. Several climate risk management strategies or objectives will have co-benefits of managing other types of risk; conversely, strategies to reduce the risk of any hazard will also help manage climate risks. Examples include the following:

- The Denver International Airport (DEN) strategic plan includes "investing for sustainability" as an objective: "Remaining financially healthy, staying operationally efficient, and working to improve our environment and our neighborhood are key components of our sustainability objectives" (DEN, n.d.). This is not an explicit example of a climate risk management objective, but one could be similar.
- The Dallas–Fort Worth International Airport (DFW) strategic plan includes the following strategic objectives and initiatives (DFW 2016). Although these are not explicitly related to climate change, they nevertheless would have a co-benefit of reducing climate risks:
  - Delivering the ultimate customer service. Master the basics (initiatives include managing irregular operations to minimize customer disruption).
  - Focusing on employee engagement. Develop sustainable leadership capabilities (initiatives include implementing a biennial succession planning process).
  - Achieving operational excellence. Implement processes to improve airport operational efficiency (initiatives include opening a new fully integrated, airport-wide Airport Operations Center and Emergency Operations Center to enable DFW to provide situational awareness, proactive response, incident management, and review).
  - Ensuring a safe and secure environment. Establish an organizational resilience framework to strengthen DFW's capacity to react, respond, and recover from threats by fiscal year 2018 (initiatives include conducting an airport-wide vulnerability assessment for critical assets and developing resilience metrics).

C. Monitor and measure progress: monitor climate resilience performance measures

Assuming that you identify climate risk management or climate resilience as a strategic objective, set and monitor performance measures for that objective—just as you would for any strategic objectives.

Climate risk management performance measures may include the following:

- Existing performance measures that could help track impacts of climate risks, such as number of enplanements and pavement condition. Consider monitoring these performance measures more closely in relation to your climate risks, for example, determining if there is a trend of increased pavement failures in relation to increased average temperatures.
- New performance measures specific to climate risk management. For example, if you are seeking to manage coastal flood risk, set a performance measure for the number of times the airport experiences flooding.

Section 4.8 and Appendix C provide more information on potential data metrics and performance measures for climate risk management.

D. Continuously improve: reevaluate and modify your climate risk management objectives over time

As you would for any other strategic issues, strategies, or long-term objectives, continuously improve your management of climate risks. This is particularly important in the context of climate risks because your understanding of the risks will change over time. See Section 4.8 on adaptive management.

E. Integrate with decision-making: continuously integrate new climate risk information into decision-making

As you would for any other strategic issues, strategies, or long-term objectives, periodically review data on performance measures to understand and improve your performance. After review, refine your strategic issues, strategies, and objectives as needed to ensure you are meeting your objectives. See Section 4.8 on adaptive management.

4.2 Master Planning Strategies

Master planning is a required process for Part 139 airports to assess the current capacity of the airport's infrastructure, evaluate current and projected demand, and identify existing and anticipated deficiencies (ACRP 2012c). Master plans typically have a 20- to 25-year planning horizon and are updated every 5 years. Master planning outlines the short-, medium-, and long-term development goals for the airport, pulling from the strategic plan and laying the foundation for a number of other planning and management systems (ACRP 2012c).

Accounting for climate change in master planning is critical to managing climate risks to infrastructure capacity. Climate hazards could threaten operational capacity and infrastructure conditions. If these hazards are not incorporated into master planning, the airport may not be able to meet its projected demand and development goals.

Examples for mitigating climate risk through master planning include

- Evaluating trends in existing conditions that could affect aviation forecasts and tourism travel,
- Upgrading infrastructure to accommodate climate change hazards, and
- Creating metrics to monitor infrastructure capacity and operational performance during extreme weather events over time.

Example: Managing Climate Risk Through Master Planning

An airport has two runways that have limited capacity under extreme heat events.

The airport realizes that climate change may increase the frequency and the severity of extreme temperature events, which may limit the number and size of planes able to take off.

Therefore, the airport uses its master planning process to consider appropriate resilience measures, which range from infrastructure changes (e.g., building longer runways) to operational changes (e.g., planning for situations where certain aircraft might not be able to take off).

Links to Other Management Systems

Airport management systems are inter-related. For example,

Master planning **informs**
- – Strategic planning,
- – Capital planning, and
- – Department/tactical level planning and

Master planning **is informed by**
- – Strategic planning,
- – Capital planning, and
- – Department/tactical level planning.

4.2.1 Climate Risk Management Overview

There are six entry points for integrating climate risk into existing master planning processes, as shown in Figure 12. Not all entry points are necessary for any climate risk management to occur, but your airport can build on each entry point to increase successively the level at which you manage climate risks to infrastructure capacity.

Figure 12. Master planning system overlaid with climate entry points and integration actions.

The entry points, in the recommended priority order, follow:

a. Conduct existing conditions survey.
b. Develop and evaluate alternatives: assess environmental impact of analysis.
c. Develop and evaluate alternatives: develop airport layout plan.
d. Monitor and measure progress.
e. Continuously improve.
f. Integrate with decision-making.

The next section explains how your airport can take advantage of each entry point for integrating climate risk.

4.2.2 Climate Risk Management Steps

A. Conduct existing conditions survey: evaluate how climate change could affect aviation forecasts or facility requirements

In this planning step, airport managers typically assess the existing conditions of infrastructure capacity and demand. An existing conditions survey is used to assess existing infrastructure, community and market conditions, economic forecasts, and operating revenues, expenses, funding sources, and funding uses (ACRP 2012c). The existing conditions survey sets the foundation of your master plan and feeds into facility requirements and forecasts. This step offers a key opportunity to evaluate how climate change could affect your infrastructure capacity and demand.

In the context of climate change, the existing conditions survey provides an opportunity to identify climate data, models, and trends early in the master planning process. Existing conditions surveys based on current conditions and historical trends can be modified to include projected trends in climate. You should draw from climate hazard data collected during the self-assessment or from other sources to develop climate-related metrics to inform your existing conditions survey. In addition to assessing climate change-related impacts, compare these findings to other potential impacts to infrastructure capacity and demand forecasts to help you prioritize or coordinate your efforts. Conduct additional analysis if needed.

Climate hazards may present risks to aviation forecasts and facility requirements. In some cases, climate change may result in opportunities for aviation forecasts if you experience a more favorable climate for tourists in the northern latitudes. Example climate change impacts that may affect infrastructure or passenger demand include the following:

- Extreme temperatures can increase the rate of pavement deterioration.
- Heavy precipitation events can reduce the adequacy of drainage systems and thereby increase the risk of flooding.
- Changes in snowfall may affect tourism and seasonal enplanements.
- Wildfires may increase the frequency of smoke-related visibility disruptions.
- Sea level rise may cause more frequent inundation of low-lying coastal areas.
- Increased storm surge depth and extent can damage infrastructure.

The following steps can help you integrate climate considerations into your existing conditions survey:

- **Understand your existing organization/facility.** Understand how your organization operates currently. You may not be aware of internal barriers to organizational procedures that may hinder integration efforts. There may also be external opportunities or barriers, depending on the current goals of the local government. These goals can change with each administration; such changes will likely affect your airport's funding or goals. Other external influences, such as constricted water resources from a nearby drought, may affect your supply chain
- **Evaluate hazards identified in the self-assessment.** Use the self-assessment to understand how climate change could affect existing conditions, such as normal temperature range, frequency of different hazards, and travel demand.
- **Incorporate climate information into level of service forecasts.** Analyze whether trends in level of service requirements, such as a decrease in winter tourism, are influenced by climate. If level of service requirements are sensitive to changes in climate, consider finding or commissioning an analysis to determine whether climate change would change level of service forecasts. Although some studies have tried to model how climate change may affect tourism demands, a number of uncertainties are associated with these models because of the complexity of the metric (Gossling et al. 2012). Gossling et al. (2012) assessed the existing literature and concluded that climate change does affect tourism, but the degree and direction of change are difficult to quantify.

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- **Prioritize immediate climate risks to existing infrastructure and aviation forecasts.** As infrastructure is reviewed on its regular schedule, consider how and when climate may impact infrastructure capacity and whether changes need to be made in the short or long term.

B. Develop and evaluate alternatives and assess environmental impacts of alternatives: consider impact of climate change through environmental analyses

In this step, your airport's planners typically conduct environmental impact analyses to document environmental conditions that should be considered in alternative development (FAA 2015). Alternative development is used to assess and evaluate the operational, environmental, and financial performance of a variety of options for meeting projected facility requirements (FAA 2015). This step of your process provides an opportunity to incorporate climate change impacts into your environmental analyses to help develop and evaluate alternatives.

This climate entry point allows you to consider how climate change hazards may affect your environmental analyses of alternatives. Environmental conditions documented in and around your airport are referenced when developing alternatives (FAA 2015). Environmental considerations often include air and water quality, floodplains, and endangered and threatened species. You should draw from the climate hazard data collected during the self-assessment or other sources to add these conditions to your environmental analysis and alternative development process. You should also consider any climate implications determined during the existing conditions survey.

The following resources can help you integrate climate considerations into your environmental analyses:

- Council on Environmental Quality. *Final Guidance for Federal Departments and Agencies on Considerations of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act (NEPA) Reviews.* Guidance for considering climate change and climate change adaptation in the NEPA review process. This guidance is no longer required by executive order, but nonetheless provides information on how organizations could voluntarily consider climate change in environmental reviews.
- NOAA. U.S. Climate Resilience Toolkit. Variety of resources and case studies for addressing climate risks and increasing climate resilience.
- U.S. Department of Transportation. Sensitivity Matrix. Guidance for identifying the threshold at which a specific asset type becomes sensitive, historical precedents for climate-related damage to that asset type, and features of the asset that may be more sensitive.
- Federal Highway Administration (FHWA). Climate Change and Extreme Weather Vulnerability Assessment Framework. Flexible framework for considering climate risk.

C. Develop and evaluate alternatives and develop airport layout plan: consider whether infrastructure changes are needed to accommodate climate change

In this step, your airport's planners typically develop an airport layout plan of existing facilities and proposed developments based on aviation forecasts, facility requirements, and alternatives analysis, in line with FAA Advisory Circular 150 (FAA 2015). The airport layout plan is a set of drawings graphically representing the long-term development plan of your airport (FAA 2015). Your airport uses the layout plan to inform decision-making, plan for facility improvements, and make sure design standards and safety requirements are met (FAA 2015). This step offers a key opportunity to consider managing climate risks to infrastructure through your airport layout plan.

This climate entry point allows you to integrate potential climate change hazards to facility requirements or aviation forecasts into your guiding airport layout plan. The plan includes both existing airport facilities and proposed developments and is supported by aviation forecasts, facility requirements, and alternatives analysis (FAA 2015). You should draw from the climate hazard data collected during the self-assessment or from other sources. You should also consider any climate implications determined during the existing conditions survey.

You may need to adjust your airport layout plan to accommodate climate risks. For example, if sea level rise is threatening your airport, you may need to account for major stormwater system upgrades, or if you are planning additions to your runway, you should consider how projected temperature change may factor into the length of the runway. The following steps can help you integrate climate considerations into your airport layout plan:

- **Assess the time horizon of your identified climate hazards.** Using your self-assessment results and airport layout plan, assess whether climate hazards will affect infrastructure in the short or long term and adjust your airport layout plan accordingly. You may want to prioritize short-term climate hazards to critical infrastructure.
- **Incorporate climate change considerations into design requirements.** Using your existing conditions survey and your self-assessment results, you should amend your design requirements for level of service requirements and alternative development and evaluation processes. Although specific climate hazards or considerations may vary across assets and facilities, general requirements should be developed for use within master planning and across other management systems. For example, the Toronto Pearson International Airport (YYZ) updated its cyclical review of potential stormwater flows to integrate projected increases in severe weather events due to climate change into its hydraulic modeling and pipe sizing engineering design practices throughout airport projects and systems (ACRP 2016b).

D. Monitor and measure progress: monitor climate resilience performance measures

Assuming that you identify climate risk management or climate resilience as a key objective of the master plan, set and monitor performance measures for that objective—just as you would for any other.

Climate risk management performance measures may include the following:

- Existing performance measures that could help track impacts of climate risks, such as number of enplanements and pavement condition. Consider monitoring these performance measures more closely in relation to your climate risks; for example, you could determine if there is a trend of increased pavement failures in relation to increased average temperatures.
- New performance measures specific to climate risk management. For example, if you are seeking to manage coastal flood risk, set a performance measure for the number of times your airport experiences flooding.

Section 4.8 and Appendix C provide more information on potential data metrics and performance measures for climate risk management.

E. Continuously improve: reevaluate and modify your climate risk management objectives over time

As you would for any other strategic issues, strategies, or long-term objectives, continuously improve your management of climate risks. This is particularly important in the context of climate risks because your understanding of the risks will change over time. See Section 4.8 on adaptive management.

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F. Integrate with decision-making: continuously integrate new climate risk information into decision-making

As you would for any other strategic issues, strategies, or long-term objectives, periodically review data on performance measures to understand and improve your performance. After review, refine your existing conditions survey, environmental analysis, and airport layout plan as needed to align your decision-making process better. See Section 4.8 on adaptive management.

4.3 Enterprise Risk Management Strategies

Enterprise risk management allows airports to assess and mitigate the risk created by uncertainty. Common airport risk management practices include changing infrastructure and operations protocols and conducting risk analyses to select insurance coverage for potential service interruptions (ACRP 2015a).

Climate risks are created by uncertainty and can be a natural fit in the enterprise risk management planning structure.

Examples of mitigating climate risk through enterprise risk management include the following:

- Identifying climate risks that could create service disruptions or threaten existing infrastructure,
- Seeking new insurance policies to account for identified climate risks, and
- Adapting training protocols to help internal stakeholders better understand climate risks and how to account for them in day-to-day operations.

Example: Managing Climate Risk Through Enterprise Risk Management

An airport needs to mitigate financial risks associated with service disruptions from severe storms.

The airport realizes that climate change may increase the frequency and the severity of storms, but needs to understand better the uncertainty of these changes by assigning a probability to different storm events.

The airport can use its existing enterprise risk management process to identify and prioritize this risk, with climate model projections to assign probabilities to these changing frequencies and severities of storms.

Links to Other Management Systems

Airport management systems are inter-related. For example,

Enterprise risk management **informs**
- Strategic planning,
- Safety management, and
- Capital planning and

Enterprise risk management **is informed by**
- Strategic planning,
- Capital planning,
- Master planning, and
- Asset management.

4.3.1 Climate Risk Management Overview

There are seven entry points for integrating climate risk into existing enterprise risk management processes, as shown in Figure 13. Not all entry points are necessary for any climate risk management to occur, but your airport can build on each entry point to increase successively the level at which you manage climate risks to infrastructure capacity.

The entry points, in recommended priority order, follow:

a. Identify risks.
b. Develop risk response plans (mitigation strategies).
c. Secure funding and implement plan.
d. Provide enterprise risk management training.
e. Monitor and measure progress.
f. Continuously improve.
g. Integrate with decision-making.

The next section explains how your airport can take advantage of each entry point for integrating climate risk.

4.3.2 Climate Risk Management Steps

A. Identify risks: identify threats from climate change

Airport planners use risk identification to determine all relevant threats to airport operations, infrastructure, and safety. In the risk

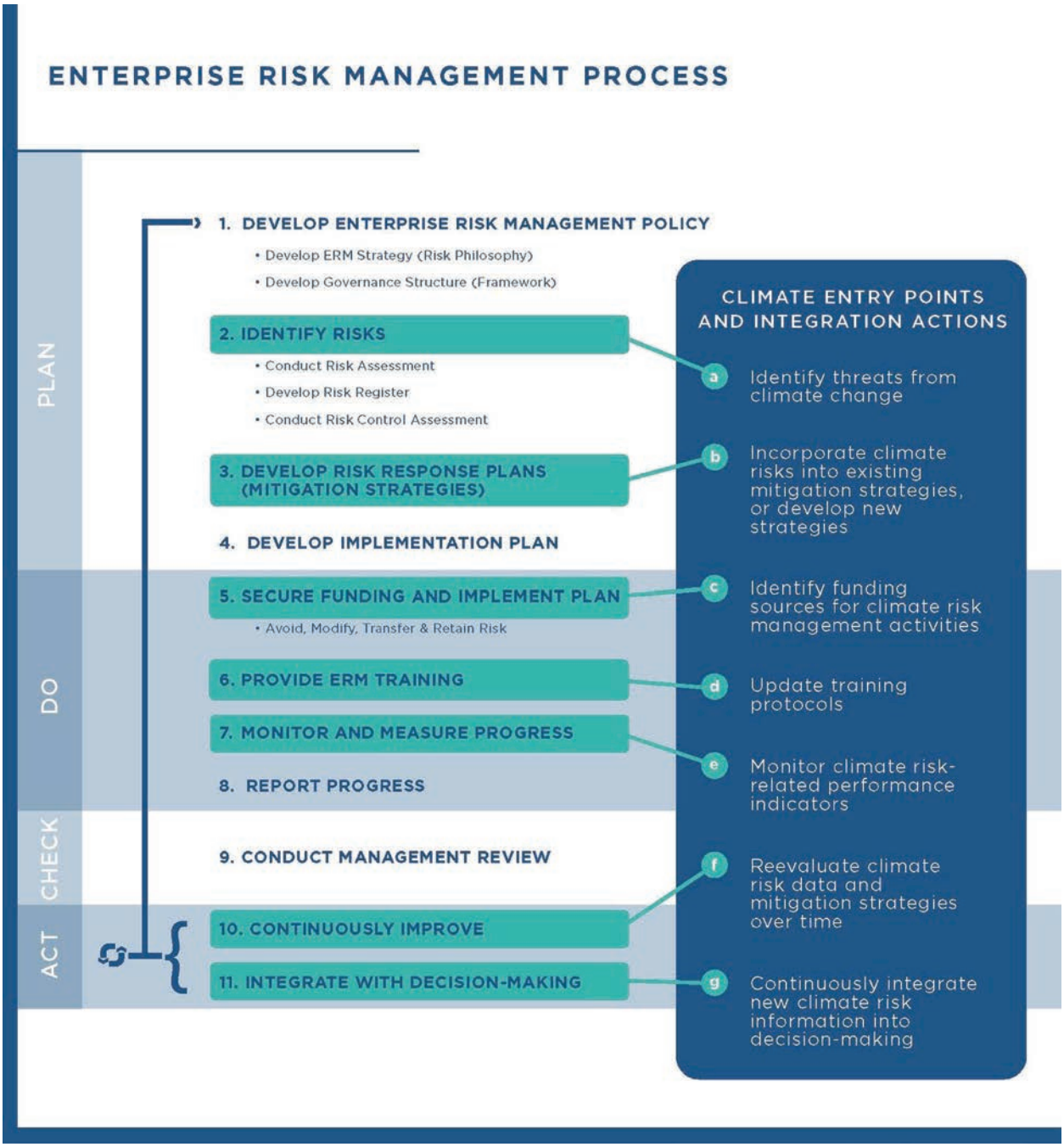

Figure 13. Enterprise risk management system overlaid with climate entry points and integration actions.

assessment and risk register, your planners can expand on hazard data from the self-assessment to generate risk projections and uncertainty analyses. To create a climate-resilient risk management system, you first need to have an accurate assessment of what climate risks are relevant for your airport. In risk identification, you can use the self-assessment results to incorporate climate risks into the existing identification process. This entry point is critical, as it will guide the actions of all subsequent steps in enterprise risk management.

Past risk identification efforts at your airport may not account for future climate change. Using your identified climate hazards and risks from the self-assessment, you should

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examine all steps in the risk identification process where these data may be needed to account fully for risks.

- **Incorporate self-assessment results into the risk assessment.** In the supporting analysis for the risk assessment, use the self-assessment outputs to account for climate hazards and risks. You may need to extend your climate analysis beyond the scope of the self-assessment; this process could entail generating climate hazard and risk projections in greater detail. You will also need to incorporate the uncertainty associated with your climate hazard and risk data into your risk assessment.
- **Prioritize climate risks in the risk register.** On the basis of your self-assessment outputs, you can determine that some climate hazards may present greater risks than others. Some climate risks may be more immediate, and others may be a greater threat in the long term. When developing your risk register, prioritize your climate risks on the basis of this information. This stop will allow you to better allocate resources and efforts to mitigating climate risks.
- **Develop methods for incorporating uncertainty into climate risk assessments.** Climate change uncertainty can be intimidating because of the many variables that influence projected climate hazards. However, climate change uncertainty should not be treated differently from other uncertainties. Rely first on common tactics for reducing uncertainty, such as using a wide range of data and identifying which modeling assumptions may need refining over time. Climate projections can also provide a level of likelihood and probability for helping define risk:
  - Qualitative probabilities can give a basic understanding of how likely a projection result is. For example, ACROS provides a low, moderate, and high confidence rating for different model outputs. You can develop similar methods for grouping and prioritizing hazards on the basis of a qualitative likelihood (e.g., more likely than not, likely, extremely likely).
  - Quantitative probabilities are sometimes attached to certain climate hazards. You may have familiarity with these probabilities in the historical context, such as storm occurrence probabilities (e.g., a 5-year storm reflects a 1 in 5 chance of occurring in any given year). Climate projections will give you a range of outputs for these probabilities and will allow you to sort and quantify uncertainty for some climate hazards.

B. Develop risk response plans (mitigation strategies): incorporate climate risks into existing mitigation strategies, or develop new strategies

Your airport then typically generates mitigation strategies based on the analysis performed during the risk identification step. Your airport can incorporate this information into existing mitigation efforts or develop new strategies for climate risks not currently accounted for. With the climate risks identified and incorporated into the risk assessment, you can move on to developing mitigation strategies for reducing the current and future impacts from climate risks.

- **Share risk information to coordinate mitigation efforts.** Many management systems will need to review and revise existing protocols to incorporate climate risks. Asset management, emergency management, and safety management systems all could immediately benefit from the climate projection data obtained in the risk identification process. Determine methods for communicating the most valuable data to planners in different parts of your airport.
- **Seek low-cost options for mitigating climate risks in the short term.** Your airport's ongoing efforts in design, construction, or procurement may be able to support climate risk mitigation through small changes with little added cost. For example, if you identify extreme precipitation as a current and future risk and your airport is actively revamping stormwater controls, suggest small design or active construction modifications, such as a larger stormwater retention pond, that could help mitigate climate risks.

- **Identify insurance plans and providers that address climate risks.** Many insurance providers have unique methods for incorporating climate risks into policies and may be able to assist you in selecting policies that address your identified climate hazards and risks while reducing your future financial risks. Your efforts in managing climate risks could help reduce insurance expenses as well, as new insurance frameworks for catastrophe bonds (i.e., natural disaster insurance) may provide rebates for investments in climate risk management projects (Re:focus Partners 2015).
- **Develop a Business Continuity Plan (BCP) or Continuity of Operations Plan (COOP).** BCP, also known as continuity of operations planning for many public-sector organizations, is "the process of developing a roadmap for continuing operations under adverse conditions and during disruptions caused by all types of incidents, emergencies, and crises" (ACRP 2013). This plan is a "natural adjunct" to enterprise risk management. A BCP is considered a good business practice and a strategic way to manage risks of all kinds. Changing climate hazards and climate risks further increase the value proposition for incorporating business continuity planning at your airport.

For additional information about developing a BCP, see *ACRP Report 93: Operational and Business Continuity Planning for Prolonged Airport Disruptions* (ACRP 2013). Small airports may also refer to *ACRP Synthesis 78: Continuity of Operations Planning for Small Airports* (ACRP 2016a).

C. Secure funding and implement plan: identify funding sources for climate risk management activities

Implementing your risk management plan requires the coordination of many parties and financial supports. If internal funding is unavailable, external sources for climate risk management may be available and can help you in implementation. Your airport may have significant climate risks, and you should integrate these new risks with your risk management spending models to maximize the use of available internal funding. Climate risk management costs can vary: some climate risk mitigation may be small-scale, such as a small addition to a developing facility design, and some may be large infrastructure projects. For the larger projects, you may not have the needed available internal funding. Seeking external resources may fill this funding gap.

For more information on assessing climate risk costs and project funding, see the section on capital planning strategies (Section 4.5).

- **Federal resources.** Work with your contacts at FAA and other federal agencies [e.g., Environmental Protection Agency (EPA), FHWA, Federal Emergency Management Agency (FEMA)] to understand better what funding may be available to support your climate risk management goals. Infrastructure funding opportunities can be diverse and spread across many federal agencies. Consultants may be a helpful resource in writing grant applications and performance analyses for this funding, as these tasks may be difficult to accomplish with airport personnel.
- **State and local resources.** Depending on your region, local and state resources may be available. For example, California state agencies often offer grant funding to municipal agencies and entities to help comply with state climate risk management goals.

D. Provide enterprise risk management training: update training protocols

Update your training protocols to include the identified climate risks, risk assessment results, and modified or new mitigation strategies. Consider that airport personnel may have little experience with climate hazards and risks. Addressing your airport's climate risks will require collaboration and contributions at all levels of airport operations and management. Use this opportunity to increase climate risk awareness, educate about the threats and impacts of

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climate risks, solicit feedback on risk mitigation, and garner support. See Chapter 3 for more information.

Leverage training resources from existing reports or local efforts to help develop these new training protocols. For example, the City of Fort Lauderdale launched a climate change training program for all city employees (Dreaming Green 2015).

E. Monitor and measure progress: monitor climate risk-related performance indicators

Monitor and measure service disruptions, personnel and stakeholder safety, and financial costs related to identified climate hazards and risks. Track how current performance compares with historical data, with a focus on specific mitigation strategies implemented to reduce these impacts. See Section 4.8 and Appendix C.

F. Continuously Improve: reevaluate climate risk data and mitigation strategies over time

This step allows you to reevaluate how climate hazards and risks are being incorporated into your enterprise risk management process. See Section 4.8 on adaptive management. Important questions to consider follow:

- Are new climate modeling data available?
- Do new hazards need to be considered?
- How have we performed in relation to specific climate hazards (e.g., extreme heat, increased frequency of severe storms)?
- Has our climate risk management progress matched airport-wide objectives?

G. Integrate with decision-making: continuously integrate new climate risk information into decision-making

Integration with decision-making ensures that your identified climate risks are being considered at all levels of enterprise risk management. Continuously coordinate with risk management personnel to help overcome barriers that may arise when incorporating climate risk considerations. See Section 4.8 on adaptive management.

4.4 Safety Management Strategies

A safety management system (SMS) is a process to manage safety risks through systematic procedures, practices, and policies including safety risk management, safety policy, safety assurance, and safety promotion (FAA 2007).The SMS is a proactive process to improve communication and minimize safety risks (ACRP 2007a).

The SMS provides a way to manage climate-related safety risks to employees, contractors, and the general public. If climate-related safety hazards are not incorporated into an SMS, the airport may be unprepared for extreme weather conditions that create new or increased safety risks such as heat stress to outdoor workers.

Some examples for mitigating climate risk through an SMS include

- Shifting construction schedules to reduce heat exposure for outdoor workers during a period of extreme heat;
- Acquiring more snow equipment to minimize safety risks to passengers, workers, and aircraft during more frequent or more severe winter storm events; and
- Identifying areas of the airport facility prone to flooding in advance of a heavy rain event, along with any potential environmental contamination risks due to flooding.

Example: Managing Climate Risk Through Safety Management

A Midwestern airport is planning to start a major construction project over the summer and is conducting a safety risk assessment.

For the past 10 years, extreme heat has not been identified as a potential safety risk during construction projects. However, the airport realizes that past risks are not representative of future risks. Therefore, the airport reviews recent weather station records and determines that hazardous working conditions (e.g., days with a dangerous heat index) have become more frequent in recent years. The safety risk assessment process updates the expected likelihood of extreme heat conditions accordingly.

Because extreme heat is identified as a risk during the safety risk assessment, the airport then identifies strategies to mitigate that risk in the event of a heat wave, such as establishing a heat plan to inform workers of the signs of heat stress, creating cooling or hydration stations on site, and adjusting the construction schedule for more work to be completed overnight.

4.4.1 Climate Risk Management Overview

There are six entry points for integrating climate risk into existing asset management processes, as shown in Figure 14. Not all entry points are necessary for any climate risk management to occur, but your airport can build on each entry point to successively increase the level to which you manage climate risks to infrastructure.

The entry points, in recommended priority order, follow:

a. Identify risks/hazards.
b. Provide SMS training.
c. Design SMS.
d. Monitor and measure progress.
e. Continuously improve.
f. Integrate with decision-making.

The next section explains how your airport can take advantage of each entry point for integrating climate risk.

Links to Other Management Systems

Airport management systems are inter-related. For example,

Safety management **informs**
- – Enterprise risk management,
- – Emergency management,
- – Strategic planning, and
- – Capital planning and

Safety management **is informed by**
- – Strategic planning,
- – Enterprise risk management, and
- – Emergency management.

4.4.2 Climate Risk Management Steps

A. Identify risks/hazards: include risks from climate change and extreme weather events in risk/hazard identification

In this step, your airport conducts safety risk assessments to evaluate the level of risk associated with a particular hazard and to prioritize their highest risks (ACRP 2007b). A safety risk assessment typically consists of a risk matrix evaluating levels of severity and likelihood to produce a final risk assessment code or value, which can be used to identify the greatest risks.

Identify climate-related safety risks in your safety risk assessment, starting with those identified in the self-assessment (Section 2.2 and Appendix A). This process is similar to determining local climate change hazards using the 5M model used

The 5M Model

5M Elements	Self-Assessment Risk Categories
Mission	Operational and business impacts
(Hu)Man/ person	Safety and security impacts
Machine	Physical impacts, operational and business impacts
Management	Operational and business impacts
Media	Environment

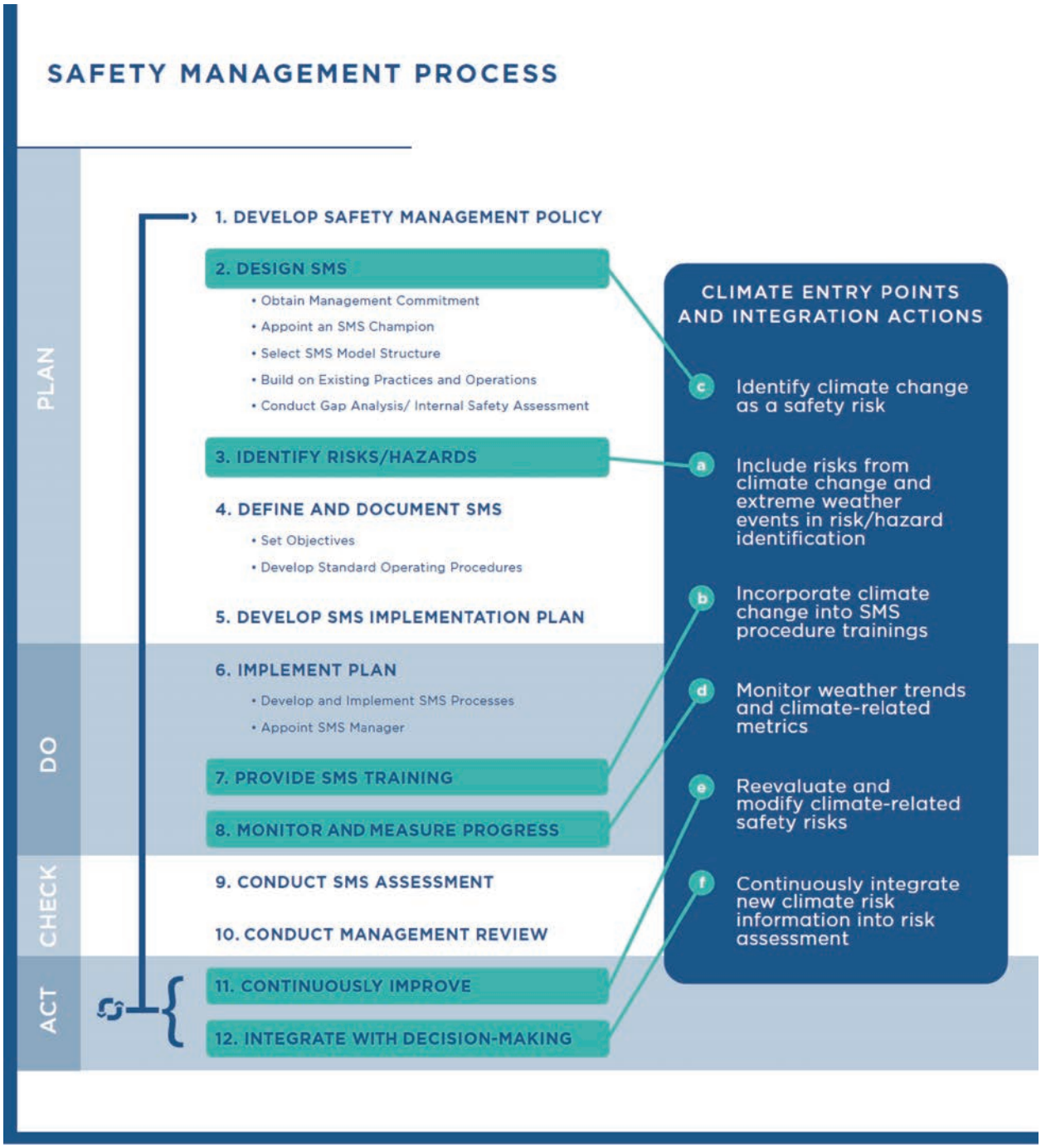

Figure 14. Safety management system overlaid with climate entry points and integration actions.

in aviation (FAA 2012) (see text box on the previous page). Examples of climate-related safety risks include the following:

- Extreme heat can increase the risk of heat stress for outdoor workers.
- Higher temperatures can increase the risk of infectious disease transmission.
- Ice events can create public and employee safety risks on roadways and pedestrian areas.
- Standing water from heavy rains can reduce brake performance.
- Flooding can create environmental contamination.
- Hurricanes or storm surge events can create dangerous operations conditions for employees and passengers.

Use the available climate data to rate the likelihood and the severity of these climate risks for the analysis at hand. For example, when conducting a safety risk assessment for a new construction project, consider realistic probabilities of heat waves during the construction period that may affect worker safety.

In doing so, consider the following tips:

- **Review assumptions and data on the frequency of weather events and evaluate whether your SMS is effectively accounting for projected changes in weather-related safety risks.** Check what range of historical data is being used to assess and inform event frequency assumptions. You should use the latest weather data to ensure that recent trends in heat, ice, and heavy rain are influencing the expected likelihood of events. Resources include the following:
  - **NOAA weather station data.** This resource provides access to NOAA weather station data sets.
  - **NOAA Climate at a Glance.** This tool allows the user to create time series graphs for user-defined climate parameters, time periods, time scales, and locations in the United States.
  - **NOAA Climate Data Online.** This resource provides access to the National Climate Data Center's archive of global historical weather and climate data and station history information.
  - **NOAA Climate Prediction Center outlook maps.** This resource provides seasonal climate outlook maps for 1 to 13 months in the future as well as extended range outlook maps for 6 to 10 and 8 to 14 days. This resource also produces special outlook products such as excessive heat index, wind chill index, and Palmer drought outlooks.
  - **NOAA severe weather climatology.** This resource uses historical severe weather data to map the historical probability of severe weather across the United States at a specified time of year. For these maps, *severe weather* is defined as tornadoes, thunderstorm winds greater than 58 miles per hour, and hail larger than three-quarters of an inch in diameter.
  - **NOAA state annual and seasonal time series.** This resource depicts historical temperature averages for U.S. states since 1895. Graphics are available for minimum, mean, and maximum temperatures and for each individual state. Decadal averages for the United States are also available for minimum, mean, and maximum temperatures.
  - **NOAA North American Climate Extremes Monitoring.** This resource uses historical data to produce data and analysis for eight indices (e.g., frost days, extreme temperatures). An interactive maps allow users to view results for a specific month, season, or year. Time series data can also be selected by weather station.
  - **NOAA snowfall extremes.** This resource provides 1-, 2-, and 3-day snowfall maximums for each county in the United States.
  - **NOAA Climate Extremes Index.** This resource uses historical temperature, precipitation, drought, and tropical storm data to calculate the climate extreme index for the contiguous United States. Regional data are also available.
  - **NOAA Heat Stress Index.** This resource provides a variety of datasets and documentation for heat stress.
  - **U.S. Army Corps of Engineers Nonstationarity Detection Tool.** This tool uses statistical analysis to determine whether there have been statistically significant changes in peak flows for any U.S. Geological Survey streamflow gage site in the United States with more than 30 years of annual instantaneous peak streamflow records.

    It may be difficult to translate climate risks directly into the probability and severity register used in your safety risk assessment.

    You may need to collect additional data beyond what is available from the self-assessment (see Appendix D). Alternatively, use professional judgment to assign probability and

Example: Translating Climate Information into a Likelihood Index

Your airport has received data on the projected number of days above 90°F by 2060. Using a likelihood index, you should evaluate the risk of injury due to the number of extreme heat days. Risks could include heat exhaustion and dehydration. The risk can be categorized as probable, remote, extremely remote, or extremely improbable. Depending on your rating, you may need to take action to reduce safety risks from high heat days.

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severity ratings informed by the best available data. You could consider working with a climate science expert from your municipality or university or a consultant to aid in the evaluation.

- **Establish a policy to review weather frequency assumptions.** To make the above process more systematic, establish a policy to review assumptions on weather frequencies. Pair this with airport-specific guidance about the procedure for doing so.

B. Provide SMS training: incorporate climate change into SMS procedure trainings

This step is used to provide SMS training to staff. Appropriate staff identified in the SMS program should periodically receive training on SMS procedures, and more advanced members of the staff should also receive training on risk management (ACRP 2007b). The step provides an opportunity to introduce your staff to potential safety risks from climate hazards. If airports choose to provide SMS training, this could occur before the safety risk assessments.

Addressing your airport's climate risks will require collaboration and contributions at all levels of airport operations and management. SMS training should be given to staff within SMS and across multiple disciplines such as operations, maintenance, and emergency management. Multidiscipline training is important, as it will require a coordinated effort across departments to address most safety risks, including climate risks (FHWA 2015). The following steps can help you integrate climate change into your SMS training:

- Update training to include climate hazard information. Update your training protocols to include the identified climate risks, risk assessment results, and modified or new mitigation strategies. Consider that personnel may have little experience with climate hazards and risks. Use this opportunity to increase climate risk awareness, educate about the threats and impacts of climate risks, solicit feedback on risk mitigation, and garner support. See Chapter 3 for more information.
- Update training to include reviewing recent weather trends. For specific SMS staff, provide an updated training that includes the steps for tracking and reviewing recent weather trends. It is likely that your airport is already tracking weather trends. You can also leverage training resources from existing reports or local efforts to help develop these new training protocols. For example, the City of Fort Lauderdale launched a climate change training program for all city employees (Dreaming Green 2015). Your SMS staff should be able to review these data to identify any recent weather trends that may affect risk and hazard identification.

C. Design SMS: identify climate change as a safety risk

This step provides an opportunity to incorporate climate risks systematically into your SMS. In the design of your SMS, establish a policy to identify climate change as a safety risk. Safety risks exacerbated by climate change could include heat exposure or flooded runway. With this designation, the effects of future climate conditions on the frequency and the severity of safety risks are more likely to be considered in your safety risk management process. For example, designating climate change as a safety risk may result in changes to personal protective equipment requirements, such as lighter or less clothing during extreme heat events to lessen heat stress on workers.

D. Monitor and measure progress: monitor weather trends and climate-related metrics

This step allows you to monitor recent weather trends that may affect worker or passenger safety. See Section 4.8 and Appendix C. Example metrics may include

- Number of days per year with rainfall above a specified amount,
- Consecutive number of high-heat days,
- Number of weather-related safety incidents reported per year,

- Number of ozone response days,
- Amount of water needed for hydration during extreme heat events, and
- Number and amount of workman's compensation related to weather incidents.

E. Continuously improve: reevaluate and modify climate-related safety risks

As you would for any other hazard or safety risk, continuously improve your management of climate-related safety risks. This action is particularly important in the context of climate risks because your understanding of the risks will change over time. See Section 4.8 on adaptive management.

F. Integrate with decision-making: continuously integrate new climate risk information into risk assessment

This step allows you to integrate new climate risk information continuously into decision-making. As you would for any other hazard or safety risk, periodically review data on climate hazard risks and recent weather trends to understand better how safety may be affected. After a review, refine your identified risks and hazards or SMS trainings as needed to ensure you are meeting the objectives of your SMS. See Section 4.8 on adaptive management.

Example: Managing Climate Risk Through Capital Planning

An airport is seeking to reduce total life-cycle costs of a planned stormwater collection and treatment system.

The airport realizes that climate change may increase the frequency and severity of heavy rainfall events, and needs to incorporate these changes into design and cost estimation.

The airport can use climate projection data for heavy rainfall return periods to determine if certain design parameters warrant revising. For example, if the likelihood of high flows exceeds current designs often enough, engineers may want to increase the capacity of the stormwater system.

4.5 Capital Planning Strategies

Airports identify needs and plan for expenditures through capital planning. Through this management system, airports allocate funding for projects that may focus on meeting service level objectives, expanding airport operations through new facilities, and rehabilitating or replacing existing facilities and assets.

Accounting for climate change in capital planning can mitigate future climate risks to facility and infrastructure developments. Climate hazards could threaten planned facilities or assets. Incorporating these hazards into capital planning may allow for a reduction of life-cycle costs due to savings in rehabilitation and maintenance needs.

Examples of mitigating climate risk through capital planning include the following:

- Identifying climate risks that could threaten existing or planned infrastructure,
- Incorporating climate change projection data into infrastructure and other asset design processes, and
- Prioritizing the allocation of funding to facilities and assets most vulnerable to climate risks.

Links to Other Management Systems

Airport management systems are inter-related. For example,

Capital planning **informs**
- – Strategic planning and
- – Master planning and

Capital planning **is informed by**
- – Strategic planning,
- – Enterprise risk management,
- – Asset management,
- – Safety management, and
- – Master planning.

4.5.1 Climate Risk Management Overview

There are ten entry points for integrating climate risk into existing capital planning processes, as shown in Figure 15. Not all entry points are necessary for any climate risk management to

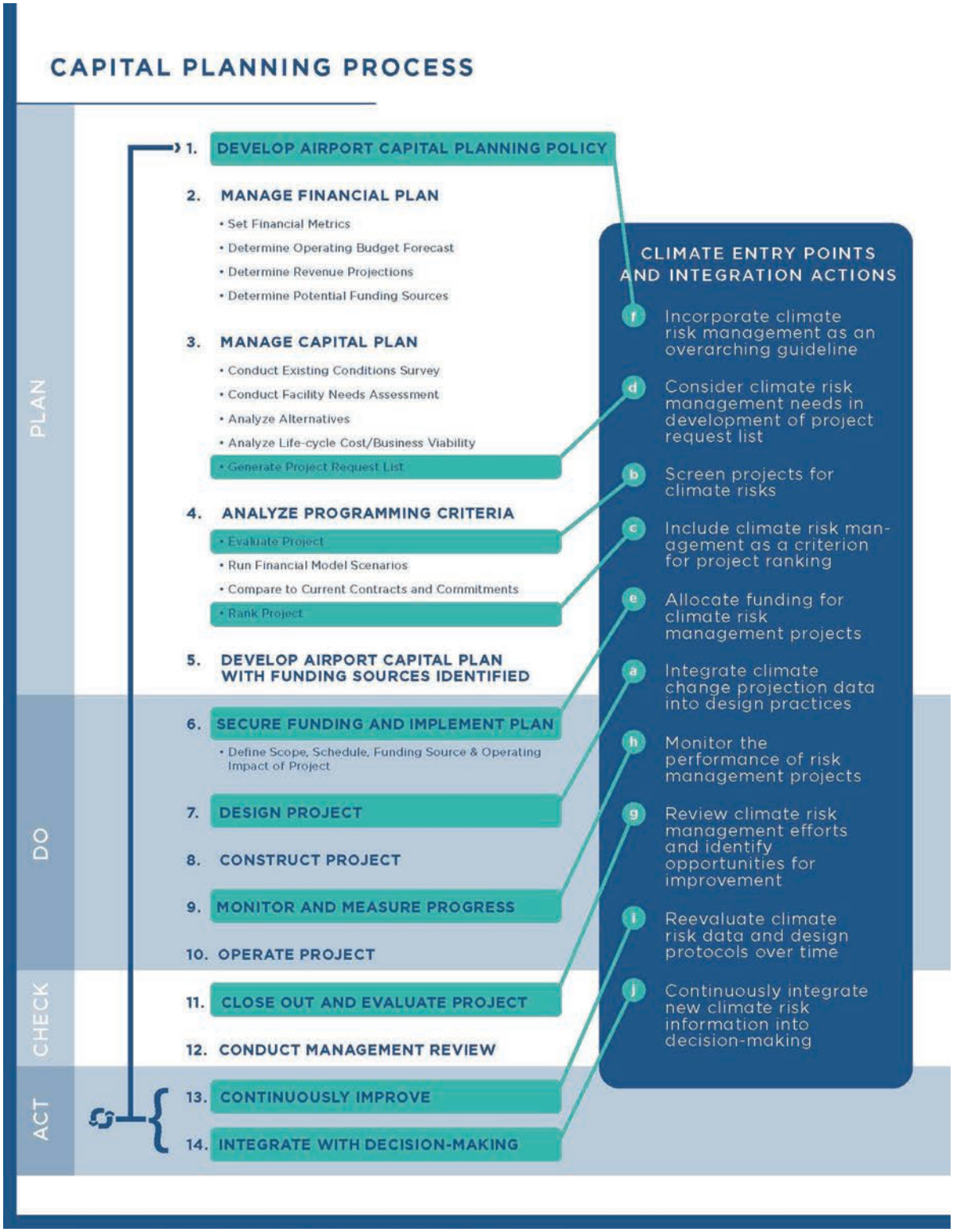

Figure 15. Capital planning system overlaid with climate entry points and integration actions.

occur, but your airport can build on each entry point to successively increase the level to which you manage climate risks to infrastructure.

The entry points are listed in recommended priority order:

a. Design project.
b. Evaluate project.
c. Rank project.
d. Manage capital plan.
e. Secure funding and implement plan.
f. Develop airport capital planning policy.
g. Close out and evaluate project.
h. Monitor and measure.
i. Continuously improve.
j. Integrate with decision-making.

The next section explains how your airport can take advantage of each entry point for integrating climate risk.

4.5.2 Climate Risk Management Steps

A. Design project: integrate climate change projection data into design practices

At this point in the capital planning process, your airport's engineers or your contractors plan and design selected projects. Your existing architectural and engineering design practices, whether led by airport engineers or contractors, may not account for climate hazards and risks. Your airport may currently associate climate risks with extreme events, but your designers and planners should use climate data to determine how average design criteria and parameters (e.g., temperature, precipitation) will be impacted by climate change.

This step of the process is an opportunity to ensure that your projects are planned and designed with climate change in mind. Further, it is the opportunity to prioritize projects on the basis of climate risk. Therefore, using climate change projection data when designing assets will help you manage climate risk. See Appendix D for more information on accessing projection data.

A growing body of practice exists on incorporating climate risk into project design and engineering. Your engineers can incorporate climate projection data into design parameters without overhauling the entire design process (FHWA 2017). FHWA's *Synthesis of Approaches for Addressing Resilience in Project Development* summarizes the state of the practice and establishes the adaptation decision-making assessment process (ADAP) (FHWA 2017). Key points include the following:

- **Establish tiers of analysis.** You may not need extensive climate analysis when integrating climate data into your project design. Your project may not be exposed to climate risks, it may be a temporary project without long-term implications, or it may not present significant consequences in failure. By looking at these project characteristics, you can use your resources for the projects that need analysis most.
- **Require contractors to build to manage climate risks.** When partnering with contractors in design (or achieving project design through other business mechanisms, such as public–private partnership discussed in Part E, "Secure Project Funding"), ensure that your climate risk management goals are met by creating general design guidelines that incorporate climate change data. For example, the Massachusetts Bay Transportation Authority (MBTA) requires climate risk assessments for new designs (MBTA 2016).

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- **Use existing tools to translate climate model outputs into design parameters.** Your self-assessment will act as a starting point for climate hazards and risks, but the design stage may require you to conduct project-specific climate risk assessments. Standard climate projections may not provide raw data suitable for design. These data, like daily temperatures, can be converted into variables such as annual/daily minimum and maximum temperatures for use in design. You can make these conversions with existing resources, such as the U.S. DOT climate data processing tool (USDOT 2016).
- **Consider a range of projection scenarios.** Climate models will offer a range of projections based on greenhouse gas emission scenarios. It may be tempting to select average scenarios or to select a more favorable scenario. Consider using variations of a parameter (e.g., for precipitation, wetter and drier variations), capturing the range of possible effects to gauge your risks and risk tolerances.
- **Plan for uncertainty by using flexible design practices.** Climate risk projections will always have associated uncertainty (see Section 4.3.2), making initial design decisions difficult. You can minimize the impacts of these uncertainties by incorporating flexibility into your designs to allow for low-cost adaptation in the future. For example, living shorelines use natural systems to control flooding, prevent erosion, and treat runoff (NOAA 2017b). These shorelines can be added to or manipulated after construction to suit changes better in precipitation or sea levels.
- **Consider establishing design standards for climate risk.** To simplify the process and to reduce the burden on individual project managers and engineers, establish policy-level design standards for any new infrastructure. For example, the Port Authority of New York and New Jersey (PANYNJ) Engineering Department established climate resilience design guidelines. These guidelines establish specific temperature, precipitation, and flooding projections to be designed for at port authority facilities (PANYNJ 2015). Use these design standards to address any barriers that your designers may have with local or national building codes hindering the integration of climate risk data.

At first, incorporating climate risk into your project design may occur on a project-by-project basis or only for the most critical and long-lived projects. A more comprehensive approach would establish standard operating practices or design standards.

B. Evaluate project: screen projects for climate risks

Before projects enter the design phase, your airport evaluates a list of projects. The evaluation stage is an opportunity to use climate change data for identifying exposure to climate risks and the probability and consequences of project failure.

Use the results from your self-assessment to do a high-level screening of what projects may be vulnerable to your airport's climate risks.

- **Downscale climate risks to specific projects.** Not all projects will have the same level of exposure to your identified climate risks from the self-assessment. You may need to obtain a greater level of detail to determine risks specific to each project. Use readily available climate data tools to help determine project climate risk, such as NOAA's sea level rise viewer for projecting inundation risks for flood-prone areas (NOAA 2017a). Other projects, such as pavement designs, may need a stronger focus on temperature projections.
- **Select and apply evaluation criteria.** You can select and apply specific criteria for evaluating all potential projects. Creating consistent criteria will also allow you to readily compare projects in future capital planning steps. Criteria could include capital costs, risk of failure, project service life, and operational benefits. For example, the City of Philadelphia selected four criteria for evaluating climate risk management strategies: capital costs, operational costs, capacity for change in operations, and co-benefits (e.g., social, economic, environmental benefits) (City of Philadelphia 2015).
- **Generate cost–benefit studies.** Leverage your capital planning life-cycle cost evaluations to create a cost–benefit comparison between projects. This step is an important opportunity to

communicate clearly to airport executives the value of doing or not doing a project. Costs should represent initial capital investments, and benefits should represent life-cycle costs post project construction. Climate risk cost–benefit analyses can be time-intensive and expensive; some direct benefits of climate risk management will be harder to quantify than others. For example, expected reductions in service disruptions from enhanced stormwater controls may have a clear associated cost, but increasing water conservation to alleviate drought impacts is difficult to quantify. You may need to rely on internal stakeholders to create valuations for some benefits that you have identified. Using existing research and case studies can also help overcome hurdles in cost–benefit analyses:

- ACRP (02-78) and the National Cooperative Highway Research Program (NCHRP) (20-101) have forthcoming reports designed to guide efforts in climate risk management cost–benefit analyses for airports and transportation (TRB 2015, TRB 2017).
- Miami–Dade County created a cost–benefit curve (i.e., graphical plot of costs versus benefits) to compare visually the economic feasibility of different climate risk management projects (Miami–Dade County 2016).
- The Resilience Dividend Valuation Model provides a framework for determining the net benefits of a resilience project compared to the status quo (i.e., business as usual), with several case study applications to follow (RAND 2017).
- For flood risk analyses, a recent New Jersey case study following Hurricane Sandy used FEMA's benefit–cost tool in analyzing flood resilience upgrades for the community (Cooper et al. 2016).

C. Rank project: include climate risk management as a criterion for project ranking

Within the programming process, your airport may develop project rankings as a final step before deciding which projects will be included in the capital plan. Use the results of your life-cycle cost analysis, project evaluation, and financial modeling to help determine which projects can reduce your financial risks the most. You can integrate climate change into this process to help prioritize projects to reduce the impacts of climate risks.

Climate change will affect potential projects differently, and potential projects may have different effects on your airport's overall risk. Some may be needed more than others to increase airport resilience. Using your project evaluation results, particularly any cost–benefit analysis results, determine which projects are a greater priority than others in reducing climate risks.

- **Collaborate with stakeholders to develop a rating system.** If cost–benefit analyses cannot be performed because of capacity, data, or cost constraints, you may find it difficult to rank projects when using several criteria in project evaluation. You can determine how much your organization values each criterion to create an easier comparison between projects. This determination could involve working with different internal stakeholders who will be affected by a given project. While this process will not provide a single score for any given project, it will help give better insights for what may be more valuable to your airport.

D. Manage capital plan: consider climate risk management needs in development of project request list

In this step, your planners identify current and future airport needs and begin to develop alternatives for addressing these needs. This step offers another key opportunity to identify needs related to climate risks and propose projects that can address those needs.

- **Identify facilities, assets, and infrastructure vulnerable to climate risks.** Using the self-assessment results, determine what existing or planned facilities, assets, and infrastructure

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maybe be impacted by climate risks. This action could have varying levels of detail. You may do a brief qualitative assessment, grouping each facility into exposure categories (e.g., "safe," "some impact," "large impact"), or you may decide to do more detailed vulnerability assessments (following, for example, the ADAP process) (FHWA 2017).

- **Generate project request list.** As you generate your project request list, consider projects that will help mitigate your climate risks that you may have not previously thought of. These projects should cover a wide range of applications to give you a better idea of how risk mitigation potential and capital costs will vary. For example, flooding controls could range from constructing a sea-wall to creating an emergency pumping system to digging a retention pond. Resources such as ACROS and FHWA's climate change adaptation guide provide detailed lists of adaptation options for you to draw from (ACRP 2015b; FHWA 2015).

E. Secure funding and implement plan: allocate funding for climate risk management projects

Implementing your capital plan requires the coordination of many parties and sources of financial support. If internal funding is unavailable, external sources for climate risk management may be available and can help you in implementation.

Project costs can vary: some climate risk mitigation, such as an incremental change to a developing facility design, may be small-scale, and some may be new, large infrastructure projects. Incremental costs will likely need to be covered within existing capital budgets.

For the larger projects, you may not have the needed internal funding available. Securing external resources may be able to fill this funding gap. Be aware that costs may change after design; build in buffers to absorb these variations. Potential external sources for climate risk management projects include the following:

- **Federal resources.** Work with your contacts at FAA and other federal agencies (e.g., EPA, FHWA) to understand better what funding may be available to support your climate risk management goals. Infrastructure funding opportunities can be diverse and spread across many federal agencies. Consultants may also be a helpful resource in writing grant applications and performance analyses for this funding, as these tasks may be difficult to accomplish with internal personnel.
- **State and local resources.** Depending on your region, local and state resources may also be available. For example, California state agencies often offer grant funding to municipal agencies and entities to help comply with state climate risk management goals.
- **Public–private partnerships.** Public–private partnerships are an alternative for bridging funding gaps for climate risk management. These risk-sharing partnerships to fund infrastructure development present investment advantages to both public and private organizations, but traditional frameworks for public–private partnerships may need to be restructured to ensure that both parties are aligned in climate risk identification and mitigation goals early in the project design process (PPIAF 2016). The Environmental Defense Fund recently published a framework for overcoming public–private partnership investment challenges for climate-resilient and sustainable infrastructure in its *Unlocking Private Capital to Finance Sustainable Infrastructure* report (Environmental Defense Fund 2017).
- **Resilience bonds.** Your efforts in reducing climate risks could help reduce insurance expenses as well, as new insurance frameworks for catastrophe bonds (i.e., natural disaster insurance), also referred to as resilience bonds, may provide rebates for investments in climate risk management projects (Re:focus Partners 2015).

F. Develop airport capital planning policy: incorporate climate risk management as an overarching guideline

The capital planning entry points mentioned could be done on an ad hoc, project-by-project basis. However, by incorporating climate risk management into your overall capital planning policy, you can ensure that climate risks are at least considered at each stage in the capital planning process.

- **Create a general climate risk guiding policy.** California recently passed legislation to require all state infrastructure investments to consider climate change throughout a project's lifetime and to establish a working group to create guidelines for data use and best practices (California State Legislature 2016). The state bill's general language and goals could be a helpful example when you are drafting a broad, climate risk management policy for your capital planning process.

G. Close out and evaluate project: review climate risk management efforts and identify opportunities for improvement

Project closeout and evaluation offer an opportunity to review lessons learned throughout your capital planning process. In this step, you can review how climate change data were used and where you could improve your climate risk management efforts.

Evaluate completed projects to determine how different decisions may have altered or improved your airport's resilience or mitigation of a given climate risk.

- **Create a review protocol specific to climate risk management.** To help guide future improvement, create a review protocol that focuses on how your capital planning process incorporated climate risks. Questions to ask could include the following:
  - Did the climate projections that we used in design reflect our collected data?
  - What was the cost–benefit of our investment in the short term and long term?
  - Could a different design alternative been a better option in reducing risks?

H. Monitor and measure progress: monitor the performance of climate risk management projects

Monitor the performance of your climate risk management projects to help inform future investments. For example, measure the historical and postinvestment service disruptions for a given event threshold (e.g., 8 inches of rain in 24 hours). See Section 4.8 and Appendix C. Continuously improve: reevaluate climate risk data and design protocols over time

Seek out opportunities for improving your future climate risk management investments on the basis of collected data. This process can apply to investments that may be underperforming and sufficiently meeting expectations. For example, new climate change data may be available from models and scenarios, or current design protocols may need to incorporate different climate hazards than before. See Section 4.8 on adaptive management.

I. Integrate with decision-making: continuously integrate new climate risk information into decision-making

Continuously integrate new climate risk information and analysis into your decision-making to ensure that all steps in your capital planning process consider climate change. See Section 4.8 on adaptive management.

Example: Managing Climate Risk Through Asset Management

An airport's runway is susceptible to pavement deterioration.

The airport realizes that climate change may increase the frequency and the severity of extreme temperatures, and the airport needs to incorporate the increased probability of pavement deterioration or failure into its risk determination.

Therefore, the airport uses its asset management process to assess how the climate hazard may affect runway performance and whether changes need to be made to the maintenance schedule or life cycle and residual life evaluations of the runway.

Links to Other Management Systems

Airport management systems are inter-related. For example,

Asset management **informs**
- Capital planning and
- Master planning and

Asset management **is informed by**
- Master planning,
- Aviation forecasts and facility requirements, and
- Capital planning.

4.6 Asset Management Strategies

Asset management systems steer the short- and long-term investments and strategies related to physical airport assets, with the goal of optimizing the assets' performance, minimizing risks and costs, and meeting the objectives of the strategic or master plan (ACRP 2012b).

Asset management offers a natural fit for incorporating climate change information into the assessment of future asset performance. If climate hazards are not incorporated into asset management, overall life-cycle costs can increase due to higher-than-anticipated maintenance and replacement costs.

Some examples for mitigating climate risk through asset management include the following:

- Evaluating trends in weather and climate-related asset performance,
- Maintaining a specified level of performance under various climate scenarios,
- Upgrading infrastructure to accommodate climate change hazards, and
- Developing and tracking climate-related metrics (see Appendix C).

The following resources can help you integrate climate change into your asset management plan:

- American Association of State Highway and Transportation Officials (AASHTO), *Integrating Extreme Weather into Transportation Asset Management Plans* (AASHTO 2015);
- World Bank, *Integrating Climate Change into Road Asset Management* (World Bank 2017);
- AASHTO, *Transportation Asset Management Guide* (AASHTO 2013); and
- AASHTO, *Integrating Extreme Weather Risk into Transportation Asset Management* (AASHTO 2012).

4.6.1 Climate Risk Management Overview

There are seven entry points for integrating climate risk into existing asset management processes, as shown in Figure 16. Not all entry points are necessary for any climate risk management to occur, but your airport can build on each entry point to successively increase the level to which you manage climate risks to infrastructure.

The entry points, in recommended priority order, follow:

a. Maintain assets.
b. Set target levels of service.
c. Determine business risk (criticality).
d. Determine existing conditions.
e. Monitor and measure progress.
f. Continuously improve.
g. Integrate with decision-making.

The next section explains how your airport can take advantage of each entry point for integrating climate risk.

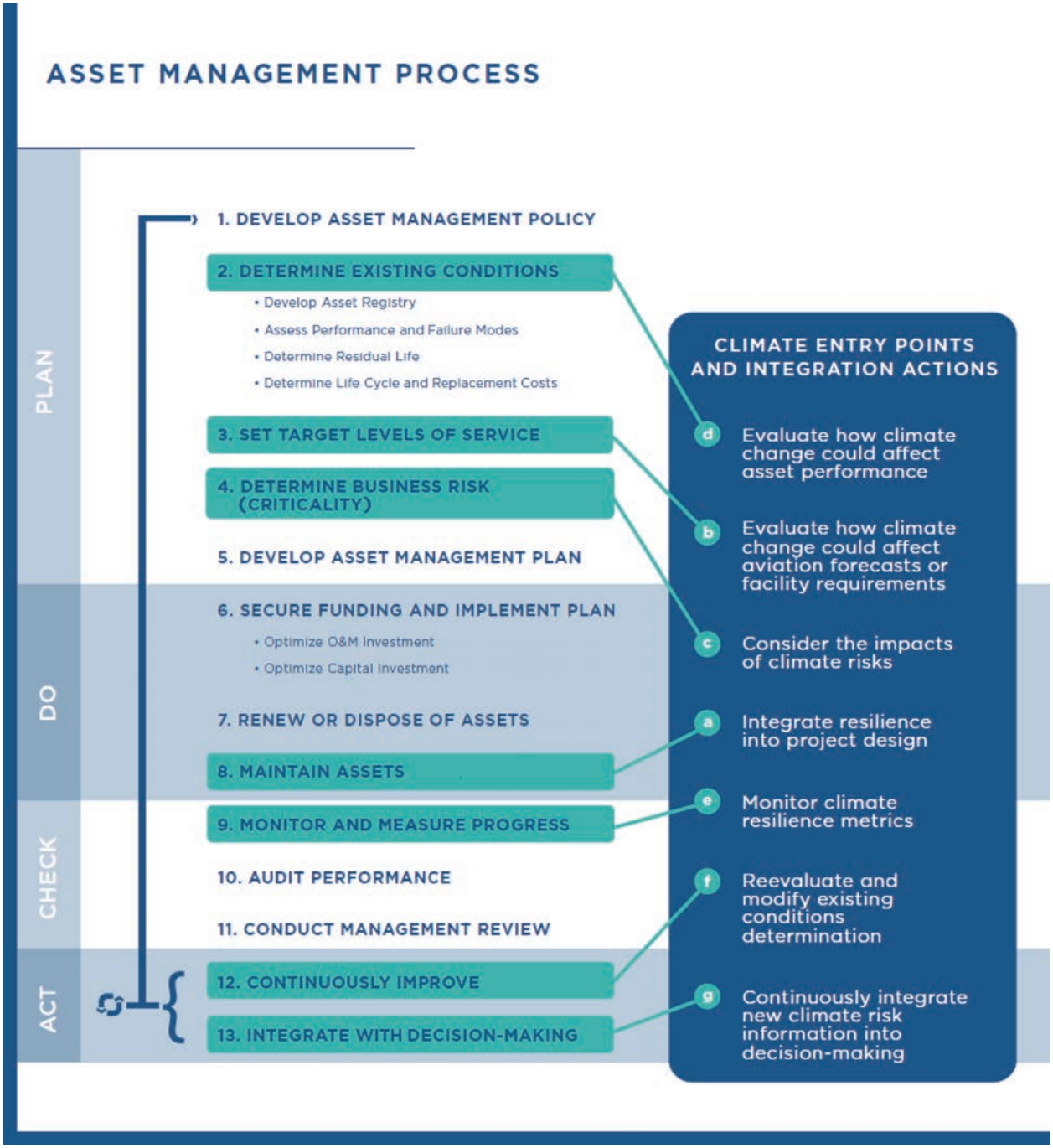

Figure 16. Asset management system overlaid with climate entry points and integration actions.

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4.6.2 Climate Risk Management Steps

A. Maintain assets: integrate resilience into project design

This step is for maintaining asset performance and allows you to use asset rehabilitation and replacement as early opportunities for managing climate risks in the design phase of projects. These projects will have already been funded, but climate risk management can often be integrated at this stage without adding significant costs. For example, if excavation is already occurring for the replacement of underground storm drains or water mains, you could take the opportunity to select pipe size and thickness on the basis of projections for increased precipitation or stresses from extreme temperatures.

B. Set target levels of service: evaluate how climate change could affect aviation forecasts or facility requirements

This step is used in your asset management planning process to identify gaps in performance and to identify maintenance and operating strategies for closing performance gaps (ACRP 2012b). This step provides a key opportunity to incorporate climate change data into your level of service assessment and understand better how changes in the level of service may affect asset performance and maintenance needs.

This climate entry point allows you to adjust your target levels of service, given your expected climate hazards. You should draw from climate hazard data collected during the self-assessment, existing conditions determination, and business risk determination to set or reevaluate your target level of service. Although your target level of service is set in the planning stage of asset management, that level is likely to change and therefore should be reevaluated periodically (ACRP 2012b).

Climate hazards may present risks to your aviation forecasts and facility requirements. These risks may then affect your asset performance and target level of service. In some cases, climate change may result in opportunities to increase your airport's target level of service, such as experiencing a more favorable climate for tourism in the northern latitudes. However, in many cases, climate change may create additional strains on assets that decrease asset performance, reduce design life, and affect the target level of service. The following steps can help you integrate climate considerations into your target level of service:

- **Incorporate climate information into level of service forecasts.** Analyze whether trends in level of service requirements, such as a decrease in winter tourism or additional strain from extreme temperatures, are influenced by climate. If asset performance and level of service requirements are sensitive to changes in climate, consider finding or commissioning an analysis to determine whether climate change would change level of service forecasts. Although some studies have tried to model how climate change may affect tourism demands, some uncertainties are associated with these models because of the complexity of the metric (Gossling et al. 2012). Gossling et al. (2012) assessed the existing literature and concluded that climate change does affect tourism, but the degree and direction of change are difficult to quantify. If you have a master plan, you may have already conducted this analysis. In addition to travel demand forecasts, asset performances can be assessed by the condition of the asset. This information can be pulled from your existing conditions determination. Once your service forecast analysis with climate data is complete, set your target level of service accordingly.
- **Prioritize climate risks to existing infrastructure and aviation forecasts.** After reviewing your existing conditions determination and business risk determination in the context of climate change, prioritize your immediate climate risks to existing assets and aviation forecasts when setting your target level of service. As you reevaluate your target level of service over time, be sure to review and prioritize any potential climate risks on a similar time horizon

to your level of service determination. You should consider whether any changes need to be made in the short or long term.

- **Create a plan for critical assets in advance of an event.** Before an impending weather event, establish a review, inspection, and maintenance plan for your critical assets. For example, if a hurricane is expected to hit in the coming week, you can refer to this plan to identify your critical assets and to determine how you will maintain them during the course of the hurricane. Each event also gives you an opportunity to review the effectiveness of the plan and make adjustments as needed. Boston (Massport) uses this strategy for snow equipment in advance of a snowstorm.

C. Determine business risk (criticality): consider the impacts of climate risks

This step is used to evaluate your asset risks and identify the greatest business risks (ACRP 2012b). Asset risks include asset failure, or an inability to function at a desired level (ACRP 2012b). Business risks are risks to the organization, including the financial impacts of asset failure (ACRP 2012b). With the information and analysis from the existing conditions determination, this step requires you to associate a risk with a given asset or collection of assets. This step provides a key opportunity to integrate climate risks into your assessment.

This climate entry point allows you to identify critical assets that are defined as high cost or likely to significantly decrease levels of service if they fail (ACRP 2012b). You should draw from climate hazard data collected during the self-assessment or from other sources as part of the risk exposure calculations for specific assets. After incorporating the climate hazard data into the business risk determinations, you will be able to better compare and prioritize the greatest risks to your airport.

Climate impacts can increase the risk of asset deterioration or failure. Climate risk considerations may affect the life-cycle and replacement cost calculations of your business risk determination. The following step can help you integrate climate risk into your business risk determination.

- **Evaluate the probability and consequences of asset failure under climate change conditions.** Risk exposure is a product of the probability of failure and the consequences of failure. To determine risk exposure for each asset, you should use the self-assessment results to evaluate how climate hazards may affect the probability of failure and the degree of consequences. Consequences of failure may include injury to airport workers, airline staff or passengers, damage to aircraft, and disruption to service (ACRP 2012b).

D. Determine existing conditions: evaluate how climate change could affect asset performance

This step focuses on data collection and analysis to determine the current condition and projected maintenance needs of your existing infrastructure. The existing conditions determination is an opportunity to identify maintenance and rehabilitation needs as well as climate-related data and trends early in the asset management planning process. This step offers a key opportunity to evaluate how climate change could affect asset performance.

This climate entry point allows you to evaluate how climate change could affect the performance, residual-life, life-cycle, and replacement costs of your assets, as existing infrastructure often may not be suited for the additional strains associated with climate change. You should draw from climate hazard data collected during the self-assessment or from other sources to develop climate-related metrics to better monitor asset conditions. In addition to assessing climate change-related impacts, compare these findings to other potential

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impacts to help you prioritize or coordinate your efforts, and then conduct additional analysis if needed.

Climate change has the potential to decrease asset performance under extreme conditions. Examples of climate change impacts that may affect assets include the following:

- Extreme temperatures can exacerbate deterioration of critical assets such as runways.
- Heavy precipitation events can limit the capacity of stormwater drainage systems and increase flood frequency or culvert maintenance needs.
- Snow events can change asset maintenance, snow removal, and deicing needs.
- Sea level rise can increase the flood frequency of low-lying areas.
- Hurricanes and storm surge can cause erosion, scouring, and undermining of pavement.

The following steps can help you integrate climate considerations into your existing conditions determination:

- **Evaluate hazards identified in the self-assessment.** Use the self-assessment to understand how climate change could affect your existing conditions, such as normal temperature range, frequency of different hazards, and travel demand.
- **Update scheduling, prioritization, and asset condition analysis.** Update your existing conditions process to incorporate the relevant hazards identified in the self-assessment. You may find that you need to schedule maintenance more frequently or that the residual life of an asset has changed and may need to be prioritized above other assets. Updating asset modeling and scheduling needs has been a common entry point for incorporating climate change for U.S. transportation authorities (FHWA 2012).
- **Develop metrics for events that exceed thresholds.** Develop and track climate-related metrics to identify trends. Your airport likely has unique asset thresholds where performance is compromised or failure can occur, such as flooding from overloaded storm drains or pavement cracking from high heat. Tracking these types of metrics over time may reveal trends, or they can be coupled with climate scenario projections to better communicate climate risks and how to manage them to personnel.
- **Use event expense codes.** Use event-specific expense codes (also known as work order numbers, failure codes, or charge codes) to track the costs and impacts associated with a specific extreme event. Assign and disseminate the code at the first sign of the event, and use it to track labor, materials, and other costs associated with event preparation, response, and recovery. By assigning a code to a specific weather event, you can assess the severity of the impacts and costs and easily compare the event to others.

E. Monitor and measure progress: monitor climate resilience metrics

This step allows you to develop specific metrics to monitor and measure the performance of your assets under increasing climate risks. See Section 4.8 and Appendix C. Examples of performance measures include the following:

- Identify the water level or temperature at which an asset would be compromised.
- Minimize disruptions from extreme events to fewer than a certain number of hours per event.
- Maintain critical infrastructure integrity under various climate scenarios.

F. Continuously improve: reevaluate and modify existing conditions determination

This step allows you to evaluate your collected data continuously for changes in performance and to identify ways to improve your methodology for integrating and tracking climate risk and asset performance. See Section 4.8 on adaptive management.

G. Integrate with decision-making: continuously integrate new climate risk information into decision-making

This step allows you to integrate new climate risk information and analysis continuously into your decision-making process, focusing specifically on your previously identified risks and critical assets. See Section 4.8 on adaptive management.

4.7 Emergency Management Strategies

Emergency management is the method that airports use to plan a response to emergency situations, including severe weather-related emergencies. FAA requires that airports identify many types of hazards during the emergency management process, including natural hazards.

Climate change could affect the nature and type of emergency events—particularly extreme weather events—that airports face. Emergency management systems will be the front lines of an airport's climate change response if the airport experiences extreme events such as flooding, hurricanes, or wildfire. It may also be the first management system used to address climate risk at airports that are not facing existential threats from climate change.

Integrating climate risk into emergency management planning involves reviewing existing plans in light of expected climate risks to determine whether the existing plans are sufficient or whether proactive changes are needed.

Examples of mitigating climate risk through emergency management systems include the following:

- Developing an emergency response plan for ice storms in a location where more winter precipitation is falling as rain or ice rather than snow and
- Evaluating extreme event trends in light of climate change as part of postevent evaluation activities.

Example: Managing Climate Risk Through Emergency Management

An airport experiences two back-to-back flooding events, straining emergency response resources.

After the events, the airport examines recent trends and climate change projections and decides that this type of compound event could recur in the future.

Therefore, the airport updates its emergency management plan to adjust its supplies and other preparation activities accordingly.

Links to Other Management Systems

Airport management systems are interrelated. For example,

Emergency management **informs**
- – Airport emergency planning and
- – Safety management and

Emergency management **is informed by**
- – Safety management,
- – Enterprise risk management, and
- – Airport emergency planning.

4.7.1 Climate Risk Management Overview

There are five entry points for integrating climate risk into existing asset management processes, as shown in Figure 17. Not all entry points are necessary for any climate risk management to occur, but your airport can build on each entry point to successively increase the level to which you manage climate risks to infrastructure.

The entry points, in recommended priority order, follow:

a. Identify risks.
b. Develop risk response processes/mitigation strategies.
c. Conduct management review.
d. Continuously improve.
e. Integrate with decision-making.

The next section explains how your airport can take advantage of each entry point with respect to climate risk.

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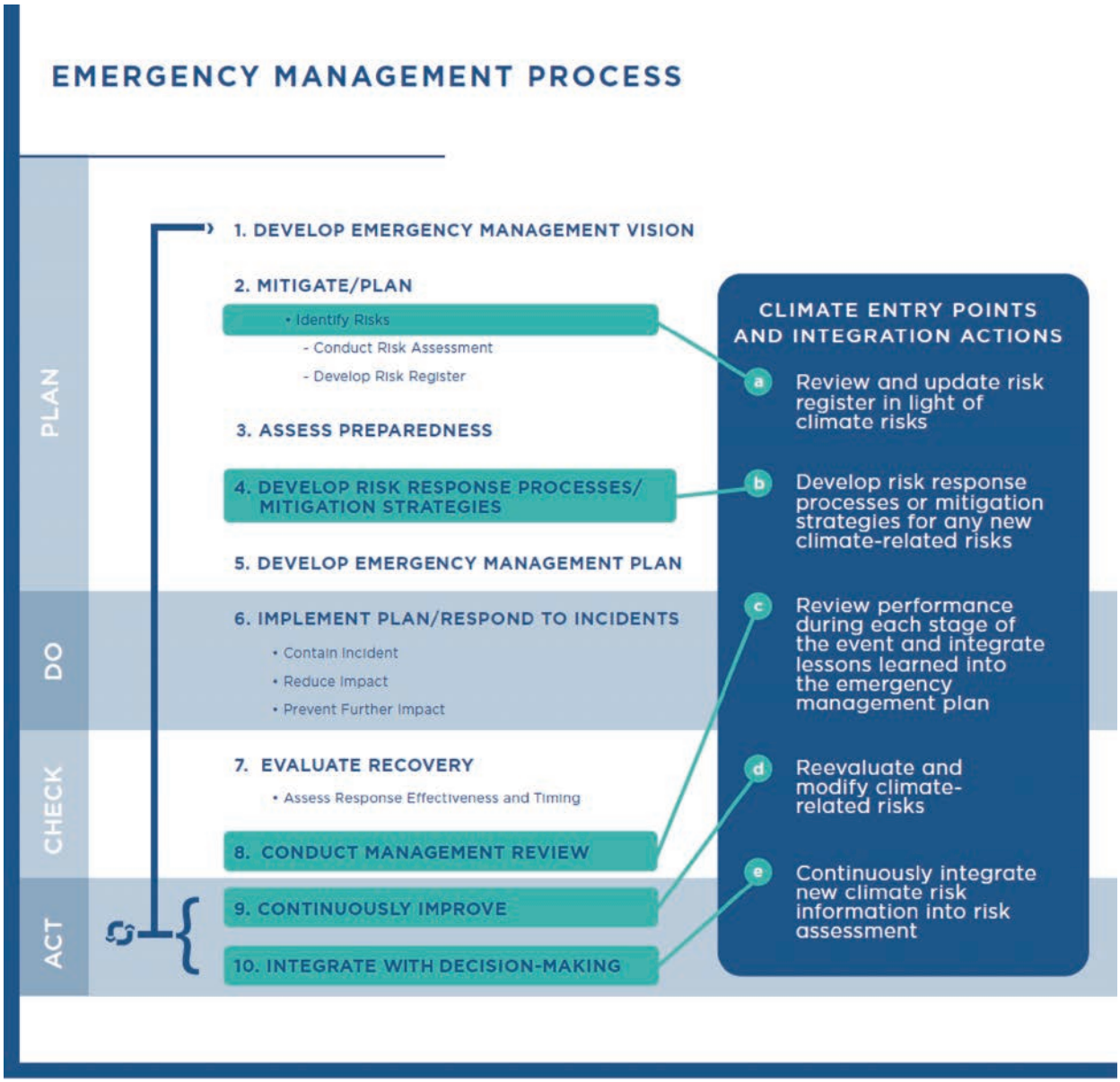

Figure 17. Emergency management system overlaid with climate entry points and integration actions.

4.7.2 Climate Risk Management Steps

A. Identify risks: review and update risk register in light of climate risks

At this stage of emergency management planning, your airport identifies potential risks and develops a risk register to inform you of the types of events that may need your response. This stage should include identifying ways in which climate change may affect the type of emergency events your airport needs to plan for. This process could include the following:

- **Possibility of new types of events (e.g., floods, heat waves, hurricanes, ice storms).** For example, climate change could mean that your airport experiences heat events that are currently rare. Similarly, an increase in extreme precipitation events could bring flooding to areas not currently flood prone.

- **Increased severity of existing types of events.** You may be no stranger to heat waves or flooding events, but climate change could mean that events reach levels not previously experienced or occur with more frequency. Such changes could affect the resources that your airport has available to respond.
- **Changing risks associated with other risk management activities at the airport.** Any actions taken at the airport can affect emergency management planning. To the extent that the airport builds any infrastructure or makes other changes to reduce climate risks, emergency managers should review and mitigate for any potential ripple effects. For example, the Allegheny County Airport Authority recently installed a white roof on the Pittsburgh International Airport's (PIT's) terminal building. First responders and operations personnel periodically access the roof as part of typical safety and maintenance procedures. Because of the slippery and highly reflective new roofing material, new maintenance protocols and personal protective equipment were required. The additional staff time and the capital costs associated with the emergency management and operations departments were addressed after the installation of the roof as part of an adaptive response to the infrastructure change.

Start with the climate risks identified in the self-assessment process. Key questions to ask yourself include the following:

1. Does my existing emergency management plan cover all types of risks that my airport may experience in the near term, including those from climate change?

   The **ACRP Airport Weather Advanced Readiness (AWARE) Toolkit**, which accompanies ACRP Report 160, can provide some information to answer this question (ACRP 2016b).

   The toolkit's exposure information module provides information on how frequently different weather events occur in an airport's location and which of those are "rare but plausible" (Figure 18). "Rare but plausible" events are those for which airport managers are typically least prepared (ACRP 2016b). The toolkit includes the following 15 extreme weather event types: flooding, heavy rain, tropical cyclones, tornadoes, lightning, hail, heavy winds, extreme heat, extreme cold, snow, blizzards, ice, dense fog, dense smoke, and dust storms.

   The kit also provides information (on the page with detailed results) about whether those events are expected to become more or less frequent because of climate change (Figure 19).

   The toolkit also includes best practices for managing each type of the extreme weather events, explained further below.

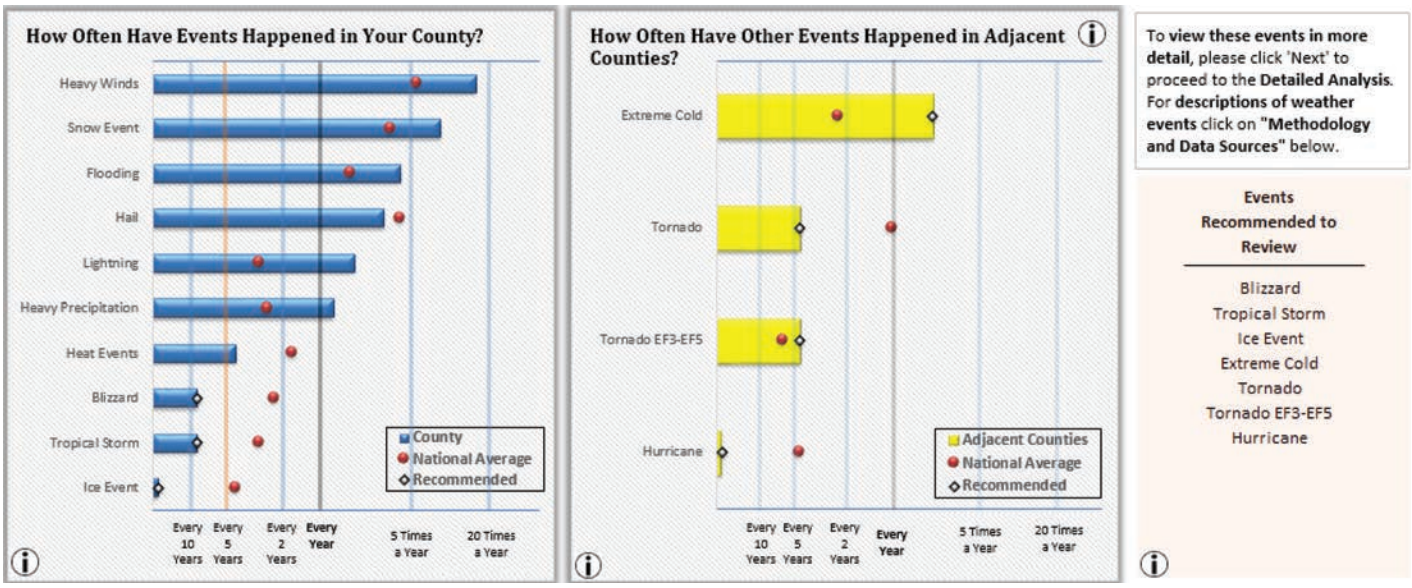

Figure 18. Example AWARE toolkit output of the exposure information module.

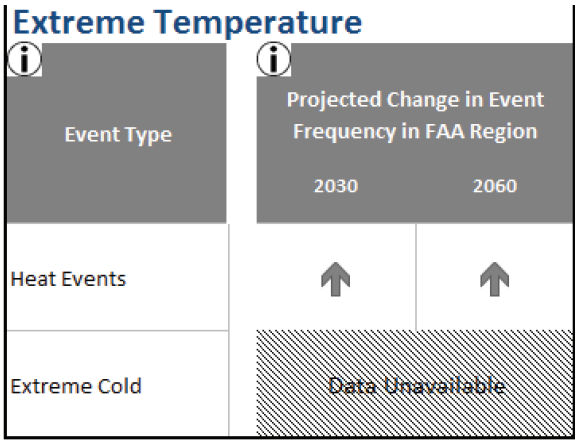

Figure 19. Example AWARE Toolkit's output of the exposure information module on projected change in event frequency.

2. Are any changes necessary to my existing emergency management plan if extreme weather events become more frequent or severe?
   - Would anything need to change in the emergency management plan or response actions if your airport experiences flooding two years in a row? Or is the worst case scenario flood that you are planning for still the worst case possible?
   - With higher temperatures, workers may be able to work fewer continuous hours or have less productivity. What does this mean for staffing? Do you need additional facilities and hydration stations to shelter from heat? Are alternate shifts needed? Should your airport change the standard gear or uniforms issued to staff?
   - With higher temperatures, is it necessary to make changes in drop-off areas or parking garages to ensure passenger comfort and safety?
   - Higher temperatures and more extreme weather could compromise infrastructure and equipment integrity and could require emergency repairs at increased cost. Does the reserve and replacement (i.e., emergency) fund need to grow to accommodate these changes?
   - Might your airport experience different insects, which in turn bring different diseases or other risks?
3. Could climate change affect any nonweather risks in my emergency management plan? For example, increased temperature could affect the spread of infectious diseases.

B. Develop risk response processes/mitigation strategies: develop risk response processes or mitigation strategies for any new climate-related risks

Once risks are identified, your airport develops risk response processes or mitigation strategies to reduce the risks or to improve the airport's ability to respond. For extreme weather events that your airport may not be familiar with, review the AWARE toolkit readiness modules. These modules provide best practices for preparing for each of 15 weather event types, organized and filterable by the following:

- Weather event type,
- Airport functional area (administration and finance, planning and environment, airfield operations, terminal operations, ground transportation and parking, and safety and security),

Business Continuity Planning or Continuity of Operations Planning

Business continuity planning, also known as *continuity of operations planning* for many public-sector organizations, is "the process of developing a roadmap for continuing operations under adverse conditions and during disruptions caused by all types of incidents, emergencies, and crises" (ACRP 2013).

This planning is distinct from emergency management planning in that business continuity planning is focused on ensuring the continuity of essential airport functions.

Airports should also consider developing a BCP or COOP. Continuity planning is considered a good business practice, and climate change further increases its value proposition.

For additional information about developing a BCP, see *ACRP Report 93: Operational and Business Continuity Planning for Prolonged Airport Disruptions* (ACRP 2013). Small airports may also refer to *ACRP Synthesis 78: Continuity of Operations Planning for Small Airports* (ACRP 2016a).

- Implementation stage (planning, mitigation, response, recovery), and
- Best practice type (communications, equipment, funding, infrastructure, personnel, procedures).

Also review FEMA's *National Response Framework* for guidance on best practices for all types of disasters and emergencies (FEMA 2016).

Given the dynamic nature of climate risks, it will also be particularly important for airports to debrief and update their risk register regularly for weather events. Some strategies to support this function include the following:

- **Require after-action reports.** Postaction reports can be compiled after extreme weather events to describe what happened, identify causes, and create clear recommendations for improvement (FHWA 2015).
- **Establish collaborative debrief sessions.** Debriefing sessions can be organized to discuss challenges and needs associated with extreme weather and climate risks. These sessions should be multidisciplinary and include key personnel across airport management systems to identify opportunities for improvement (FHWA 2015).

C. Conduct management review: review performance during each stage of the event and integrate lessons learned into the emergency management plan

As always after any incident, review performance during each stage of the event. Identify and document lessons learned that can be integrated into your airport's emergency management plan and improve performance. Additionally, you should consider the role of climate change in each event that your airport has experienced and whether your assessment of risk for other event types should be updated.

Further, evaluate your airport's emergency reserve budget. Use an annual review process to track how often your airport has to tap into the fund—which may be used for emergency

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response, emergency infrastructure repairs, etc.—and determine whether the reserve funding amount needs to be increased.

D. Continuously improve: reevaluate and modify climate-related risks

This step allows you to reevaluate how climate hazards and risks are being incorporated into your emergency management process. See Section 4.8 on adaptive management. Important questions to consider include the following:

- How do we expect the frequency or the severity of hazards to change?
- Have new hazards emerged that need to be considered?
- How have we performed in relation to specific climate hazards (e.g., extreme heat, increased frequency of severe storms)?

This review may be particularly important after an extreme event. After the event, review recent trends and the latest climate projections to determine whether extreme events are the beginning of a potential trend, rather than a one-off. In some cases, and depending on the risk tolerance of your airport, it may make sense to prepare for future occurrences of the event.

E. Integrate with decision-making: continuously integrate new climate risk information into risk assessment

This step allows you to integrate continuously new climate risk information into decision-making. As you would for any other hazard, periodically review data on climate hazard risks and recent weather trends to understand better how your airport may be affected. After a review, refine your risk register to include updated climate-related risks. See Section 4.8 on adaptive management.

4.8 Cross-Cutting Adaptive Management Strategies

Goal of Adaptive Management Regarding Climate Risk

Begin tracking and regularly reviewing data so that you are aware of changes in trends and are ready to respond to climate risks as they become increasingly prevalent.

In addition to the system-specific strategies addressed above, it is important for your airport to establish adaptive management strategies to regularly track and continuously incorporate new data and information into your airport's decision-making processes over time. Most airports already practice adaptive management in some form, such as annual budget reviews or property condition assessments, because it can inform managers of any changes that may affect operations or performance. The value proposition for adaptive management is even stronger in light of climate change, as climate change may create changes in weather or travel patterns potentially influencing whether you meet your performance measures.

Adaptive management strategies are appropriate for all airports, regardless of their climate risks or existing management systems. Adaptive management can occur within or across management systems. Even if you are already using adaptive management, review this section to make sure that you are tracking the right variables to capture your potential climate risks.

Acting now to create processes to monitor specific metrics—such as climate hazards and their associated impacts on airport costs and performance—can help your airport understand risks better over time and identify and mitigate the risks accordingly. For example, you may not have sufficient information today to make a business case for specific investments, but tracking—and analyzing—the costs associated with climate-related impacts can guide investment decisions

over time. These approaches can also help you monitor the effectiveness of certain climate risk management strategies, and what opportunities exist for improvement (FHWA 2015).

The following strategies can help you track and monitor the appropriate data.

4.8.1 Identify Data Metrics

Your airport could begin tracking a number of data metrics to detect changes in local climate conditions and understand more fully the true costs to your airport. Table 4 provides example metrics for asset performance, operations, overall expenditures, and the frequency or the intensity of weather events that can be useful for your adaptive management efforts. You may be tracking some of these metrics already, but not in terms of climate change. Appendix C presents a full list of example metrics.

Align your data metrics with your priority climate risks and management systems identified in the self-assessment (Chapter 2). You may also wish to begin tracking metrics for long-term risks so that you are aware of any changes in asset performance, operations, expenditures, or event frequency and severity. You may need to prioritize data metrics on the basis of available resources, relevance to airport strategic priorities, and likely climate impacts at your airport (see Section 2.2).

4.8.2 Use Event Expense Codes

One strategy that some airports and transportation agencies, such as the Southeastern Pennsylvania Transportation Authority (SEPTA), have found useful is using event codes to track the costs and the impacts associated with a specific extreme event. The code is assigned at the first sign of an event and can be used to track labor, materials, and other costs associated with event preparation, response, and recovery. For example, in advance of Hurricane Sandy, SEPTA developed a labor charge code to better capture the costs associated with the event, including work done in advance of, during, and after the storm (ICF 2013). By assigning a code to a specific weather event, you can assess the severity of the impacts and costs and easily compare the event to others.

4.8.3 Use Existing (or Create New) Annual Processes to Review Data

Having some sort of process in place to track gradual changes is key, whether it is for changes in climate or operations and performance. If you are not tracking the data, you might not notice gradual changes through observation alone.

Table 4. Example Data Metrics.

Data Metric	Tracking Frequency
Asset Performance	
Duration of damage or closure (i.e., how long was asset out of service)	For each event
Pavement condition (such as occurrences of **buckling, rutting, and cracking** on runways and other paved surfaces)	Annually
Operations	
Changes in **energy usage**	Annually
Number of **weather-related flight delays or cancellations**	Annually
Overall Expenditures	
Quantity of **staff time** spent preparing for, responding to, and recovering from weather events	For each event
Cost of damages to infrastructure and facilities	For each event
Weather Event Frequency and Severity	
Frequency of storm events (e.g., thunderstorms, hurricanes, snow storms, other severe weather)	For each event
Frequency of extreme temperatures (e.g., heat waves or cold fronts)	For each event

You may already have an annual process in place to review data that could be modified to include the types of data metrics presented in Table 4 and Appendix C. For example, at Southwest Florida International Airport (RSW), the engineering department submits an annual report to the budget director that summarizes facility conditions, maintenance and investment needs, and expected useful life of facility components. A recent annual review found that jet bridges at the airport were reaching their end of life earlier than anticipated; this change was in part because of high heat and humidity. As a result, the airport developed a strategy to replace the jet bridges.

In addition, include an annual review of the airport's reserve and replacement budget for emergencies. Update the process to track how often and why the airport used the funding to determine whether the reserve funding amount needs to be increased.

If you do not have an existing process in place that would fit this purpose, you could create a simple annual review process to monitor changes in trends.

Annual reviews can also help bring awareness to trends in extreme weather events. After an extreme event, having this information can help you evaluate, for example, whether you should invest in a new piece of equipment to improve response to a similar future event.

4.8.4 Identify a Tipping Point

As you begin tracking these metrics, identify a tipping point when your airport will begin thinking about, and planning for, long-term changes. It may be beneficial to hold a meeting with representatives from various departments, including master planning, asset management, capital planning, and safety management, to analyze scenarios and determine the appropriate tipping points for the metrics that you are tracking. The tipping point value should be reflective of what your airport deems to be a significant change in the frequency or severity of events requiring a potential change in your management processes.

For example, Boston (Massport) initially used flood mapping tools to identify a target flood level height for new and existing structures and has begun flood-proofing high-priority structures. However, after observing flooding in new areas during recent severe rainfall events, Massport has started to revisit its flood-proofing design standards.

If your airport reaches a tipping point, you should transition from monitoring conditions to actively implementing risk strategies. The previous sections within this chapter highlight system-specific strategies that you can adopt to integrate climate risk into your planning processes.

CHAPTER 5

Next Steps

With this handbook, you have identified your relevant climate risks and strategies for mitigating these risks within your management system. You now need to take the next steps to implement your plan, such as

- Building support for climate risk management efforts (see Chapter 3),
- Establishing monitoring processes (see Section 4.8),
- Identifying and prioritizing needed actions, determining who will complete these actions, and coordinating with these individuals.

As you begin this process, revisit Chapter 4 for recommendations on implementation. The strategies in this handbook are intended to improve, not to overhaul dramatically, the processes that you already have in place. For example, a less-vulnerable airport, such as an inland airport not exposed to flooding, might consider tracking climate-related metrics in the short-term to gain a better perspective on what climate risks will require significant investments in the long term. More vulnerable airports may consider developing a climate resilience goal through strategic planning to guide airport planning efforts.

Climate change integration can be a slow, incremental process. Even with support from executives and upper-level management, managing climate risks will require engagement and buy-in at each personnel level. For example, data collection in asset management requires the participation and the commitment of everyone, from managers to maintenance crews, who has a detailed knowledge of the physical status of assets. Be prepared for dips in momentum as your climate change integration efforts continue, especially if your airport is frequently limited in capacity to take on new responsibilities. Revisiting and refocusing on your original goals and objectives can help overcome stalls in progress. Despite setbacks, generating a proactive approach for mitigating climate risk now can avoid significant costs in the future.

Once in place, your climate risk management processes will continually need monitoring and improvements. Climate change projection data are constantly changing, and you will need periodic cycles of updates to ensure that you are preparing for changes in hazards and risks. You should look to engage with staff at each level to understand what is and what is not working in your integration strategies. For management systems that include performance metrics, you should closely monitor metrics related to climate hazards and risks, such as weather-related service disruptions.

Future ACRP and Transportation Research Board research will help expand the strategies and resources presented in this report. This research will include technical approaches for analysis techniques that support climate risk mitigation efforts (see ACRP Project 02-78 and NCHRP Project 20-101) as well as strategic needs.

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APPENDIX A

Self-Assessment Worksheet

Table 2 and Table 3, located in Chapter 2 of this handbook, provide examples of risks and additional guidance for completing this worksheet.

A	B	C	D	E
Expected Hazards	**Expected Timing**	**Physical Risks**	**Business and Operational Risks**	**Safety and Security Risks**
☐ High temperatures				
☐ Heavy precipitation and flooding				
☐ Snowstorms				
☐ Ice storms				
☐ Drought				

(continued on next page)

A	B	C	D	E
Expected Hazards	**Expected Timing**	**Physical Risks**	**Business and Operational Risks**	**Safety and Security Risks**
☐ Wildfires				
☐ Sea level rise				
☐ Hurricanes				
☐ Other:_____				
☐ Other _____				
Highest risk rating:				

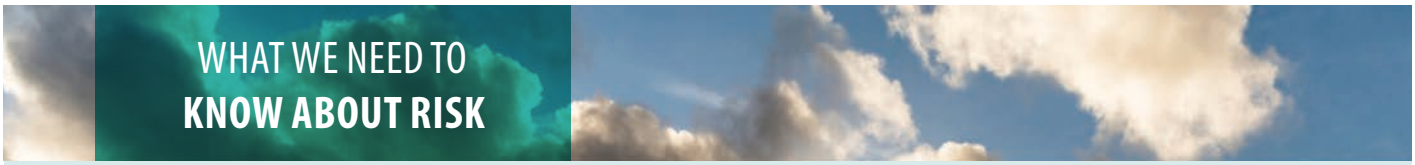
When you have completed your self-assessment, return to Section 2.3 to identify how to start managing your climate risks.

APPENDIX B

Template for Communicating with Airport Executives

Before you can identify, develop, and propose strategies for climate change integration at your airport, you may need to build support. This appendix contains a blank template for communicating about these risks with airport executives, as well as a completed version that you can reference for an example.

Use the template on the following page to enter key information for your airport. Replace "<Enter text here>" with information specific to your airport. For examples of what to enter, hover over the text field on the blank template or see the "EXAMPLE" template filled out on the subsequent page. You can find the template online by searching the TRB website (www.TRB.org) for *ACRP Research Report 188: Using Existing Airport Management Systems to Manage Climate Risk*.



WHAT WE NEED TO KNOW ABOUT RISK

Recent trends show that the frequency and the type of extreme weather events are changing, with impacts across industries and societies worldwide. New and different hazards pose a risk to < Enter Text Here >***, in both the near- and the long-term, but there are changes we can make today to manage these risks over time.***

Potential Near-term Risks

< Enter Text Here >

Benefits of Taking Action

< Enter Text Here >

Recent Trends and Observed Impacts

< Enter Text Here >

HOW OTHER AIRPORTS ARE ADDRESSING CLIMATE RISK

Airports of all sizes are starting to manage their climate risks, including airports in Boston, Istanbul, San Diego, Philadelphia, New York, and Toronto.

FOR EXAMPLE:

- Massport **(Boston Logan International Airport)** in Boston, Massachusetts, assessed flood risks. From this, Massport set a new design flood elevation for infrastructure and began a process to systematically floodproof critical assets.
- In Canada, **Toronto Pearson International Airport** accounted for increased frequency and intensity of microburst storms in a hydraulic analysis for a new culvert and is evaluating the potential impacts of a new precipitation mix on deicing fluid use and water quality.
- In Turkey, **Istanbul New Airport**, the world's largest, built-in water and power efficiency is expected to save around USD 8.5 million annually and create less dependence on local supplies.

Where to Go from Here?

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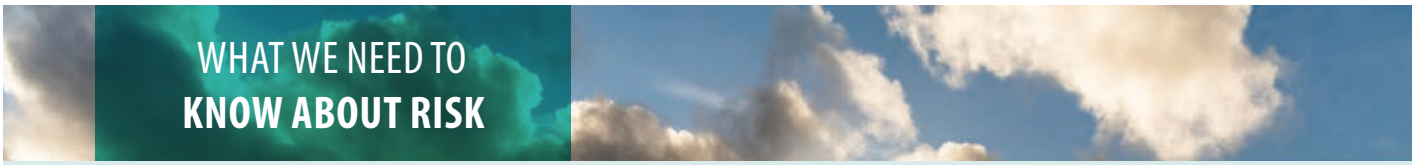

WHAT WE NEED TO **KNOW ABOUT RISK**

Recent trends show that the frequency and the type of extreme weather events are changing, with impacts across industries and societies worldwide. New and different hazards pose a risk to < Enter Text Here >***, in both the near- and the long-term, but there are changes we can make today to manage these risks over time.***

Potential Near-term Risks

- More frequent heavy rain events (up to 3 times more events with more than 2 inches of rain in 24 hours within the next 20–30 years) could lead to
  - More frequent drainage system failures and
  - Higher risk of environmental contamination.
- Increase in heat waves (up to 25 days per year above 95 degrees Fahrenheit) – could lead to
  - Reduced efficiency of outdoor staff due to need for more, frequent breaks, and
  - Risks to elderly travelers.
- Increased risk of pavement rutting and shoving.

Benefits of Taking Action

- Save on maintenance costs for drainage system maintenance, pavement repair, and other weather-related costs
- Avoid costly mistakes in drainage design for planned runway extension project
- Maintain compliance with environmental regulations
- Improve safety and security for staff and passengers

Recent Trends and Observed Impacts

- Runways were flooding from heavy downpours four times in the past five years, and resulted in
  - 27 canceled flights,
  - $20,000 in clean-up costs per event ($80,000 total), and
  - $40,000 in lost revenues per event ($160,000 total).
- Number of emergency response calls for workers in heat distress has doubled from the current 5-year period from the previous period.
- Observed 10% increase in cooling costs over past 5 years.

HOW OTHER AIRPORTS ARE ADDRESSING CLIMATE RISK

Airports of all sizes are starting to manage their climate risks, including airports in Boston, Istanbul, San Diego, Philadelphia, New York, and Toronto.

FOR EXAMPLE:

- ❺ Massport **(Boston Logan International Airport)** in Boston, Massachusetts, assessed flood risks. From this, Massport set a new design flood elevation for infrastructure and began a process to systematically floodproof critical assets.
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- ❺ In Turkey, **Istanbul New Airport**, the world's largest, built-in water and power efficiency is expected to save around USD 8.5 million annually and create less dependence on local supplies.

Where to Go from Here?

- Create airport policy to require all new infrastructure designs to incorporate future precipitation projections.
- When emergency management plan is due for update this spring, ensure extreme heat is adequately captured.
- Follow the ACRP Handbook to integrate climate risks into the asset management system.
- Continue to track and analyze flood frequency and frequency of heat-related issues.
- Distribute climate change projection information to all departments.

APPENDIX C

Data Metrics to Monitor

A key component of integrating climate risk into airport management systems is monitoring climate-related metrics over time. You will want to track both the frequency and the severity of climate impacts. Data points for monitoring these changes fall under four primary categories: asset performance, operations, overall expenditures, and weather event frequency and severity. Table 5 provides a list of suggested data points, tracking frequency, and the relevant management systems for each. The personnel needed will vary depending on the type of data and management system.

Table 5. Data points to monitor.

Data Point	Tracking Frequency	Strategic planning	Master Planning	Enterprise Risk Management	Safety Management	Asset Management	Capital Planning	Emergency Management
Asset Performance								
Extent and cause of damages to infrastructure and facilities, including photos	For each event					✓		
Duration of damage or closure (i.e., how long was asset out of service)	For each event					✓		
Pavement condition (such as occurrences of **buckling, rutting, and cracking** on runways and other paved surfaces)	Annually					✓		
Facility condition	Annually					✓		
Expected life vs. actual life of assets	Annually					✓		
Frequency of **storm drain overflows or blowouts**	Annually					✓		
Frequency of **water-ponding**	Annually					✓		
Causes of weather-related flight delays (e.g., runway not long enough during a high-heat event)	For each event					✓		✓
Causes for repairs (make sure staff can categorize damage as related to heat, flooding, freeze/thaw, etc.)	For each event					✓		
Type and severity of weather event that caused damage (preferably by specific event/date)	For each event			✓		✓		✓
Changes in **remaining service life**	Annually					✓		

(continued on next page)

Table 5. (Continued).

Data Point	Tracking Frequency	Strategic planning	Master Planning	Enterprise Risk Management	Safety Management	Asset Management	Capital Planning	Emergency Management
Operations								
Changes in **energy usage/service interruptions**	Annually	✓	✓					
Changes in **water demand/shortages**	Annually	✓	✓					
Number of **weather-related flight delays or cancellations**	Annually/ seasonally	✓	✓					
Duration of **airport closure**	For each event	✓	✓					
Operational impacts to **access roads**	For each event					✓		
Frequency/duration of **runway (or other asset) closures** due to flooding (or other hazard)	For each event					✓		
Changes in **seasonal work requirements** (e.g., changes in winter weather season, construction timing)	Annually	✓	✓				✓	
Changes in **equipment needs or usage** (e.g., number of snow plows in use or number of days snow plows were needed)	Annually					✓		
Number of **ozone response days**	Annually				✓			✓
Frequency and type of **emergency responses** (e.g., slip and falls, heat exhaustion, fire)	Annually				✓			✓
Frequency of **tick or other insect bites**	Annually				✓			
Frequency of **bird strikes**	Annually				✓			
Overall Expenditures								
Frequency of **emergency fund** requisitions (i.e., how often you spend your emergency fund)	Annually					✓		✓
Quantity of **staff time** spent responding to weather events	For each event	✓	✓				✓	
Quantity of **contract staff** required to address weather issues	For each event	✓	✓				✓	
Worker's compensation due to injuries from extreme weather events	Annually						✓	
Track the **costs of materials/staff** required to prepare for and recover after a weather event (e.g., personal protective equipment, deicing supplies, or hydration needs)	For each event						✓	
Track the **cost of damages** to infrastructure and facilities	For each event				✓	✓	✓	
Track **maintenance and repair costs**	Annually					✓	✓	
Weather Event Frequency and Severity								
Frequency of storm events (e.g., thunderstorms, hurricanes, snow storms, other severe weather)	For each event							✓
Frequency of extreme temperatures (e.g., heat or cold waves)	For each event							✓
Severity of storm events (e.g., amount of precipitation and extent of flooding)	For each event							✓
Frequency of extreme temperatures (e.g., above a relevant threshold)	For each event							✓

APPENDIX D

Climate Data Resources

If you find that additional information would be helpful for assessing your airport's vulnerability, detailed, location-specific climate information is available from a variety of sources. Listed below are the current best available data sources, which are updated regularly as new data become available.

The sources below, drawn from *Synthesis of Approaches for Addressing Resilience in Project Development* (FHWA 2017), provide temperature and precipitation data and projections in the form of regional or downscaled projections. Often, for project-level analysis, you need to access downscaled climate data at a finer resolution. These sources provide downscaled climate projections as readily downloadable data sets. They are listed in order from lowest to highest level of effort. For example, Climate Explorer allows you to view projections, while later databases allow you to download raw climate data outputs, which you would have to process yourself. If you find yourself in need of more rigorous climate assessment, your airport could use the U.S. DOT Coupled Model Intercomparison Project (CMIP) Climate Data Processing Tool to analyze these datasets, hire experts, or partner with a university.

Temperature and Precipitation Data

Options for Accessing Preprocessed High-Resolution Temperature and Precipitation Data

These resources provide projections of specific variables based on high-resolution, downscaled climate model data:

- Climate Explorer. This resource, found within the U.S. Climate Resilience Toolkit, provides interactive, customizable graphs and maps of observed and projected temperature, precipitation, and other climate hazards for every county in the contiguous United States. The tool can be used to find climate information for the area around your airport and shows two possible future projections for climate hazards.

  Variables included mean daily maximum temperature, mean daily minimum temperature, days with max above 95°F, days with min below 32°F, heating degree days, cooling degree days, mean daily precipitation, and days of precipitation more than 1 in.
- USGS National Climate Change Viewer. This tool includes historical and future climate projections from a variety of models and allows users to visualize the changes in climate (e.g., temperature and precipitation) and the water balance (e.g., snow water equivalent, runoff, soil water storage, and evaporative deficit) for any state and county.

  Variables include annual, monthly, 10th percentile, 25th percentile, 50th percentile, 75th percentile, and 90th percentile maximum temperature, minimum temperature, precipitation, runoff, snow, soil storage, and evaporative deficit.

Options for Accessing Raw High-Resolution Temperature and Precipitation Data

If the variables, time periods, or other aspects of the above data are insufficient for your needs, perform custom analyses of the raw climate model data.

Data Sources

- Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections (DCHP) database. This tool contains publicly available, downloadable, downscaled climate projection data for the contiguous United States (for temperature and precipitation).
- USGS Geo Data Portal. The web portal provides access to climate data sets, including projections for temperature and precipitation using different downscaling techniques.
- Coordinated Regional Climate Downscaling Experiment (CORDEX). This tool provides a model evaluation framework and an interface that users can look at climate simulations in climate change impact, adaptation, and mitigation studies.
- North American Regional Climate Change Assessment Program (NARCCAP). This is an international program that provides high-resolution climate scenarios for North America, with the use of regional climate models, coupled global climate models, and time-slice experiments.

Processing Options

- U.S. DOT CMIP Climate Data Processing Tool. This Excel-based tool processes data from the DCHP database to provide local-scale projections for climate variables that are significant for transportation planners, specifically temperature and precipitation (e.g., number of days above 95°F, hottest 7-day temperatures, and largest 3-day precipitation events).
- Partner with an external expert (e.g., NOAA Regional Integrated Sciences and Assessments Center, universities, and consultants)

Sea Level Rise Data

Airport managers must determine appropriate sea level rise scenarios for their location and needs and determine how sea level rise will affect flood frequency at their location. To develop these estimates, conduct an independent study to capture local conditions. A variety of resources can help you gather these data.

Selecting the appropriate sea level rise scenarios requires parameters beyond temperature and precipitation scenarios. Most data sources provide projections at the national level, although some are adjusted for local upshift and subsidence. However, in areas where relative sea level rise rates are not available or when outstanding coastal processes are not accounted for, you may need to develop your own estimates. Airports should choose a range of global sea level rise estimates and integrate data on local land characteristics to determine local sea level rise.

The following sources can be used to find sea level rise estimates and data. The majority of listed resources provide sea level rise projections, while the last resource is a visualization tool to explore sea level rise potential in different areas.

Sea Level Rise Projection Sources

State and Local-level Resources

- State and local guidance on sea level rise scenarios. Examples include the following:
  - California Department of Transportation's Guidance on Incorporating Sea Level Rise.
  - Massachusetts Sea Level Rise: Understanding and Applying Trends and Future Scenarios for Analysis and Planning was released in 2013 and provides guidance on selecting and applying sea level rise scenarios.
  - Southeast Florida Regional Climate Change Compact Unified Sea Level Projections provides projected sea level rise for the southeastern part of the state through 2100 and guidance on how to select appropriate scenarios.

National Resources

- *NOAA Technical Report NOS CO-OPS 083: Global and Regional Sea Level Rise Scenarios for the United States* (2017) provides updated estimates for global mean sea level rise through 2100 in 10-year increments, while also identifying reasonable ranges through 2200. The report provides six scenarios, plus the probability that each might occur under different scenarios (RCP2.6, 4.5, and 8.5). Though mostly national, the report does include some information on how global changes would manifest regionally.
- U.S. Army Corps Sea Level Change Curve Calculator is a web-based tool that produces a table and graph of projected sea level changes at a specific location, using user input data. If no state guidance is available, this resource can be used to adjust global sea level rise estimates for local land elevation through 2100. This tool uses NOAA tide gauge data and sea level rise estimates from the National Research Council (NRC), Intergovernmental Panel on Climate Change (IPCC), and NOAA, and it provides projections for high, medium, and low scenarios.
- National Climate Assessment (NCA) describes high-level projections of all climate stressors, focused on geographic regions (e.g., Pacific Northwest, Southwest, and Southeast). This resource can be a good overview of the types of climate changes expected in a region. It includes the rate of global and regional sea level rise, including historical and projected changes. The NCA is updated every four years.

Sea Level Rise Mapping Resources

- NOAA Sea Level Rise Viewer is a web mapping tool that allows you to visualize community-level impacts of sea level rise and coastal flooding. You can download sea level rise data for a variety of locations and use the tool to visualize exposure to sea level rise at levels up to 6 feet. However, this tool does not account for erosion, subsidence, or other processes. Therefore, the viewer is not recommended for detailed site analyses but can be used as a screening tool.
- Climate Central's Surging Seas: Risk Zone Map is an interactive online map presenting sea level and coastal flood risk information for the United States. Using its features, you can see projections for a particular area or modify the water level between 0 and 10 feet to view inundated areas.
- Climate Central's Surging Seas: Risk Finder is an interactive screening/scoping tool that provides detailed local projections of more than 100 infrastructure and population variables. The tool uses maps, local sea level and flood risk projections, and other variables presented in an accessible way. This tool is not appropriate for site-level assessment, hazard assessment, or many more specific uses.

APPENDIX E

Quick Start Handbook

Quick Start Guide:

Using Existing Airport Management Systems to Manage Climate Risk

Prepared for
Airport Cooperative Research Program • Project 02-74
Transportation Research Board of The National Academies

Prepared by
ICF
with Gresham, Smith and Partners, and Faith Group, LLC

Washington, DC • January 2018

1.0 INTRODUCTION

This Quick Start Guide accompanies ACRP Research Report 188. The guide and handbook present a practical approach for airports to account for risks from a changing climate when assessing risks as part of existing management systems. Each chapter of the associated handbook provides additional detail and insights associated with the chapter subject area.

1.1 Who should use this Quick Start Guide?

- Do you manage airport infrastructure or services?
- Does weather affect the infrastructure or services that you manage?
- Does weather influence your airport's ability to operate?
- Do you wish to reduce the financial, operational, and safety risks at your airport?

If you answered "yes" to any of the questions above, this Quick Start Guide is for you. Even if your airport has not experienced extreme weather events in recent years, it is important to understand how the climate may change in your area and the associated vulnerabilities and risks to maintaining your day-to-day operations.

1.2 Why should my airport be concerned about climate change?

A changing climate creates uncertainty in the type, frequency and intensity of weather events that may occur. Recent trends at your airport may already be evident, such as

- Increased frequency of intense storms or microbursts,
- Longer lasting or more frequent extreme temperatures,
- Drought, and
- Flooding from higher tidal storm surges and increased sea-level rise threats.

New or different hazards resulting from changing climate conditions can create impacts to your airport both in the short- and long-term:

- Limiting the service life of existing infrastructure assets.
- Altering the type and frequency of emergency response situations. These could require added capacity to avoid service disruptions (e.g., flooding from microbursts that compromise worker safety and asset functionality).
- Expanding or shortening the tourism season for your community, resulting in new economic considerations.

Your airport may already have management systems that manage risk to severe weather and other hazards. You can use these existing systems to address your new impacts from a changing climate.

CLIMATE RISK

DEFINITION: The potential losses associated with individual or multiple climate hazards, defined in terms of expected probability and frequency, exposure, and consequences . Also known as *climate change risk* (ACRP 2015a).

1.0 INTRODUCTION

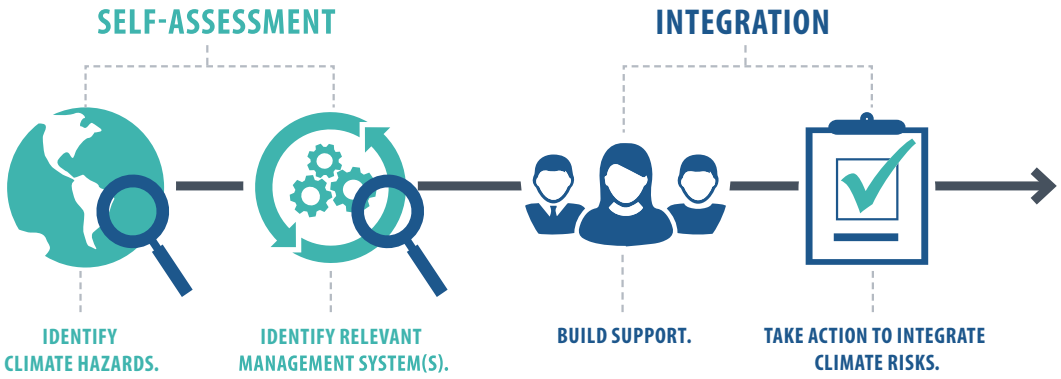
WHAT ARE THE BENEFITS OF INTEGRATING CLIMATE RISKS INTO EXISTING MANAGEMENT SYSTEMS?

- **Save on costs** for pavement repair, drainage system maintenance, and other weather-related costs.
- **Improve safety and security** for staff and passengers
- **Avoid being caught unprepared** for an extreme weather event
- **Avoid underestimating infrastructure sizing requirements**
- **Maintain compliance** with environmental, safety, and other regulations
- **Improve reliability and customer service**
- **Maintain continuity of operations** during an extreme event
- **Improve ability to recover** from an extreme event

1.3. How do I start managing my climate risks?

The following four elements, listed below and addressed in subsequent sections of this Quick Start Guide, are the key action items for managing climate risks using the common management systems in place at your airport.

The first two elements are part of a self-assessment process and the final two elements support integration into your management systems.



WON'T MY BUSINESS-AS-USUAL PROCESSES TAKE CARE OF MY CLIMATE RISKS?

Some business-as-usual processes, such as annual engineering assessments, can help you to stay on top of trends and impacts as they occur. This adaptive management approach is best suited to manage *gradually changing* risks over time. When climate change poses *immediate threats*, adaptive management may not be sufficient. This Quick Start Guide will help you identify opportunities to proactively address impacts.

2.0 SELF-ASSESSMENT

Your airport is unique. You have a set of established management systems used to conduct business, some of which may follow industry standards while others may be a less formal process. Your airport experiences "typical" weather that may change in the future due to a changing climate. And the team at your airport is already familiar with addressing and mitigating risks.

2.1 What are my relevant climate hazards?

Information on the anticipated local climate hazards is available from numerous sources—so many, in fact, that many airports find it overwhelming. The following steps are intended to simplify that process:

USE THIS INFORMATION TO FILL OUT COLUMNS A AND B OF THE SELF-ASSESSMENT WORKSHEET

1. If you have little previous exposure to the topic of climate change and the associated impacts, **review the *National Climate Assessment (NCA)* chapter for your region** for a high-level overview. If you are already familiar with this information, continue on.

2. **Use the *ACRP Airport Climate Risk Operational Screening (ACROS) Tool*** to gather detailed, airport-specific projections of climate hazards and associated impact to your infrastructure assets.

SHORTCUT! Without going through the full tool to evaluate climate risks, you can use the ACROS tool to gather climate projections for your airport in less than 10 minutes:

❶ Open the ACROS tool

❷ Enter your airport code

❸ Click the "Reports" button at the bottom left pane to generate a summary table of the climate hazard projections at your airport

3. **Check whether there have been other climate change assessments in your location.** For example, check with your local city government or university for existing published studies. These may provide additional information beyond the ACROS tool.

4. **If your airport is coastal**, look for information on whether any parts of your airport or its access roads could be affected by sea level rise. Check the following sources of information:
   - » **Locally-specific studies** – Many coastal areas have existing sea level rise mapping studies that consider local land elevations, vertical land movement rates, expected sea level changes rates in the area, and local coastal processes. Check with your state or local government offices and nearby universities for existing sea level rise assessments.
   - » **NOAA** – If no locally-specific studies are available, the ***NOAA Sea Level Rise Viewer*** is a tool to visualize community-level impacts from coastal flooding or sea level rise (NOAA 2017).

The answers to these questions and completion of the **Appendix A – Self-assessment Worksheet, located in the accompanying handbook** is your first step in this process. The self-assessment will help you understand your airport-specific climate hazards; the risks these hazards pose to operations, workers and passengers; and which of your existing management systems are best for managing these risks. **Please see Chapter 2 of the handbook for more self-assessment details.**

2.0 SELF-ASSESSMENT

2.2 What are my expected climate risks?

Now that you have information on anticipated local climate hazards, evaluate what risks these pose to your airport. The degree of risk depends on: the magnitude of change for each climate hazard, the sensitivity of your airport infrastructure and operations to those changes, and your preparedness to adapt.

USE THIS INFORMATION TO FILL OUT COLUMNS C, D, AND E OF THE SELF-ASSESSMENT WORKSHEET

1. **High-level risk assessment** is appropriate if you are not ready to spend time on a more detailed risk assessment. Work with others in your airport to evaluate how the projected climate hazards could disrupt service, cause safety concerns to airport workers or passengers, and change service demand (e.g., tourism season variations), among other items.

TIP! Default results from the ACROS tool provide a structured process for conducting a risk screening to identify what's most at risk to projected climate change (ACRP 2015a).

2. For a more **detailed risk assessment**, involve staff from multiple departments to assess and prioritize risks by completing the **ACROS tool**. The tool includes sequential screens where users rate the criticality (i.e., importance) and vulnerability on their assets to the hazards.

2.3 Which of my management systems should I use to address my climate risks?

Consider the different types of management systems you regularly execute at your airport. Different management systems may be more appropriate for managing different types and levels of risk. For example:

Strategic Planning	Well-suited to manage multi-discipline, potentially existential risks to the airport, such as the risk of long-term inundation from sea level rise or the potential for significant changes in passenger or other use demand
Master Planning	Useful to manage long-term infrastructure risks that can impact forecasted service levels, such as those from extreme temperatures, sea level rise or flooding
Enterprise Risk Management	Applicable to holistically address risk identification, planning and response coordination across the airport, such as those addressing airport service reliability
Safety Management	Well-suited to manage safety-related risks, such as extreme heat and the health effects on workers
Capital Planning	Applicable to address infrastructure management and investment through a multi-year approach that ensures basic safety, security and operational efficiency and maximizes economic potential
Asset Management	Well-suited to manage the status of existing assets and infrastructure, as well as risks related to changes in operations and maintenance costs
Emergency Management	Useful to manage risks from operational changes due to extreme events (e.g., new risk of wildfires or ice storms)

Select the management system(s) that are best suited to address your identified risks. Climate risks likely can be addressed using any of the above common management systems. **Refer to Chapter 2.3 of the handbook for additional explanation.**

3.0 BUILDING SUPPORT

Before you can identify, develop, and propose climate risk integration strategies at your airport, you may need to build support and consensus. The following strategies can help you build the support you need. Chapter 3 of the handbook presents additional strategies and examples.

–Template for Communicating with Airport Leadership.

3.1 Identify a champion

Climate risk management initiatives may be most successful when there is a specific individual or team that generates support and excitement. This champion, or champions, drive climate risk integration across your airport so that it is considered in each management system planning cycle. The role of this champion is not to single-handedly do all the work, but to gather the support that is needed, foster collaboration, and sustain momentum for the effort.

3.2 Define roles and responsibilities

Clearly defining the responsibilities of involved individuals and their specific tasks is important, especially when starting out. This efficiently and effectively helps each individual to understand and take actions in their departments that align with the champion's objective.

3.3 Make the case to executive management

Securing the buy in of airport executives and senior management on the long-term value and benefits of your effort creates alignment on multiple levels. To start, executive leadership sets the priorities for individual departments. Executive management also has a broad view of the organization and may provide insight and access to resources to further refine how climate risks are addressed internally.

A template and guide for speaking with executive management is included in the **handbook's Appendix B, Template for Communicating with Airport Executives.**

3.4 Build support across airport departments

Building an awareness of the risks from changing climate conditions will require a coordinated and persistent approach. The end goal is to develop consensus and share information to account fully for these risks. Engaging executive management to assist with facilitating this coordination is encouraged, where feasible.

Communicate to the different levels of management within your department the value, benefits and available information already collected to date (as part of the self-assessment process) to build momentum for continued engagement. From there, find opportunities to connect with other departments. You may find you are not the only person actively seeking to integrate climate risk, and other teams may have begun efforts.

3.5 Coordinate with external stakeholders

Airlines, other commercial airport tenants, fixed base operators (FBOs), and concessions (i.e., external stakeholders) are dependent on airports to maintain business continuity. Coordinating with these stakeholders allows you to address indirect climate risks that cannot be directly mitigated by your airport. These risks might range from energy and water supplies to road access.

3.6 Communicate effectively

Keeping your message straightforward, focused, positive, and solutions-based will increase understanding.

Effective strategies to communicate climate risks within your airport include:

1. **Focus on risks from climate change, not the causes.** The science behind the forces that create climate change can be challenging to communicate, and sometimes can create tension. Focusing instead on the risks, and those risks specific to your airport and region, can simplify this message.
2. **Keep the message positive**. A proven approach is to focus your message on what CAN be done to mitigate risks from climate change, whether as an individual or team. When people feel they are empowered to address a risk, they are more likely to act.
3. **Focus on why this matters to your audience .** The risks to any particular airport functional area may vary. While keeping your core points and objectives the same, tailor your message when addressing different audiences. For example, planners involved in emergency management will better relate when the focus is on risks and hazards associated with frequency and intensity of severe weather events, while asset management personnel will be more interested in impacts to infrastructure maintenance and operational reliability.

4.0 USING MANAGEMENT SYSTEM FLOWCHARTS

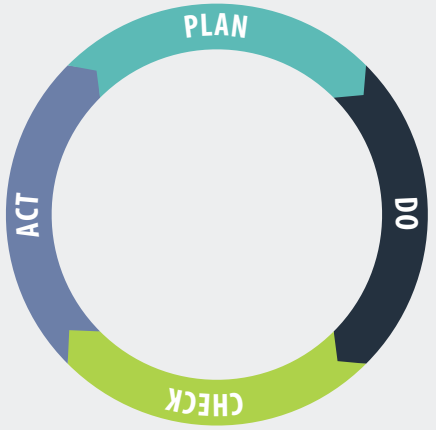
You have completed the self-assessment, identified the climate hazards and evaluated the associated risks to your airport. You have buy-in from the appropriate decision makers. **Well Done!** Now one of your management systems is ready to begin the planning cycle. Let's get started.

QUICK START GUIDE'S AIRPORT MANAGEMENT SYSTEMS

4.1 What are management system flowcharts?

The Quick Start Guide includes a flowchart overview of the main steps in each of the seven common management systems. The steps are organized into the International Organization for Standardization (ISO)'s Plan-Do-Check-Act framework (ISO 2015). This 4-step framework helps you align the flowchart steps with your own planning process, even if you do not have a formal management system or follow the steps exactly as outlined. A simplified flowchart is also presented (following page) to illustrate the various components.

Depending on the selected management system and your preferred level of climate integration, some climate entry points may be more relevant than others. This is an opportunity to account for, or integrate, climate risks into the management system(s) you regularly update. **Chapter 4 of the handbook provides details to maximize each entry point.**



PLAN ▶
- Define scope and objectives.
- Collect and analyze data.
- Identify risks/problems.
- Develop a plan to solve problems/meet objectives.

DO ▶
- Implement plan.

CHECK ▶
- Verify plan meets objectives by monitoring and measuring progress.

ACT ▶
- Improve process effectiveness based on findings.
- Integrate with future decision-making.

4.0 USING MANAGEMENT SYSTEM FLOWCHARTS

4.2 How do I use the management system flowcharts?

Step1. Identify the management system. - Referencing the list of 7 common management systems, select the system you will be reviewing. Locate the associated flowchart in Section 5.0 of this Quick Start Guide.

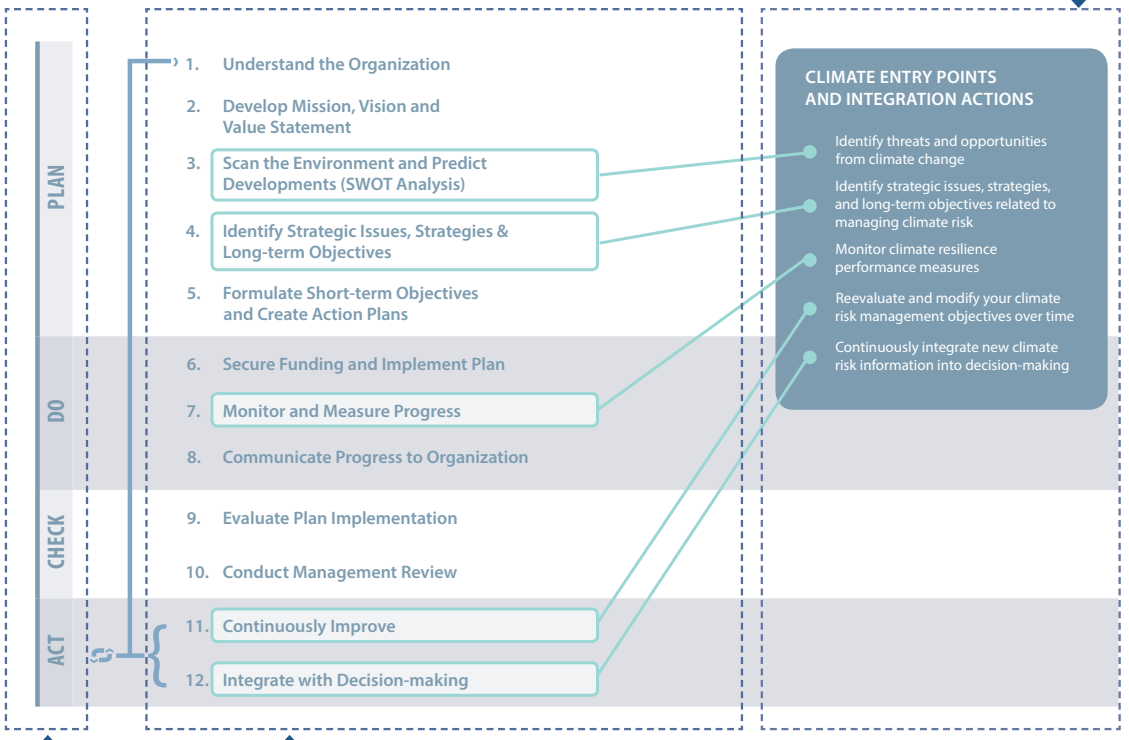
Step 2. Review the management system flowchart for climate entry points. – You are likely familiar with the typical steps you take when creating a system and implementing the system for any particular topic area. Compare your typical process with the detailed flowchart. Identify the steps with a corresponding climate entry point and integration action and determine those that apply to your tailored implementation of your management system.

Step 3. Execute the management system – Complete the plan-do-check-act steps of your management system as you typically would and account for climate risks at the pre-identified climate entry points. Look for opportunities to coordinate with other management system data collection and prioritization. For example, end of life data collected during asset management system implementation may inform the prioritization of funding determined during the capital planning process.

Step 4. Continuous improvement – Each time the management system planning cycle commences, consider new or different risks from updated climate change data.

HOW TO READ YOUR FLOWCHART

CLIMATE ENTRY POINTS AND INTEGRATION ACTIONS -These describe the climate-related risk assessment steps, or climate entry points, along with the corresponding suggested action(s) during that step



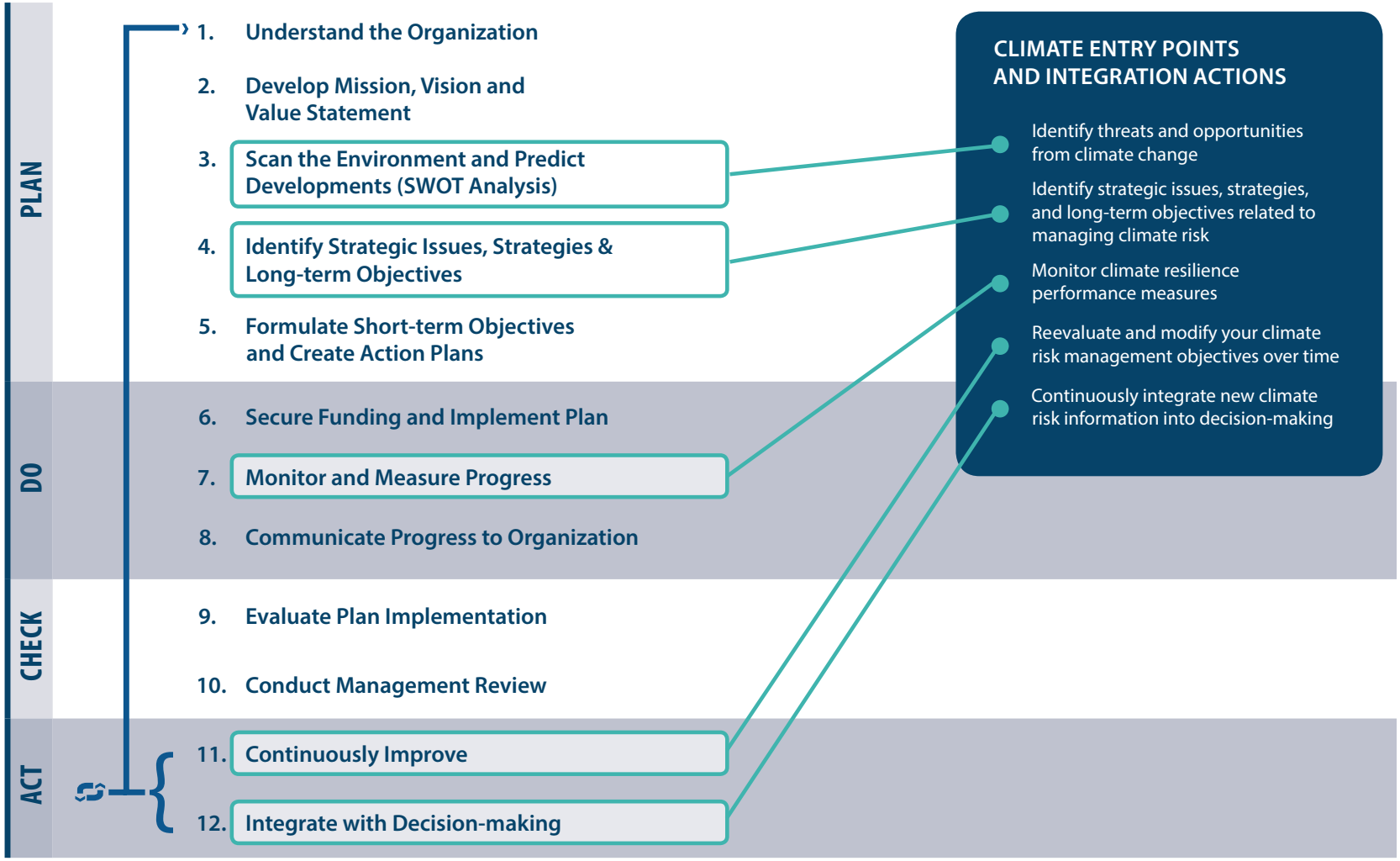
4 Steps of the **Plan-Do-Check-Act Cycle**

TYPICAL STEPS followed to complete the development of a system, implement the system, verify the system is meeting objectives by monitoring and measuring progress, and communicating outcomes to integrate system revisions

5.0 SYSTEM INTEGRATION STRATEGIES

5.1 Strategic Planning

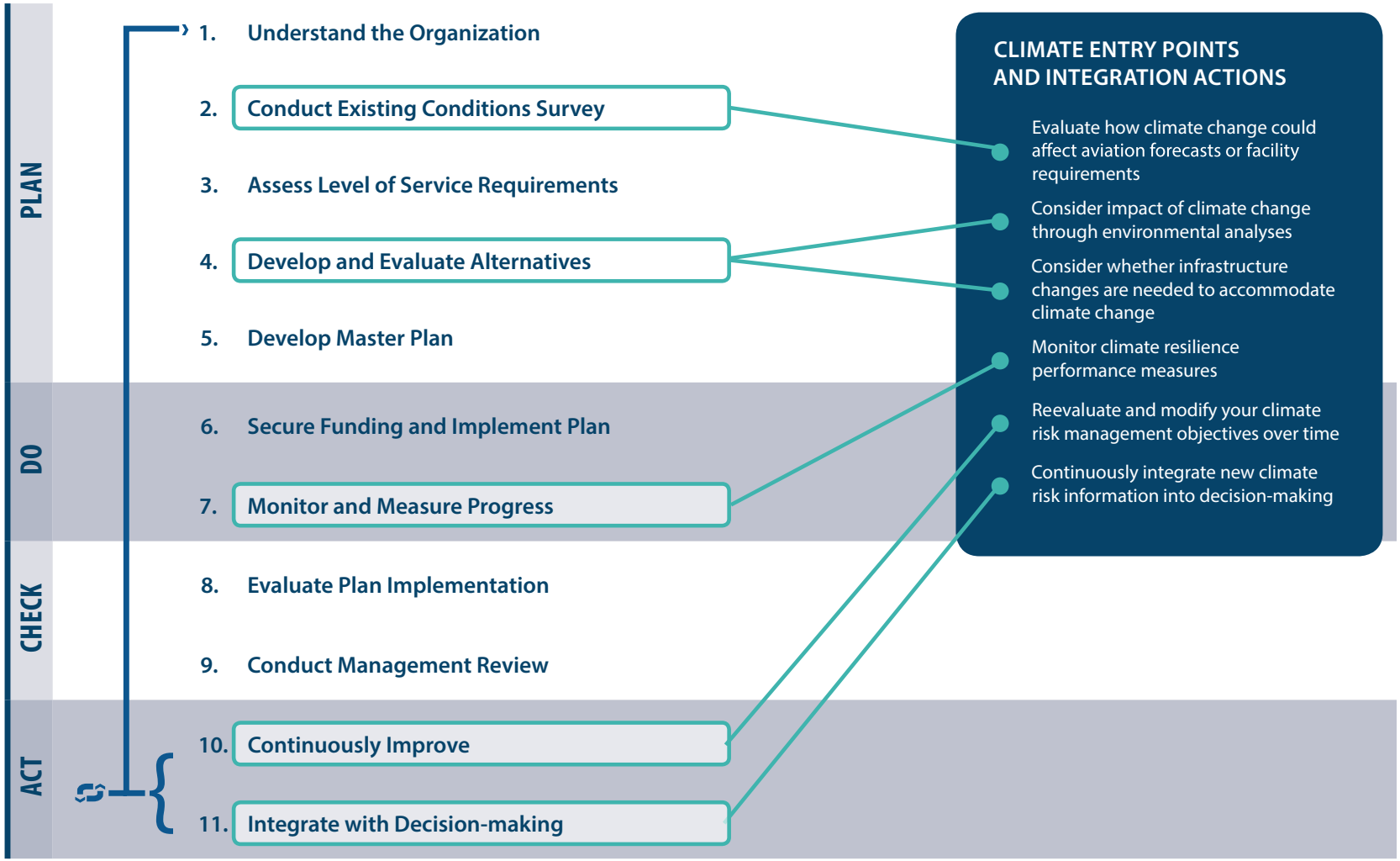
Refer to Section 4.1 of the handbook for additional information.



5.0 SYSTEM INTEGRATION STRATEGIES

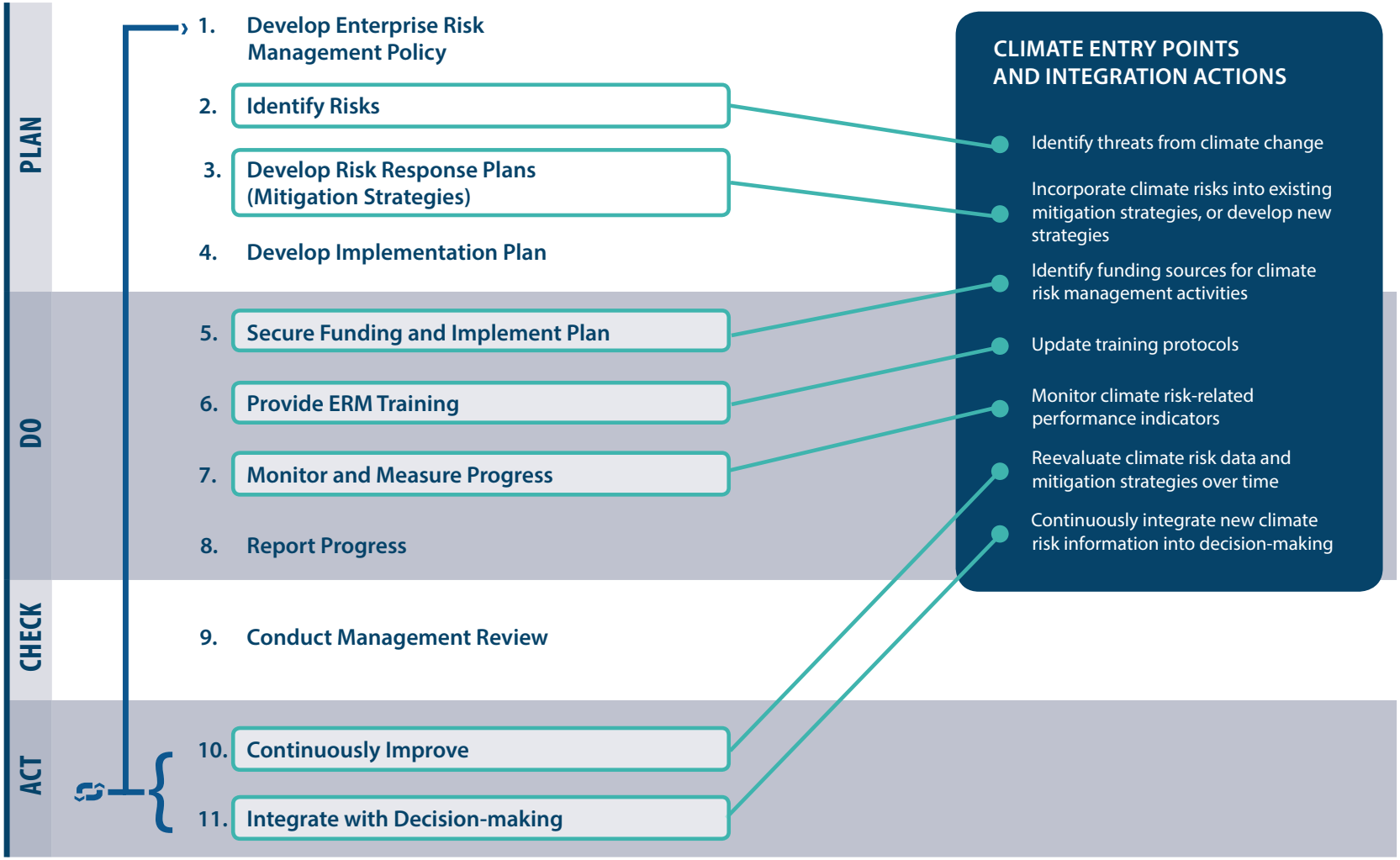
5.2 Master Planning

Refer to Section 4.2 of the handbook for additional information.



5.3 Enterprise Risk Management

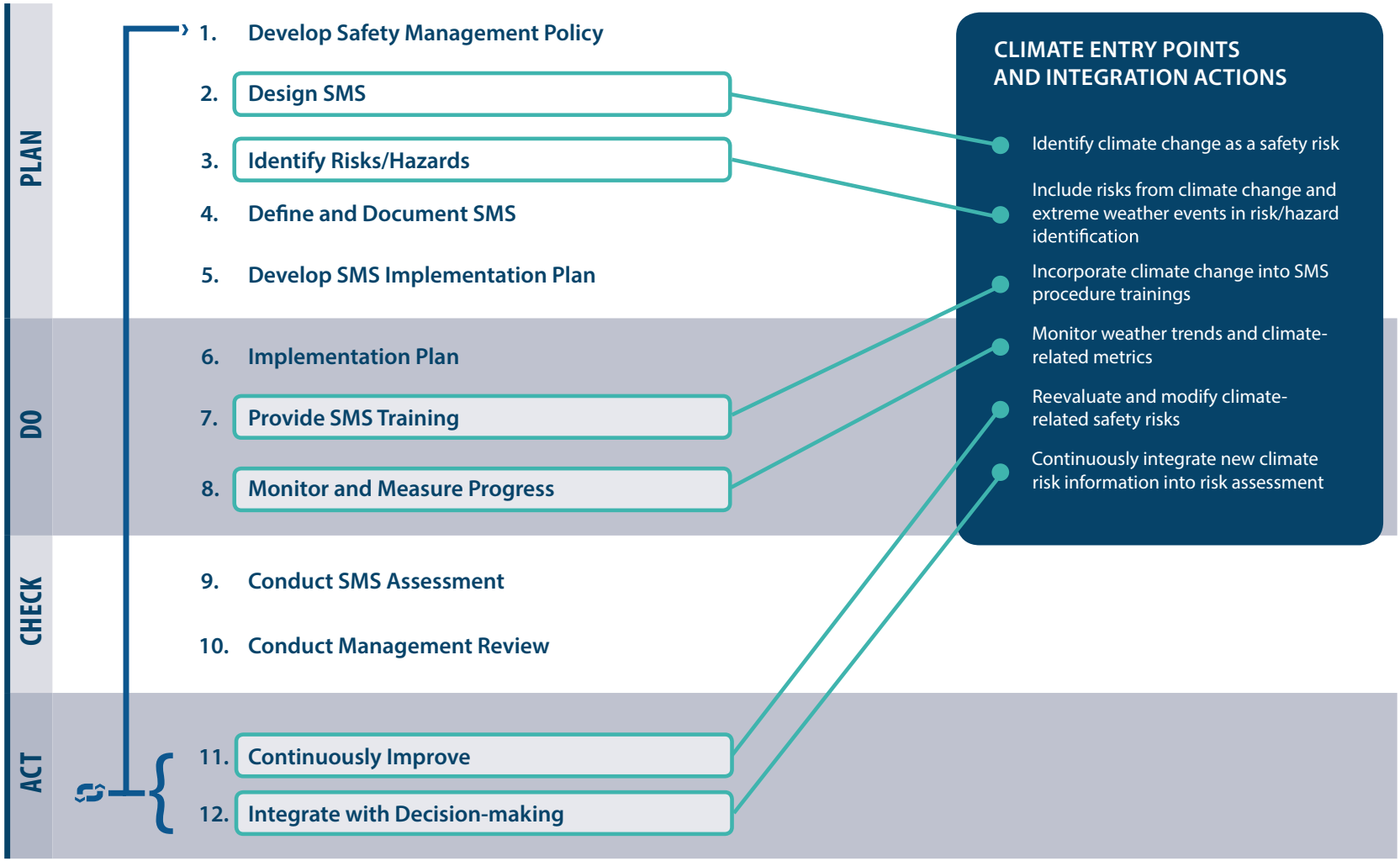
Refer to Section 4.3 of the handbook for additional information.



5.0 SYSTEM INTEGRATION STRATEGIES

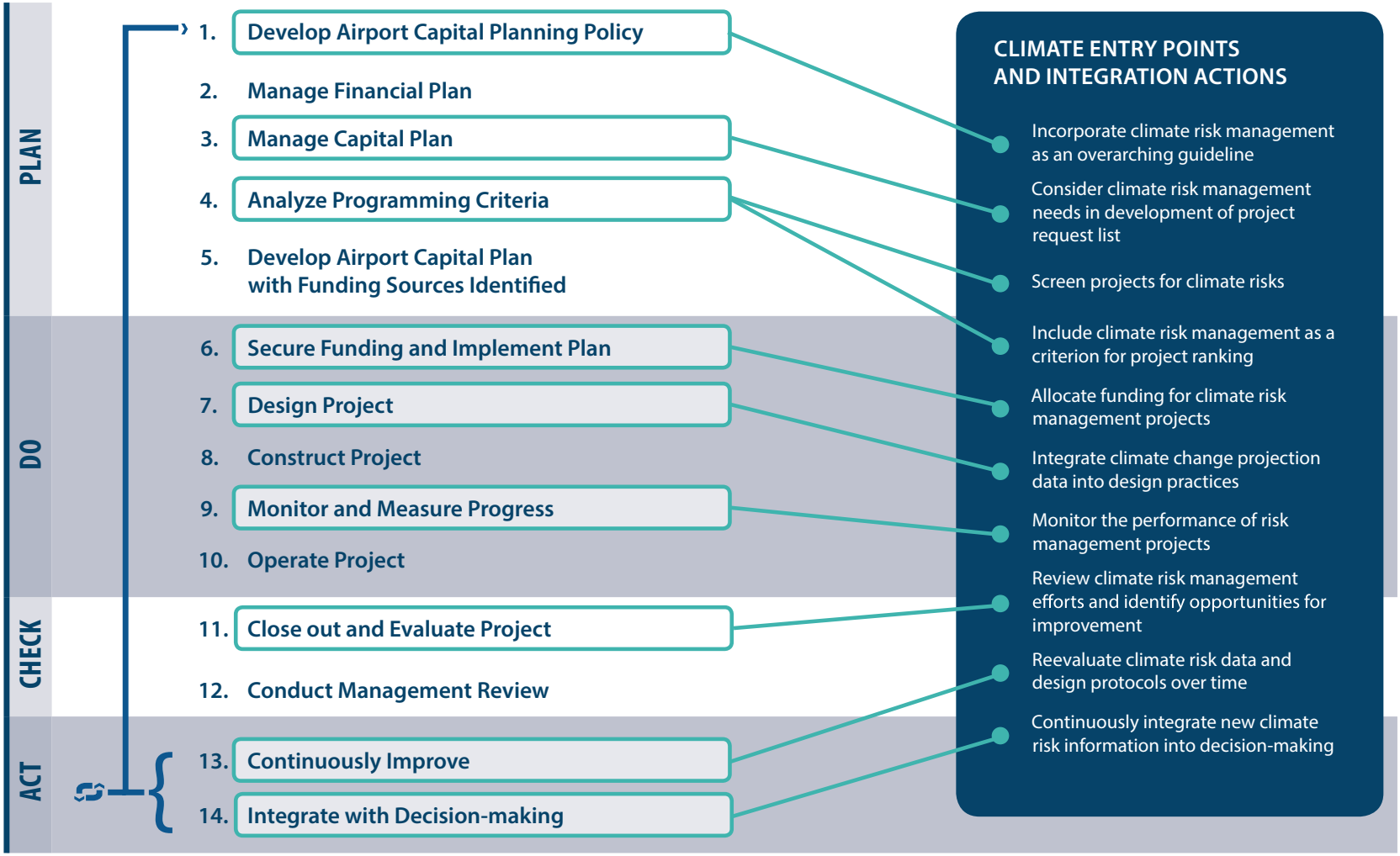
5.4 Safety Management

Refer to Section 4.4 of the handbook for additional information.



5.5 Capital Planning

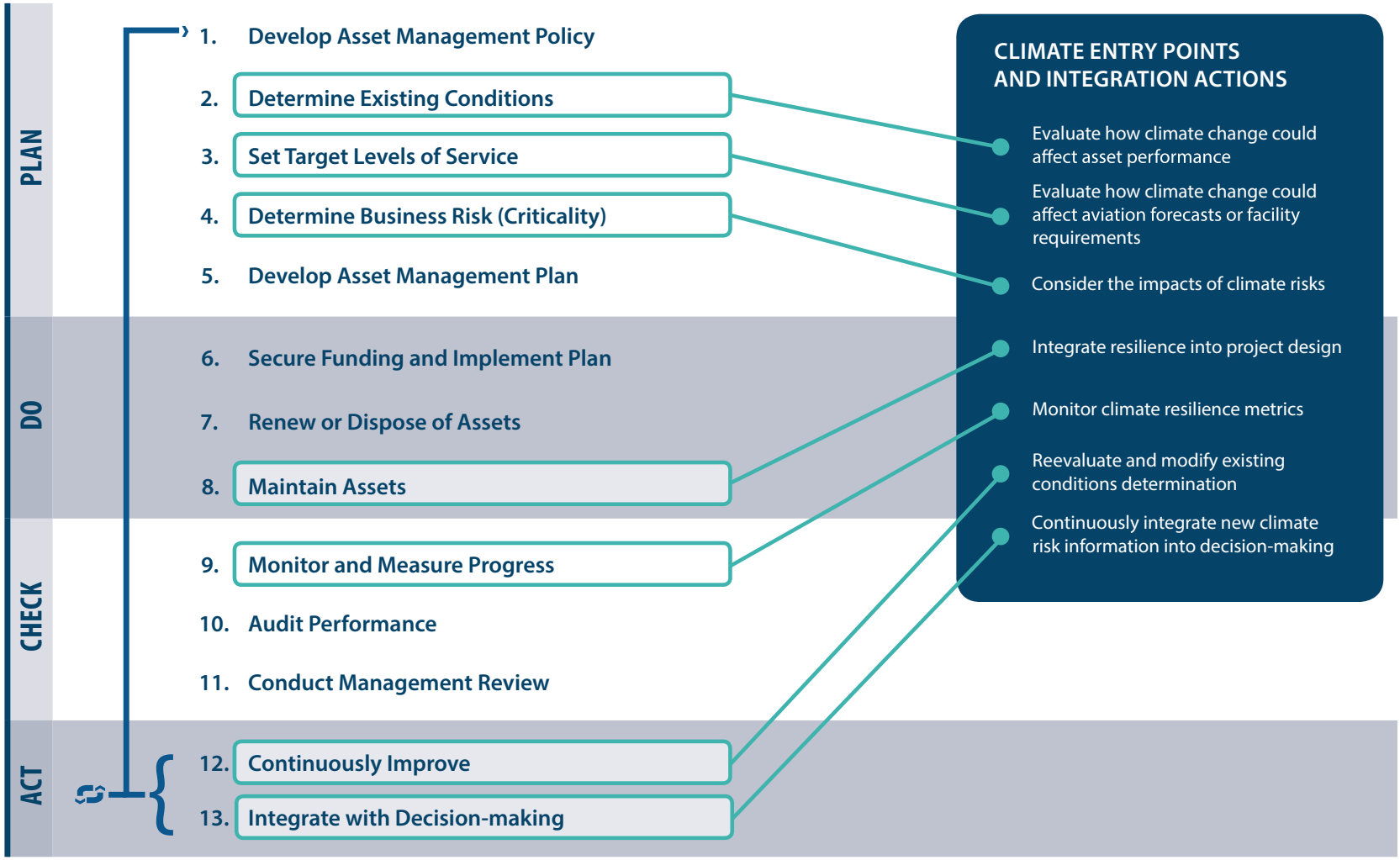
Refer to Section 4.5 of the handbook for additional information.



5.0 SYSTEM INTEGRATION STRATEGIES

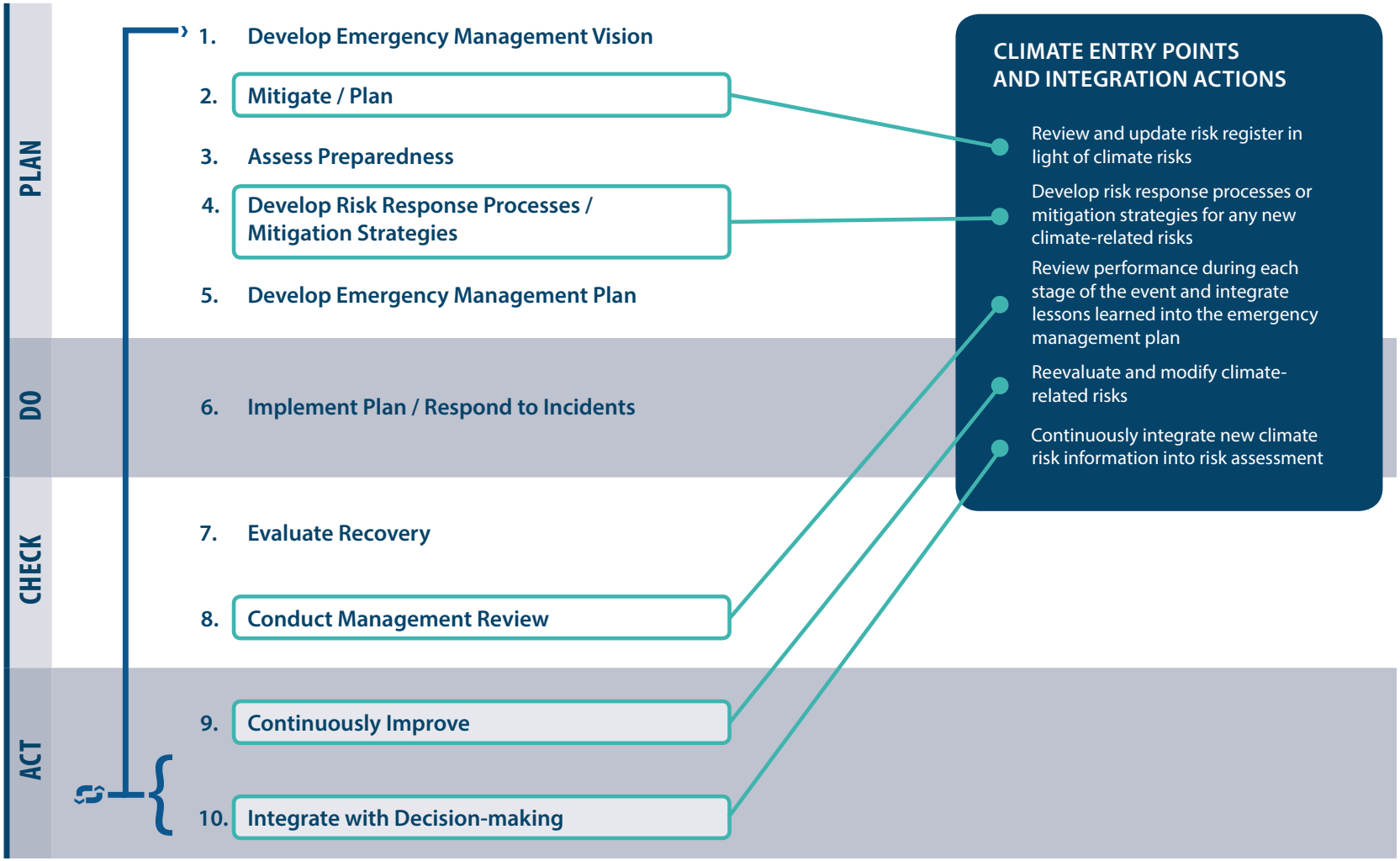
5.6 Asset Management

Refer to Section 4.6 of the handbook for additional information.



5.7 Emergency Management

Refer to Section 4.7 of the handbook for additional information.



5.8 Cross-cutting Adaptive Management Strategies

Refer to Section 4.8 of the handbook for additional information. In addition to the system-specific strategies, begin tracking and regularly reviewing data so that you are aware of changes in trends and are ready to respond to climate risks as they become increasingly prevalent.

EXAMPLE STRATEGIES INCLUDE:

IDENTIFY DATA METRICS

Begin tracking data metrics, such as those listed below, to detect changes in local climate conditions. This will help to understand the true costs to your airport. You may be tracking some of these metrics already, but not in terms of climate change. Align your data metrics with your priority climate risks and management systems identified in the self-assessment.

DATA METRIC	TRACKING FREQUENCY
ASSET PERFORMANCE	
Duration of damage or closure (i.e., how long asset was out of service)	For each event
Pavement condition (such as occurrences of buckling, rutting, and cracking on runways and other paved surfaces)	Annually
OPERATIONS	
Changes in energy usage	Annually
Number of weather-related flight delays or cancellations	Annually
OVERALL EXPENDITURES	
Quantity of staff time spent preparing for, responding to, and recovering from weather events	For each event
Cost of damages to infrastructure and facilities	For each event
WEATHER EVENT FREQUENCY AND SEVERITY	
Frequency of storm events (e.g., thunderstorms, hurricanes, snow storms, and other severe weather)	For each event
Frequency of extreme temperatures (e.g., heat waves or cold fronts)	For each event

USE EVENT EXPENSE CODES

Use event codes to track labor, materials, and other costs associated with event preparation, response, and recovery. By assigning a code to a specific weather event, you can assess the severity of the impacts and costs to easily compare the event to others.

USE EXISTING (OR CREATE NEW) ANNUAL PROCESSES TO REVIEW DATA

You may already have an annual process in place that can be modified to include climate-related data metrics. If you do not, consider creating a simple annual review process to monitor changes in trends.

IDENTIFY A TIPPING POINT

As you begin tracking these metrics, identify a tipping point when your airport will begin thinking about, and planning for, long-term changes. The tipping point value should be reflective of what your airport deems to be a significant change in the frequency or severity of events requiring a potential change in your management processes. If your airport reaches a tipping point, you should transition from monitoring conditions to actively implementing risk strategies.

See the handbook for additional information.

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
FAST	Fixing America's Surface Transportation Act (2015)
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
TDC	Transit Development Corporation
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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