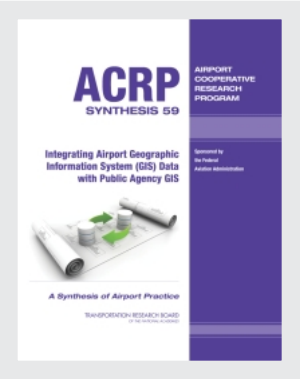

Integrating Airport Geographic Information System (GIS) Data with Public Agency GIS

DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP SYNTHESIS 59

Integrating Airport Geographic Information System (GIS) Data with Public Agency GIS

A Synthesis of Airport Practice

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AIRPORT COOPERATIVE RESEARCH PROGRAM

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

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

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

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

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

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

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

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Cover figure: GIS data can be effectively exchanged between airports and public agencies as shown in concept in the cover image. *Source*: blackdaliya/Shutterstock.

FOREWORD

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

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

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

PREFACE

By Donna L. Vlasak
Senior Program Officer
Transportation Research Board

The report identifies effective and emerging data exchange practices that airports and public agencies can use to increase the data they have access to, while reducing the cost of identifying, collecting, and maintaining these data. It synthesizes the need expressed by airports and public agencies to exchange geographic information and related resources, highlighting effective practices and industry trends. The audience for this report is airport planners, designers, engineers, and geographic information system (GIS) specialists and their counterparts in public agencies.

The report findings are based on a literature search, as well as information from 44 of 47 organizations (i.e., 94%) contacted that responded to the on-line survey and/or agreed to be interviewed by phone.

Randall J. Murphy, President, Grafton Technologies, Inc., Newburyport, Massachusetts, and Ramzi K. Bannura, Annapolis, Maryland, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

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

INTEGRATING AIRPORT GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA WITH PUBLIC AGENCY GIS

SUMMARY

Airports and the communities they serve have a mutual dependence. This interdependence requires that airports and municipal, county, and state agencies share information. Much of this information is geographic in nature, identifying the locations of assets, facilities, infrastructure, events, or boundaries. Specifically, airports require geographic information from surrounding communities to support planning and development, airspace analysis, property acquisition, noise mitigation, environmental protection, customer service, and other procedures. Public agencies require geographic information from airports for transportation planning, compatible land development, emergency response, and zoning. The objective of this study was to investigate why airports need to share data with public agencies, how they can effectively satisfy this need, and how they can overcome the challenges that exist.

For the most part, airports and public agencies have satisfied their need to exchange data with one another through informal requests of colleagues or peers they have met at conferences or meetings or through a mutual colleague (i.e., word of mouth). Online tools such as websites or portals that support File Transfer Protocol (FTP) downloads or web services (i.e., data returned to fulfill a specific user's or application's request) are increasingly being used to facilitate this exchange without formal agreements. The increased use of data, software, and hardware resources in the "cloud" is a clear trend; the majority of responding organizations (25 of 44, or 57%) indicated they have and will continue to tap these resources.

Productive exchanges between airports and public agencies at times extend beyond data to include the software, hardware, and human resources required to collect, disseminate, and use geographic information. Many smaller and medium-sized airports, for example, do not have the staff or budgets they desire; so they rely on software and hardware resources of parent municipal or county agencies to host web services and/or applications. In a few cases, human resources (in the form of analysts, database administrators, programmers, and other subject matter experts) have been "loaned" to an airport by its parent agency.

Individuals and agencies that have recognized the potential benefits of data exchange often create regional collaborative forums that ensure data resources are known and easily accessible. National forums, such as the Open Geographic Information System Consortium (OGC) also exist, whose mission is to standardize data and system interoperability through consensus among academics, industry professionals, and vendors.

Although there is a clear and growing need for airports and public agencies to exchange data, most respondents reported that they cannot find or obtain much of the data they need. This is partially because the majority of the data exchanged today are still identified by word of mouth and transferred by conventional mail or e-mail.

Technical barriers have largely been addressed by industry standards, cloud-based technology, low-cost file storage, and high network bandwidth. However, despite the proliferation of enabling technologies, barriers were discovered that restrict effective data exchange between airports and public agencies. Airports and public agencies alike report that organizational impediments, such as cumbersome agreements, legal constraints, rigid standards and procedures, restrictive policies, and lack of resources, are more challenging to overcome than technical barriers. Individuals who share

a collaborative spirit and are willing to invest their time and resources in establishing forums, committees, and online resources have demonstrated that these barriers can be overcome.

The findings presented in this report are based on a literature search as well as interviews and survey responses. The survey achieved a 94% response rate, with 44 from the 47 airports, agencies, organizations, and vendors contacted.

Some organizations that have been particularly successful in exchanging data are highlighted as case examples illustrating specific practices that others may want to emulate. Some of the relevant findings from the case examples are:

- A culture of open data and software sharing can provide airports and other GIS practitioners with significant value at a reduced cost, increasing the return on investment of their GIS programs.
- Airports can obtain help from local agencies in developing GIS data to meet FAA requirements and deploy useful applications that leverage these data.
- Common GIS data and application needs of different departments can be addressed together to save the overall organization money while leveraging useful data and applications.
- An institutionalized commitment to data sharing is needed to establish the standards, procedures, and policies that support data exchange.
- Frequent collaborative meetings promote agencies' development and deployment of quality data.
- Advance planning and coordination can allow regional collections of aerial imagery to meet specialized airport and FAA requirements.

CHAPTER ONE

INTRODUCTION

Over the past several decades, U.S. cities and counties, and more recently airports, have developed geographic information system (GIS) programs to meet their constituents' need for geographic information (graphical objects referenced to the earth's surface with relevant attribute details and descriptive metadata; that is, information about the data itself). This information provides them with intuitive maps that display the location of assets, facilities, infrastructure, events, and boundaries that they need in order to carry out their job. GIS also provides this information for analytic applications that can evaluate the most efficient routes, identify physical constraints, assess the most effective location for new infrastructure, and address a variety of other sophisticated analyses.

To feed these GIS programs, airports and their surrounding communities require geographic information to prepare maps and answer inquiries that satisfy a broad variety of business needs. The demand for this information is rapidly growing as new technologies facilitate its use and electronic maps become more pervasive in day-to-day life. Specifically:

- Airports have used geographic information for decades to support planning, design, construction, operations, and maintenance. Traditionally, this information has been developed and used within computer-automated design (CAD) software. Over the last few decades, airports have been employing GIS along with CAD, and more recently building information modeling (BIM), to gain additional analytic capabilities and to help disseminate the data within applications designed to support specific business processes. As the use of these software platforms grows, their interoperability has become an increasingly important concern, as discussed in the FHWA whitepaper, "The Interoperability of Computer-Aided Design and Geographic Information Systems in Transportation" (referenced in the Bibliography). The ultimate goal of several airports interviewed is to maintain one master set of geographic information in a central repository. This would help them eliminate the redundancy and gaps in information that have resulted from years of disparate data files on individual hard drives.

  Regardless of what format is provided, airport geographic information is largely, but not exclusively, specific to the unique operations of an airport and/or to the geographic character of an airport and its immediate vicinity. The precision required, and the relatively small extent of a typical airport's property, necessitate detail and accuracy.

  The application of geographic information at airports has expanded to support airport development, property management, utility locating, airfield maintenance, operational inspections, and a variety of other uses (McNerney 1994, p. 9; Murphy 2006; Robertson 2008). Although the number of staff members assigned to these GIS programs is relatively small (one to nine in the cases of the respondents who shared this information), their ability to collect and disseminate valuable geographic information has grown with the expanded capabilities of web-based technologies and cloud- (i.e., Internet-) based data, application, software, and hardware resources.

  Although larger airports have had the resources to adopt GIS earlier and more broadly within their organizations, medium-sized and smaller airports are beginning to be able to access the growing amount of GIS data and applications available at increasingly lower costs. The FAA Airports GIS program is also stimulating demand for GIS among medium-hub and smaller airports. This is partially because of future requirements these airports may need to meet (DeLeon and O'Donnell 2012), but also because of the growing data and application resources FAA will be making available to them. Despite this growth, additional outreach and training is needed to help airport managers and staff understands the benefits of GIS to their organizations.

- The FAA Airports GIS Program provides a national repository for standardized airport data and a platform for future applications and tools that FAA and airports require, with a focus on the geographic information needed to support flight procedure and airfield development, and the eventual goal of including thousands of airports in the United States. Some of the individuals interviewed acknowledged that the FAA program is one of the largest enterprise GIS programs in the world. The requirements for these data are detailed in FAA Advisory Circulars (ACs) that are being rolled out to airports nationwide, starting with the larger airports (DeLeon and O'Donnell 2012). These ACs specify how data required by FAA is to be collected, documented, structured, and submitted. Once the data have been uploaded into the FAA's Airports GIS, it is available to authorized users through a variety of applications and tools. One such tool is the electronic Airport Layout Plan (eALP) module, which allows airports to assemble an ALP using uploaded data that conform to the FAA's specifications. FAA has also begun to deploy aerial imagery and will eventually deploy other data resources into cloud- or third party Internet-based hosts to provide airports and other authorized stakeholders access to the wealth of geographic information the FAA and airports are collecting. (Additional information on the FAA Airports GIS Program can be found in the first case example in chapter five.)
- Communities that surround airports have used geographic information along with GIS for several decades to evaluate property development, infrastructure maintenance, emergency response, and environmental protection needs of citizens, developers, and emergency responders. These needs are addressed by GIS staff within public agencies, including municipal, county, and state agencies, as well as non-governmental organizations representing public interests within a specific region. These public agencies have traditionally developed GIS data to prepare maps and, more recently, to support analysis applications, many of which are designed for internal as well as public use. The geographic information agencies collect tends to cover a broader area, both geographically and in scope, than that of airports and is typically not required to be of the same accuracy, but must be comprehensive and consistent.

Although the need for geographic information differs between airports and public agencies, there are important overlapping issues that prompt the need for regular data exchange. Airports often require parcel, zoning, and environmental data from public agencies to support land development, obstruction analysis, noise mitigation, or bird strike prevention programs. Conversely, public agencies require height restrictions and noise impact data from airports for planning and development. Airports and public agencies require roadway, addressing, utilities, development, and environmental data from each other for planning, emergency response, and environmental protection purposes. Unfortunately, many airports and agencies report not knowing what is available or how to find the information they need.

SURVEY RESPONSE

The findings of this report are based on a literature search as well as information from 44 (of 47) organizations that responded to the online survey and/or agreed to be interviewed by telephone. Figure 1 shows the organizations that responded or were interviewed. The "other" category represents consultants, academics, and vendors who were not the primary focus of the study but who were asked on a case-by-case basis to provide a specific perspective. The literature search and review did not yield significant findings, because the problem addressed by this report had not been studied. The literature discovered did, however, complement the findings uncovered by interviews and survey responses; and also helped identify organizations and individuals to interview. No agency declined to be interviewed, although a few did not reply to requests. The response rate for this survey was 90%.

Organizations with an active GIS program and/or effective data exchange practice were identified through referral from other interviewees or consultants. An effort was made to interview related agencies and airports within the same region, so that different perspectives on the same data-sharing opportunities could be gained. Although the focus of the survey is on commercial airports, some non-commercial airports are indirectly represented because they are managed by the same staff as nearby commercial airports interviewed. The public agencies interviewed included county, municipal, and state agencies. Councils of government and similar non-governmental organizations in some regions were found to operate in a similar capacity as regional government agencies. Two groups

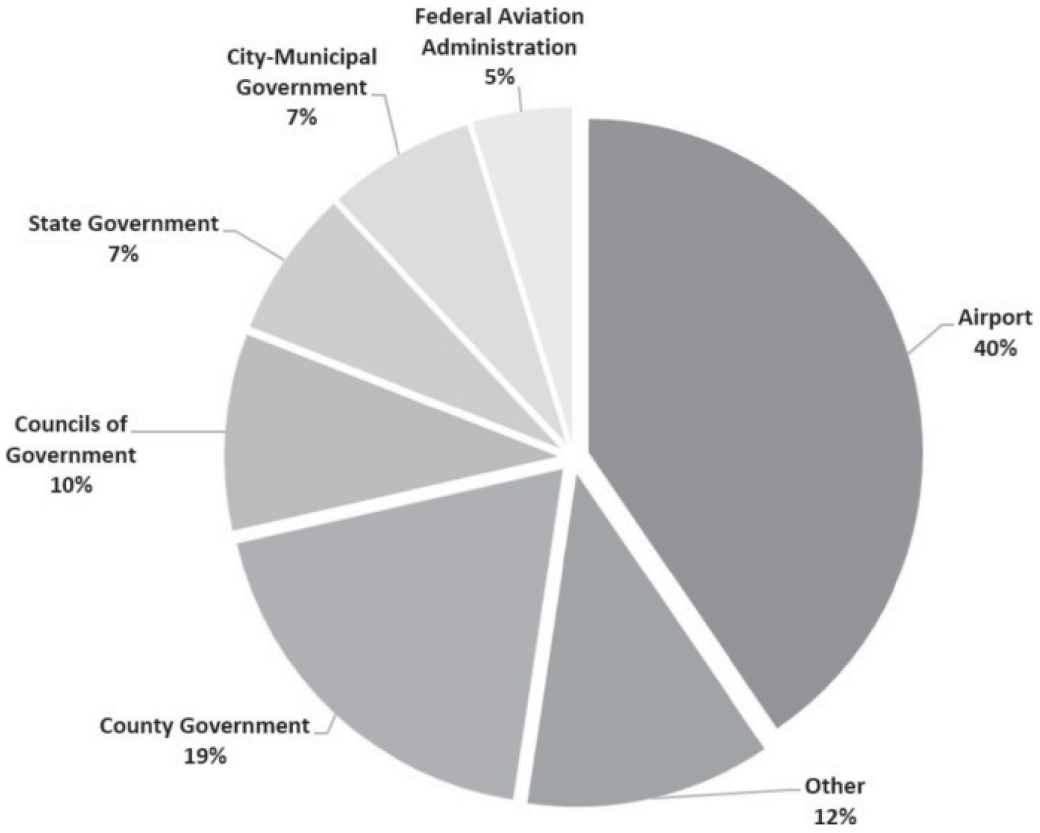

FIGURE 1 Types of organizations interviewed. *Source*: 42 of 44 survey respondents.

within the FAA were also interviewed, but their responses are treated differently because of the different objectives of these separate lines of business. In some cases, multiple individuals from a single organization participated in the phone interviews; consequently, the number of responses is a count of the number of organizations interviewed rather than the number of individuals who participated.

The online survey was primarily used as a preface to a phone call, during which each of the questions in the survey were discussed. The phone interviews were structured around a common questionnaire, provided in Appendix A, for consistency and thoroughness; although the interviews were conversational in nature so that relevant findings could be discussed in greater depth. Some respondents chose to only respond through the on-line survey because of limitations on their time. A list of all respondents who were either interviewed and/or replied to the on-line survey is provided in Appendix B.

Interview participants were asked a few questions to ascertain their being relevant to this study. The results of the first such question, as shown in Figure 2, indicate that the majority of those who responded to the question are using GIS at an enterprise level (meaning that more than one department uses a common GIS platform). This question was relevant because organizations that have an enterprise-level GIS are more likely to exchange data with other organizations that those that do not. The results of the second qualifying question, as shown in Figure 3, indicate that the vast majority of respondents have exchanged data with another organization within the past three years. Answers to these questions provide a context for the individual responses, although the interviews were completed and their responses factored into the findings regardless of the responses.

The focus of the phone interviews was on large, medium-sized, and small commercial airports, and municipal and county agencies within the same jurisdiction of the airport interviewed. Figure 4 shows the range of types and locations of organizations that responded or were interviewed. The magnifying glasses indicate case examples, described in chapter five, that highlight effective data sharing practices between specific organizations.

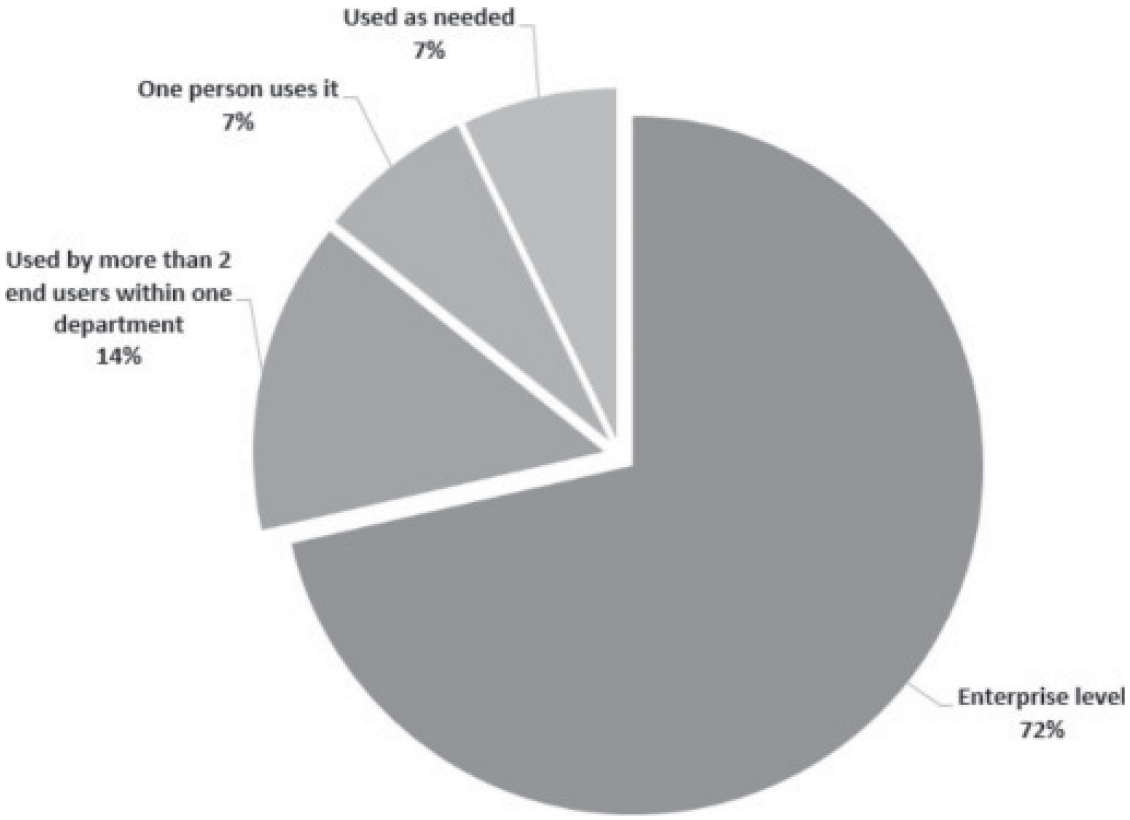

FIGURE 2 What level of GIS does your organization employ? *Source*: 13 of 44 survey respondents.

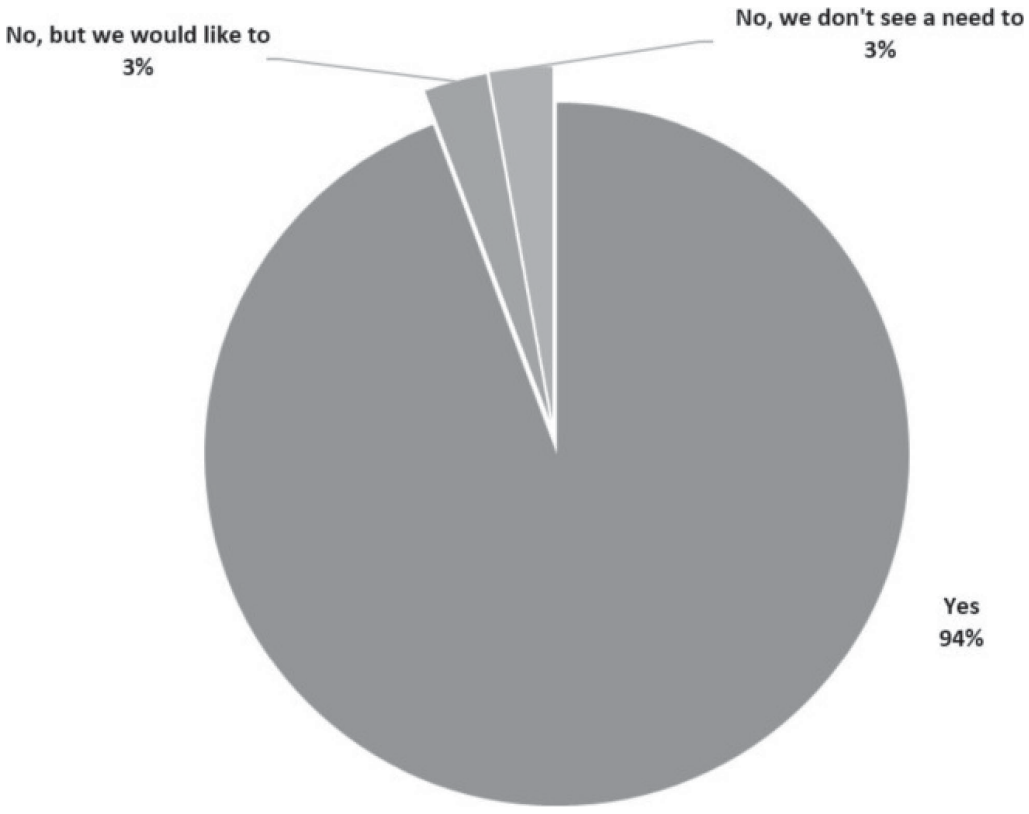

FIGURE 3 Provided or received geographic information from others? *Source*: 35 of 44 survey respondents.

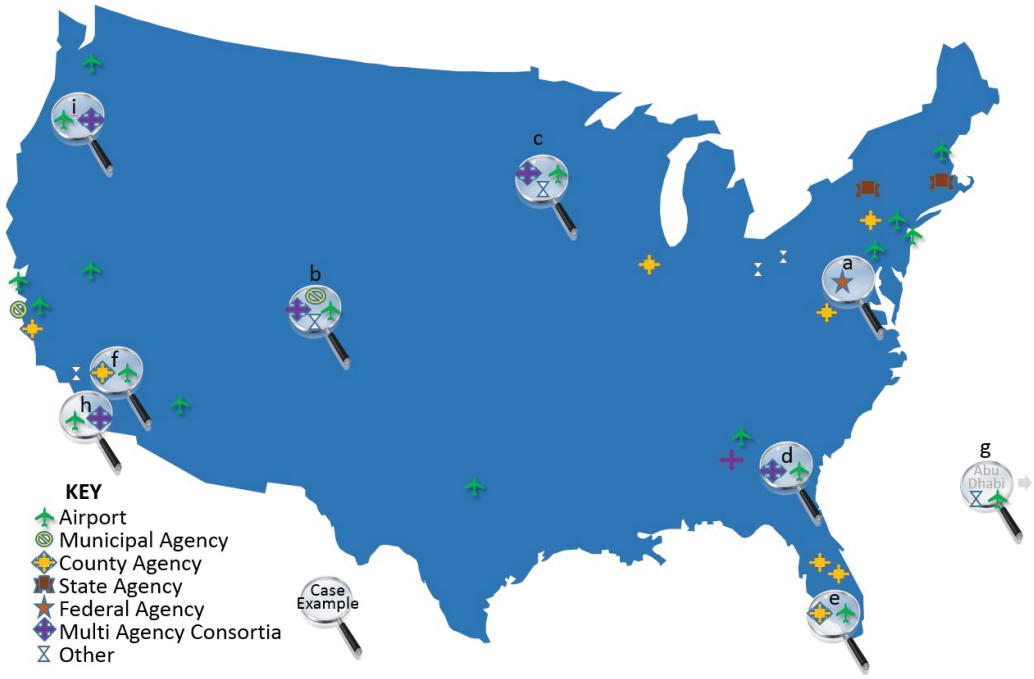

FIGURE 4 Map of organizations interviewed. *Source*: 44 of 44 survey respondents.

The response rate to the interviews exceeded 90% largely because relevant interview candidates were identified by review, referral, or industry experience, resulting in a targeted group of exemplary airports and public agencies. To ensure that the study was comprehensive, all interviewees were asked for referrals to others from their region or in other regions who could provide a helpful perspective. Interviews with these candidates were later scheduled, again with a high rate of response and interest.

In many cases, online research about the individuals and organization was conducted prior to interviews to help identify relevant and effective questions to ask. After the interviews, similar online research helped provide additional details about specific organizations, technologies employed, or industry trends mentioned during the interviews.

OBJECTIVE AND ORGANIZATION OF THIS REPORT

The objective of this study was to identify effective and emerging data exchange practices that airports and public agencies can use to increase the information they have access to while reducing the cost of identifying, collecting, and maintaining these data. This will help airports and agencies provide greater benefits to their users while lowering costs to achieve a higher return on investment (ROI).

Following this introductory chapter, chapter two defines the need to exchange data and related GIS resources between airports and public agencies. Chapter three summarizes how this need is currently met by highlighting common and effective practices. Chapter four identifies challenges airports and/or public agencies have faced when exchanging data and how they have overcome these challenges. Chapter five provides several case examples of practices that specific airports or public agencies have put into place. Conclusions from this study and suggestions for future research are offered in chapter six.

CHAPTER TWO

SHARING GIS RESOURCES BETWEEN AIRPORTS AND PUBLIC AGENCIES

Sharing GIS data, software, hardware, and human resources makes sense where common needs can be identified and organizational differences can be overcome. This is especially true where the demand for GIS data and applications is growing, but the funding available to fulfill that demand is limited. This chapter explores the need for sharing GIS data, software, hardware, human resources, policies, and procedures, based on examples from the organizations interviewed.

BENEFITS AND COSTS OF DATA SHARING AND ORGANIZATIONAL COLLABORATION

Airports and public agencies in the communities that surround them have a mutual need to share data in order to conduct analyses, make inquiries, and prepare maps and reports. In addition, public employees are obliged to collect and disseminate information to their constituents in the most cost-effective and efficient manner possible. Although these exchanges are reciprocal, the airports interviewed indicated they are more focused on internal data development initiatives, whereas most of the public agencies interviewed indicated that the collection and dissemination of data to and from other agencies is a core part of their mission. William Walter of the Florida chapter of the Urban and Regional Information Systems Association (URISA), notes:

> The airport authority, essentially a small city, developed numerous layers capturing infrastructure information used for maintenance and planning activities. When planning for expansions and development related activities, GIS information generated by the county is required to evaluate impacts on the surrounding community. Significant data manipulation efforts by the airport GIS staff were required to match local government data with the airport database. Common GIS database design standards helped eliminate this issue. Once political issues were resolved, the airport authority obtained a copy of the county database design, and imported appropriate spatial information from their existing database into the county design. Now updates to both airport and county databases can be shared through direct transfer of information (Wellar 2010, p. 43).

Benefits of Sharing and Collaboration

Sharing data and collaborating with peer agencies provide tangible benefits in the form of reduced data development and application server hosting costs. There are also intangible benefits: improved quality, maximized level of service, and better decision-making. Among the benefits of data sharing and collaboration mentioned by interview participants are:

- Lowered data collection and maintenance costs;
- Minimized redundancy when creating and maintaining data;
- More current and complete data received;
- Assurances that the most useful copy of the data is available; and
- More cost-efficient government and good public stewardship.

Although benefits can be difficult to quantify (a method of quantifying benefits as a part of GIS program ROI calculations is a topic suggested for further research), an indicator of the advantage of sharing information is how many people receive it and how essential it is to their work. Figure 5 shows that some respondents indicated that 50 or more individuals within their organization use data received from other organizations. This was particularly the case among airports because some of the land use and ownership data they receive from cities and counties is used widely within their planning, property management, and noise mitigation departments. This breadth of use is more pronounced at larger airports that employ more staff and consultants in these functions. Figure 6 indicates that survey

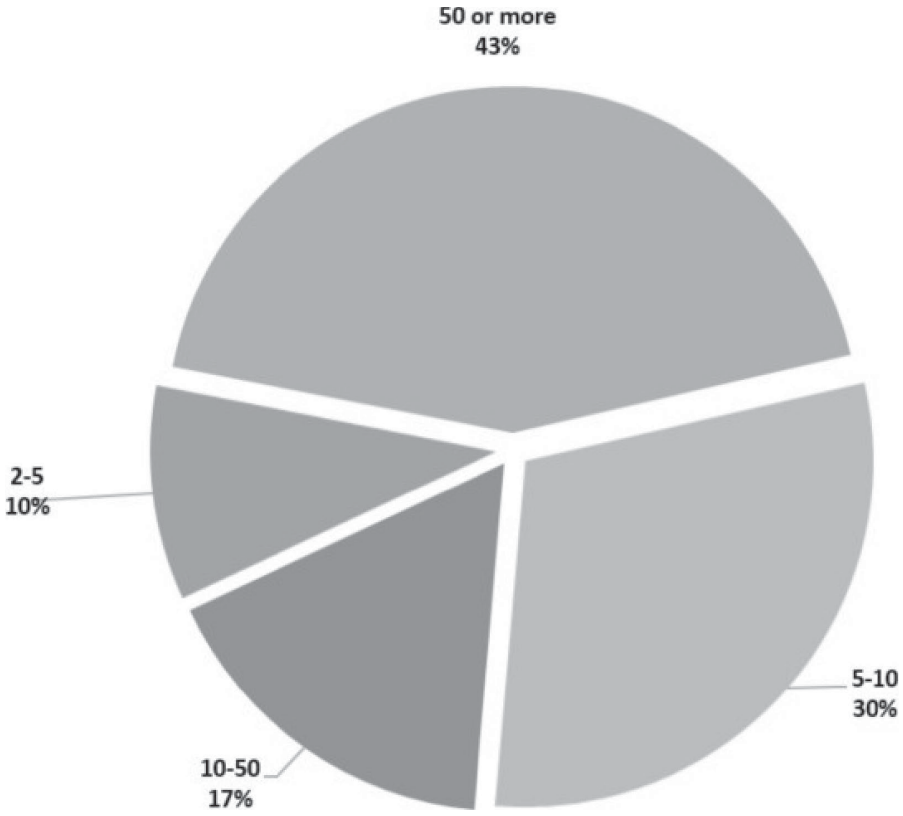

FIGURE 5 How many people in your organization use the data you receive from other organizations? *Source*: 30 of 44 survey respondents.

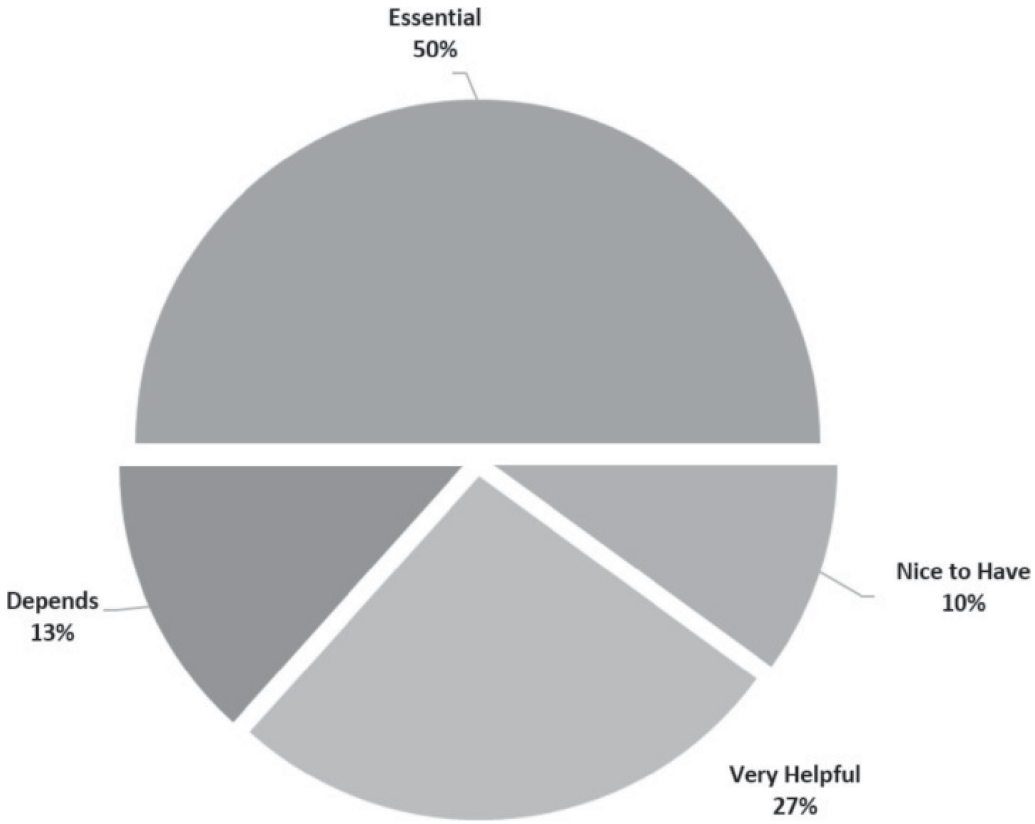

FIGURE 6 How critical is the data you collect from other organizations to people within your organization? *Source*: 30 of 44 survey respondents.

respondents often felt these data were essential, meaning that they could not complete important tasks without them or a suitable replacement.

Costs of Sharing and Collaboration

Data sharing and collaboration do have their costs, however. Participants suggested that while some costs are tangible, such as staff hours spent attending collaborative forums or the cost of hosting a data portal application, others are intangible; for example, the lack of control over data quality or perceived legal risk when data are released and altered by others. Among the more commonly mentioned costs of data sharing and collaboration by survey and interview participants were:

- Staff time spent preparing and fulfilling requests for data;
- Cost of the hardware and software required to establish an accessible data repository;
- Time spent and travel costs for attending collaborative forums and meetings; and
- Lack of control or influence over shared data resources or derivative products.

SHARING DATA

Because interview participants generally believe that the benefits of data sharing outweigh the costs, they reported sharing many data sets. Figure 7 identifies these data sets and other resources that airports and public agencies interviewed exchange with one another; the arrows indicate the flow in which the information is shared. Where the flow is bidirectional but weighted in one direction, the predominant direction is shown in black and the other in gray. The circles indicate the level of response reported for each type of exchange. The highlighted colors indicate the degree of importance the recipients ascribed to these data. The degree of importance is subjectively assigned based on the number of respondents who mentioned using the data as well as airport GIS industry surveys (McNerney 1994, Murphy 2006; Robertson 2008). Data are grouped at the category level, but specific feature classes (a.k.a. layers) are called out, along with other relevant details in the notes.

Data sets described in this section and indicated with an asterisk (i.e., *) are defined in FAA AC 150/5300-18B, *General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and GIS Standards*, which is being rolled out as a requirement to airports nationwide. This advisory circular, along with AC 150/5300-16A, *General Guidance and Specifications for Aeronautical Surveys: Establishment of Geodetic Control and Submission to the National Geodetic Survey*, and AC 150/5300-17C, *Standards for Using Remote Sensing Technologies in Airport Surveys*, define the requirements of the FAA's Airports GIS program. This program requires airports to submit data to FAA when safety-critical, planning, or other changes to the layout of the airport are made. These GIS requirements are being rolled out in incremental phases, starting with larger airports (DeLeon and O'Connell 2012). The FAA uses this standardized data to review and approve proposed changes, develop instrument approach procedures, etc. The data are made available to the FAA and authorized external users to download or use within web-based application tools the FAA is developing. Together these data and application resources are considered an enabling technology to the Next Generation Air Transportation System (NextGen).

The matrix indicates that airports often rely on aerial imagery and cadastral data, namely parcels and land use information, from public agencies. Life safety data, such as hospital and fire station locations, as well as Light Detection and Ranging data (LiDAR) are sometimes obtained as well. Conversely, public agencies rely on noise contours and, to a lesser degree, on a general layout of the airfield from airports. Both airports and public agencies often exchange road centerline, parking lot, utility, aerial imagery, and to a lesser degree elevation contour data and digital elevation models (DEMs) with one another.

Aside from data, some airports reported that they rely on public agencies (often but not exclusively ones they are a part of) for GIS data and application hosting and occasionally data collection and conversion assistance. This exchange of technical resources was particularly apparent among smaller and medium-sized airport that were interviewed.

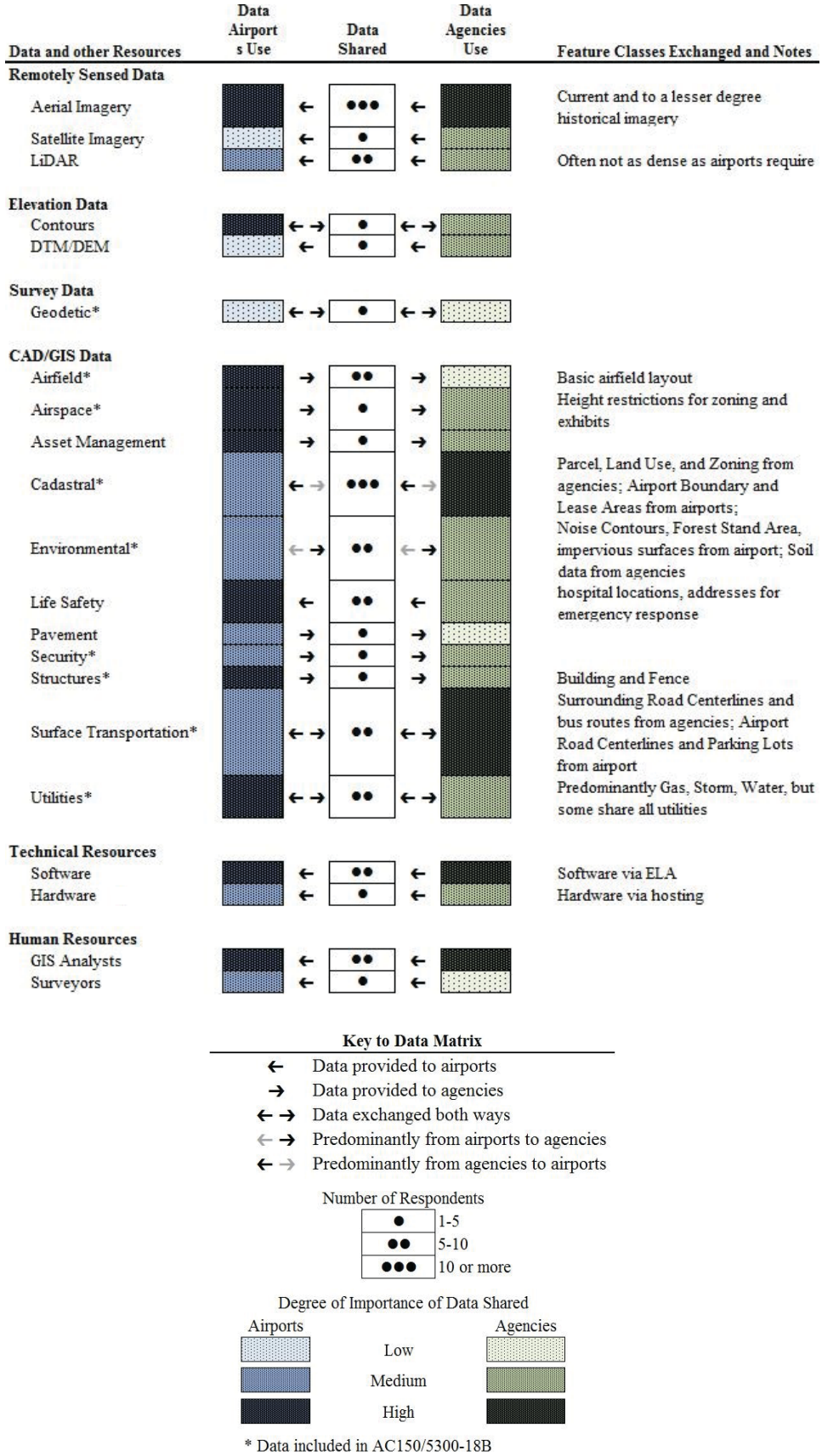

FIGURE 7 Data exchanged between airports and public agencies. *Source*: Survey respondents.

Although other forms of sharing are indicated, these are the most commonly reported by survey and interview participants. Some respondents indicated that more opportunities exist to share data and collaborate. They hope that increased use of web technology will broaden not only the volume but also the breadth of what is exchanged. At the same time, they have reported challenges in identifying and receiving some of the data they need. These challenges are described in detail in chapter four.

Data Airports Receive from Public Agencies

Many of the airports that participated in this study require orthorectified imagery, LiDAR, parcel, road centerline, construction area, utility, zoning, land use, and flood zone data from nearby public agencies. These needs, as defined by the respondents, are detailed here (data layers indicated with an asterisk are those defined and specified in FAA AC 150/5300-18B):

- Orthorectified imagery—Airports and public agencies alike require imagery collected from aerial and in some cases satellite sensors. Imagery collected by public agencies typically encompasses a broad area and therefore includes a substantial portion, if not all, of the area of interest to an airport, although perhaps not at the desired resolution or accuracy. Conversely, the extent of imagery collected by airports is typically too geographically narrow to be of use to public agencies. Airports, however, require higher resolution and accuracy to support obstruction identification, asset management, planning, and design activities. Clearly, there is a common need for imagery but of different specifications. More often, the result is separate data collection initiatives, whereby the agencies collect lower resolution and less accurate imagery over a broader area of interest, whereas airports collect high-resolution, high-accuracy imagery over their area of interest, which is often defined by the extent of aircraft noise impact or obstruction identification surfaces. The result is a reduced opportunity to reuse the imagery collected. To resolve this, some public agencies, such as Metro in the Portland, Oregon, area (see the case example in chapter five), have established collaborative imagery collection programs whereby an airport can "buy up" or contribute additional funds to achieve the specifications desired within the area of interest. Examples of such buy-ups reported directing planes to fly lower to obtain higher resolution and adding additional ground control to increase accuracy. In a few cases, these collaborative imagery collection activities have led to cost savings and, as a result, have endured for many years. Sometimes they have failed because airport needs were more easily met by project-specific aerial collections. (These challenges are further discussed in chapter four.) In most cases, agencies have freely shared their imagery with airports upon request or through anonymous web imagery mapping services.
- Parcels*—Land ownership information is typically associated with specific tracts of land or parcels. These data are often maintained by county land assessor offices. For airports, parcel data are essential for acquiring land to protect airspace for current and future aircraft operations, minimizing noise impact, protecting rights-of-way for vehicles or utilities, accounting for land acquisition funds provided by FAA, and maximizing lease revenue potential of property owned that is not used for aircraft operations. Although airports survey their own boundaries, they often rely on county assessor offices or other agencies for parcel data.

  Care must be taken when handling this information, as land ownership is a matter of legal record which in many states must be developed by licensed surveyors. Best practices suggest that GIS data be tied to survey data wherever possible and parcel measurements from GIS data not be used for legal boundary or property line interpretations (Wright and Kent 2007). This can present a challenge for airports and agencies that encompass multiple jurisdictions, which seldom adhere to a common format or data schema. The result is that airports must accommodate disparate data sets or periodically make schema adjustments to integrate the data sets each time they are updated. Even when this work is done, adjacent parcels from different authorities may reveal overlaps and gaps that the airport cannot address. Most users of these data understand and are prepared to work with them despite these quality issues. If improvements are required, surveyors are required to properly, and legally, align the data. These challenges are further discussed in chapter four.
- Land Use*—How land is currently being used and how it is likely to be used in the future is an important means of ensuring compatible land use around airports. "Unfortunately, incompatible land uses are threatening the utility of airports and aircraft operations across the county," according

to an ACRP study on land use compatibility (Ward et al. 2010). To help address this issue, airports will occasionally develop land use data themselves as part of a master planning effort, but more often they need to rely on land use data from public agencies. "The primary responsibility for integrating airport considerations into the local land use planning process rests with local governments," according to an FAA task force (FAA ASO 1998). Airports often request land use data from local government agencies on an annual basis to support their noise mitigation, land acquisition, airspace protection, and land use compatibility programs. One challenge that was reported is that airports sometimes border more than one jurisdiction that use land use categories. The result is categories which do not provide the detail airports and some agencies need for planning and analysis. (This and others issues are explained more fully in chapter four.)

In an effort to resolve this issue, not just for airports, a committee sanctioned by the American Planning Association developed the Land Based Classification System (LBCS). Many counties report using variations of the LBCS for use with remote sensor data (Anderson et al. 1976). This standard delineates developed land into the familiar residential, commercial, and industrial classes. These broad classes do not provide the distinctions airports and some public agencies need, which led to variations in the way individual organizations implemented this standard, thus creating a challenge to data sharing. In 1996, the American Planning Association and six participating federal agencies started a project to expand the scope and applicability of the LBCS. The goal was to provide more detailed, but yet broadly applicable classifications as to how land is, or is to be, used (Land Based Classification System 2000). Although the FAA participated in the development of this standard, it is unclear how many airports are actively using it. It is, however, reflected in the FAA's Airports GIS standard AC150/5300-18B. A number of cities and counties have adopted the LBCS, but the standard has not been officially reviewed or updated since the original working group disbanded.

- Zoning*—As land is developed near airports, information for local zoning becomes an increasingly important means of protecting navigable airspace and promoting compatible land use. Some public agencies have already sought input from airports so height restrictions designed to protect navigable airspace are put into place. In many cases, protocols and procedures are already in place to ensure that municipalities and airports share information well in advance to avoid development incompatible with airport needs.
- LiDAR—LiDAR data collection and processing technology has advanced, and the costs of obtaining these data have come down in recent years. The result is a very detailed and relatively accurate source of elevation data. Many airports and agencies interviewed expressed an interest in obtaining more LiDAR data in order to determine ground elevations and in some cases building or vegetation canopy heights. FAA also recognizes the value of LiDAR and defines where and how it can be used to satisfy its data requirements. As with aerial imagery, LiDAR data can be extensive and expensive to collect. For this reason, it is sometimes part of a collaborative data collection initiative such as those described earlier for aerial imagery.
- Road Centerlines*—Road centerlines, and linearly referenced addressing along these centerlines, are a common data set maintained by many of the public agencies interviewed. Airports require these centerlines to support transportation planning, emergency routing, and catchment area analysis. A challenge public agencies and a few airports have faced is misaligned centerlines at jurisdictional boundaries. Another challenge reported was that many organizations use differing addressing techniques. In some cases, these have been standardized in some regions or under broader federal initiatives such as emergency 911, 411 information, and 311 (non-emergency access to municipal services) efforts. Airports did not indicate using the accompanying linearly preferenced data that agencies typically collect.
- Construction Areas*—For planning, airspace protection, noise mitigation, and environmental needs, it is essential that airports know what nearby development is planned and where current, future, and past areas of construction activity are located. This information, particularly concerning airport property or environs, can help airports during major infrastructure development programs (ArcNews 2013). A challenge most airports and public agencies have faced is keeping this relatively dynamic data set up-to-date.
- Utilities—Pipes, wires, and manholes that carry electricity, water, fuel, and other resources to airports and which remove septic, storm water, and other wastes are an essential component of any airport's infrastructure. Geographic information that depicts these utilities is therefore an essential component of an airport's GIS. However, utilities information is among the most chal-

lenging to collect and maintain because utility assets are largely underground and are owned by a variety of entities. Knowing where subsurface utility lines and appurtenances are is therefore critical to safe and efficient airport planning, development, operations and maintenance (Anspach and Murphy 2012). Collecting these data requires coordination as new utilities are installed or may require expensive detection afterwards. Many airports, particularly small and medium-sized ones, rely extensively on data depicting public or private utilities near or on their property, much of which can be obtained directly from the public or private utility operator. Private utility companies, however, often refuse to share utilities data owing to their sensitive or proprietary nature, or because of potential future liability for any perceived quality concerns. (More information on this issue can be found in chapter four.)

- Flood Zone*—Airports, especially those near water bodies, report needing flood zone information mostly for planning purposes. These data are of increasing importance given global warming and sea rise analysis as well as the Federal Emergency Management Administration (FEMA) recent reclassification of flood zones.
- Wetlands*—Airports typically analyze storm pond and wetland areas as part of a bird strike mitigation program. Environmental compliance also requires airports to identify and sometime relocate wetlands as a part of airport construction projects.

Data Airports Receive from FAA

Airports often require Navaid equipment, obstacle, and utility data from FAA (further definitions of these data types can be found in FAA AC150/5300-18B). The FAA represents a special class of public agency because it has regulatory authority over airports in the United States and requires many to collect and submit specific information in a standardized GIS format. Specifically, Advisory Circulars 150/5300-16A (FAA 2007), 17C (FAA 2011), and 18B (FAA 2009), respectively, define how airports are to reference GIS data to the National Spatial Reference System (NSRS), acquire data through remote sensing means, and structure the data to meet FAA requirements. The national rollout of this program is defined in the FAA's Transition Policy (DeLeon and O'Donnell 2012), which has resulted in an increasing number of airports collecting GIS data that comply with FAA standards.

Another reason the FAA plays a special role with regard to exchanging data with airports is that the FAA, along with public utilities, is one of the few agencies that develops and operates facilities on airport property. Airports have traditionally desired as-built data reflecting FAA Navaid equipment and utilities, but have often not received it. This need has increased because some of the data the FAA requires to support its Airport GIS program (as described previously) originates from the FAA. This has prompted efforts within the FAA to identify data, clean up inconsistencies, and disseminate the result in a useful and efficient manner.

Following is a description of the data sets that airports interviewed desire from the FAA:

- Navaid Equipment*—The FAA Air Traffic Organization and its contractors install navigational aid equipment at airports. Survey coordinates for these facilities are seldom provided to the airports, which must wait until generalized coordinates are published. An exception to this is the Navaid equipment data airports are required to collect to be complaint with FAA AC150/5300-18B, although not all airports have collected this information to date. The result is a general lack of detail on essential components to the safe and efficient operation of an airfield. Airports that have tried to obtain these data from the FAA have reported being frustrated by not knowing who to contact and having been passed around to various points of contact, and sometimes then confronting restrictions inconsistently imposed by various parts of the FAA organization.
- Obstacles*—Under the FAA Airports GIS Program, airports are beginning to collect their own obstacle data which are somewhat different from the FAA's. In the past, these data were collected by the National Geodetic Survey under contract with the FAA or the Federal Communications Commission, resulting in numerous obstacle databases, some of which are unknown and/or are inaccessible to airports and their consultants. The FAA is undertaking an effort to consolidate these various databases into one centrally maintained and accessible database, but the program has been prolonged as a result of limited funding and organizational challenges.

- Utilities—As mentioned earlier, the FAA and its contractors often install navigational aids (and the utilities that support them) at airports without sharing that locational detail with the airport. Airport designers, contractors, and maintenance personnel need this information to develop and maintain their facilities in a safe and efficient manner.

Data Public Agencies Receive from Airports

Often public agencies require construction area, building, noise contour, obstruction identification surface, and environmental contamination area data from airports. These needs are described in detail here:

- Noise contours*—Noise from arriving and departing aircraft affects surrounding communities in a very tangible and negative way. Because of this, public agencies often require noise contour data to understand the effect of current or future air traffic. Public agencies in some jurisdictions also play an active role in sound mitigation programs. Figure 8 shows an example of airport noise contour data.
- Construction areas*—Just as airports need information on planned, current, and future development around an airport, public agencies require such information concerning airport property, particularly where it can have an impact on traffic patterns, emergency response, and environmental stewardship.
- Building addresses—Participants reported that maintaining consistent and comprehensive street addresses is time-consuming for GIS analysts at public agencies. Airports often assign its own addresses to the buildings within their property, although they need to be compatible with addressing data from nearby public agencies, especially for emergency response purposes.

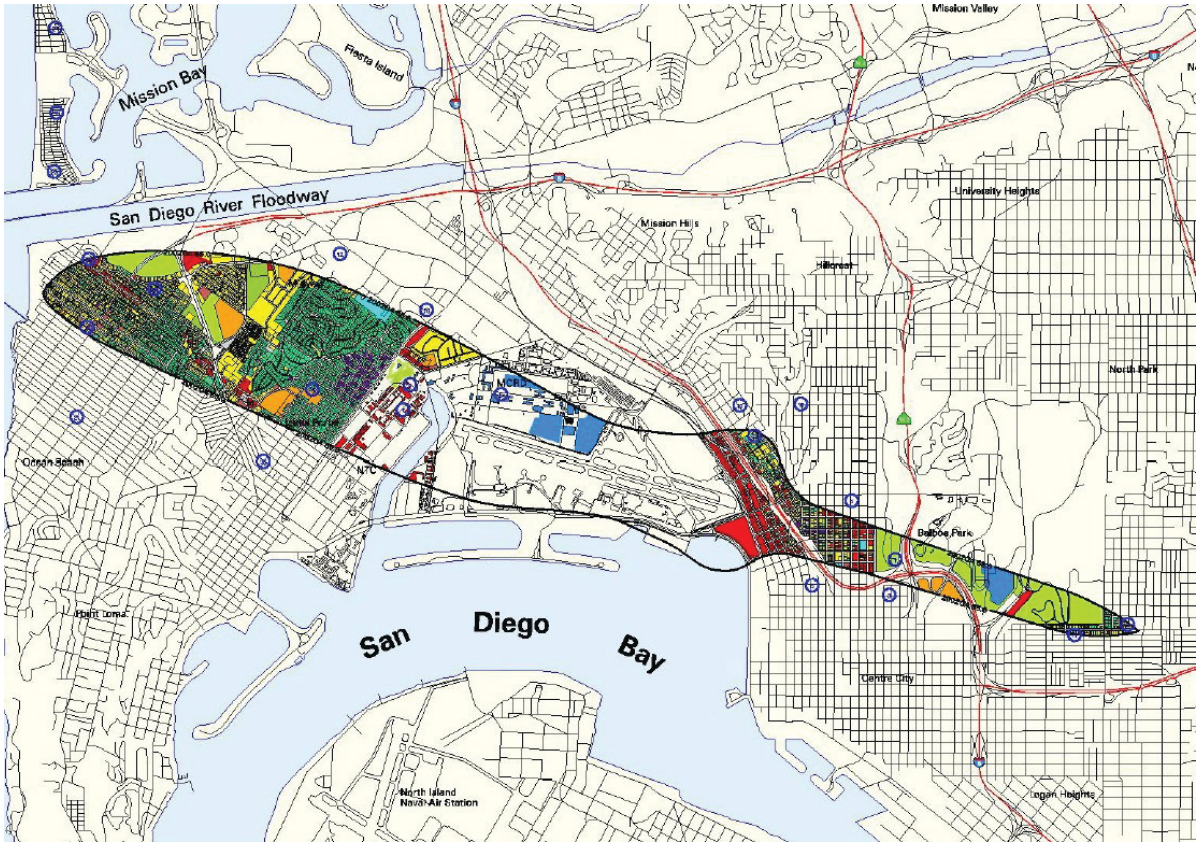

FIGURE 8 Airport noise contour map showing colored-coded land user within an average noise level. *Source*: San Diego County Regional Airport Authority.

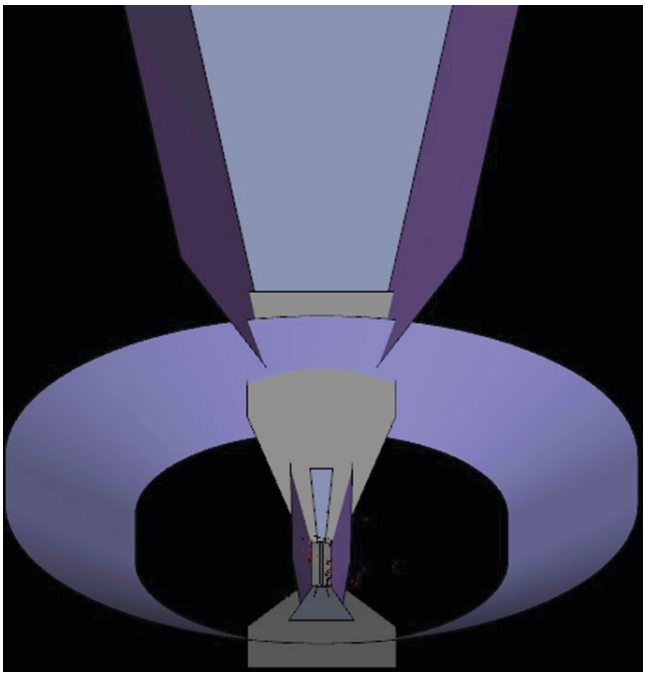

FIGURE 9 Example of obstruction identification surfaces.
Source: Grafton Technologies, Inc.

The current trend is for agencies to work closely with airports to ensure data compatibility in addressing.

- Obstruction identification surfaces*—Height restrictions to protect navigable airspace are established by obstruction identification surfaces emanating from runway ends (*ACRP Report 38* 2010). An example of such three-dimensional surfaces is shown in Figure 9. Although airport consultants typically prepare these surfaces based on the current or planned layout of the airfield, public agencies want these data to support planning and development. Several airports have indicated that they consider these data sensitive and easy to misinterpret by those who do not fully understand the complexities of airport airspace analysis. These airports prefer not to share the raw data, but will prepare exhibits for or conduct analyses to support specific questions from external agencies and at times present requested information with elaboration as to ensure understanding and caveats. Additional information on these surfaces and the topic of airspace and tall objects and their effect on airports can be found in *ACRP Report 38.*
- Environmental contamination areas*—Public agencies desire, and in some cases require, airports to report areas of environmental contamination. This information is needed to support clean-up activities, calculation of fines, or monitoring activities.

SHARING SOFTWARE AND HARDWARE

Data are not the only GIS resource that has been effectively shared between airports and public agencies. Many of the participants interviewed have provided and/or received access to the software and hardware needed to use and deploy GIS data to end users. The most prevalent form of such sharing is when one organization stores data on network file servers or hosts applications for another. These data and applications can then be accessed by either local users with authorized access or by a broader set of public users. Some of the smaller and medium-sized airports interviewed have taken advantage of hosting services that their parent county or city agencies or other regional consortia have offered, in some cases for a fee.

Software sharing can also take the form of enterprise license agreements that allow airports and agencies to obtain software free of charge or at substantially discounted prices, as part of a vendor software licensing agreement that covers all agencies (and airports) within a county or state.

Although technically software is not being shared, the collective purchasing power of multiple organizations within a given jurisdiction provides discounts that are shared. Some airports have benefitted by receiving reduced pricing on the initial GIS software purchases that have traditionally been a barrier to entry.

Similarly, parent organizations sometimes develop standardized software and hardware specifications and arrange purchasing mechanisms to facilitate procurement. In these cases, the software and hardware costs are not shared but the costs of procurement, which can be significant for some agencies, are.

SHARING HUMAN RESOURCES

In a few cases, airports reported sharing human resources with their parent city or county agencies. This was seen particularly, but not exclusively, among small and medium-sized airports that could not afford to retain the range of project management, data development, programming, and database administration skills required for an enterprise GIS. These airports have benefited from short-term "loans" of technicians for data development, surveyors for data collection, designers and administrators for database management, and programmers for application design and development, as well as other experts. Examples include a city surveyor collecting data for the airport, agency data collection initiatives that collect additional data for an airport, and city information technology staff helping an airport set up and use GIS software.

Such collaborations allow relatively small airport GIS departments to accomplish more than they otherwise could. This option was only available to airports that are part of larger city or county agencies that have well-established (and well-funded) GIS programs. The converse—airports sharing GIS resources with their parent organization—was not seen. One reason for this, which a few airports noted, is that there are federal restrictions that prevent them from spending aviation-related revenue on non-aviation (e.g., city or county) GIS programs. Although this revenue diversion restriction prevent airports from sharing resources with cities and counties, some agencies interviewed also noted cross-organizational challenges when expending funding or human resources. (Organizational barriers that may hinder effective sharing of human resources between agencies and airports, even if they are ultimately a part of the same parent organization, are described in more detail in chapter four.)

SHARING POLICIES, PROCEDURES, AND STANDARDS

Policies, procedures, and standards are important ingredients of any GIS program. Although many airports have paid consultants to develop such documents, others have benefited by being part of larger organizations that have already developed them. Airports in this situation can either adopt the parent agency policies and standards or adjust them to their specific needs. Regardless of whether they are adopted as is or customized, these documents can save an airport a substantial amount of time and money when first establishing its GIS program.

CHAPTER THREE

HOW AIRPORTS AND PUBLIC AGENCIES COLLABORATE

Airports and public agencies have found a variety of ways to share geographic information and related resources, many of which are limited, given interpersonal relationships and organizational constraints. Some professionals, however, envision a more official, centralized, online resource that would help organizations identify and access the data they require. This chapter describes how airports and public agencies reported they are currently sharing data, from the traditional "manual" methods to more progressive technical approaches.

IDENTIFYING DATA RESOURCES

A first step in exchanging data is to identify sources from other organizations and/or inform others about resources available from your organization. As Figure 10 indicates, interpersonal communications resulting from peer introductions or meetings and conventions is the predominant method of identifying data sources. Some larger, well-established regional agencies publish newsletters and/or send e-mails to members describing data they make available. The "other" category in Figure 10 represents a small but growing number of users relying on web searches, online social media, and Rich Site Summary (RSS) feeds to identify data resources available from other organizations. A few organizations mentioned publishing Web Catalog Services (WCS), which help potential users identify and assess the applicability of data resources. One respondent mentioned increasing the amount and improving the consistency of metadata to those same ends. Although many agencies are taking steps to make their data offerings known to potential users, only one respondent mentioned actively tracking web requests to determine what types of individuals and organizations were accessing it.

AS-NEEDED REQUESTS FOR DATA

Participants indicated that often the need for data from an external organization arises from a specific inquiry, desired exhibit, or requested analysis. In many case, the staffers making the request do not know what data are available, but may have some contacts that can lead them to whatever information exists. These contacts are typically GIS professionals who work for parent or peer agencies within their region.

When data are required from the FAA, airports usually initiate such requests through the district office manager; if these individuals do not have the information desired, they will re-direct the requests to others within the FAA. Some airports have noted that this can be a time-consuming process, as their requests are re-directed around the various departments within FAA and at times lost. The problem, they speculate, is not an unwillingness on the part of the FAA to provide the information, but confusing organizational communication and unclear policies, as well as a lack of knowledge about whether the data exist and where the information may be.

It appears that the key to success is interpersonal relationships—knowing those individuals who have knowledge of, access to, and authority to distribute the data desired. These relationships are often fostered through collaborative forums that attract committed GIS professionals willing to take the extra effort to exchange data with their peers.

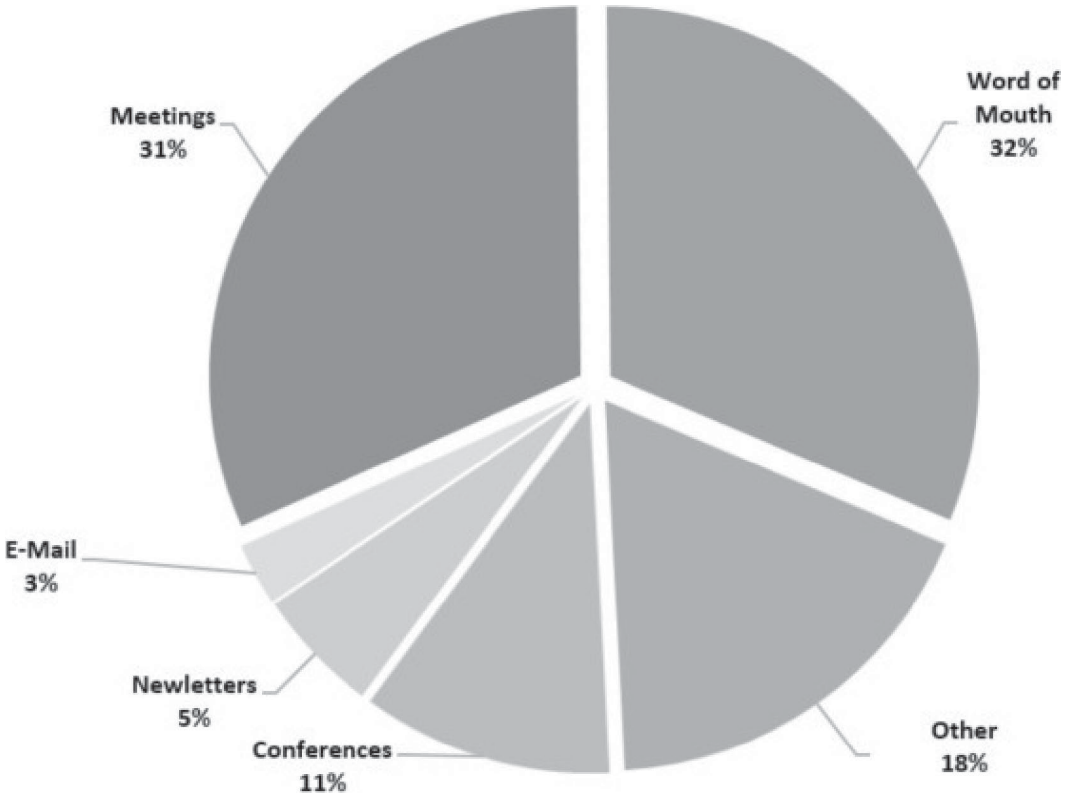

FIGURE 10 How do you find out about data available from other agencies? *Source*: 29 of 44 survey respondents.

COLLABORATIVE FORUMS

GIS professionals often participate in regional meetings, local conferences, user group meetings, etc., which allow them to meet the peers who may have data and other resources, or at least share experiences that can be mutually beneficial. However, many airport GIS professionals reported that they do not participate in these events because they perceive their needs to be different from those of their peers in other local agencies.

Typically these forums include discussions of common GIS needs as well as presentations of success stories. General functional requirements (i.e., not the technical details), data quality issues, collaboration in data collection, data standards, legal matters such as confidentiality or data use restrictions, and technical specifications are the predominant topics respondents mentioned. Once common needs are identified, follow-up discussions ensue or smaller working groups are formed; sometimes formal subcommittees or working groups are created that lead to ongoing collaboration with increased benefit.

Often these forums are established by proponents of collaboration and perpetuated by others who share their vision. However, because participation in most of these events is on a volunteer basis, they can falter when individuals who do not share the same collaborative motives become involved, when parent organizations no longer endorse a member's volunteering, or when a visionary leader leaves without a strong successor. Consistent commitment from leaders who can garner support from senior managers and political leaders is key to the success of such collaboration.

SPATIAL DATA INFRASTRUCTURE

A more institutionalized type of forum for GIS data sharing and collaboration is a Spatial Data Infrastructure (SDI). Werner Kuhn of the Institute for Geoinformatics at the University of Munster in Germany defines an SDI as "a coordinated series of agreements on technology standards, institutional

arrangements, and policies that enable the discovery and use of geospatial information by users and for purposes other than those it was created for" (Kuhn 2005). The concept is to establish the infrastructure necessary to facilitate data discovery and exchange, as well as other GIS-related collaboration among a broad set of stakeholders, in an organized and controlled manner.

SDIs can be established among any group of practitioners who share a common need for geographic information. Although the term is often applied at the national level, as with the U.S. National Spatial Data Infrastructure (NSDI), it can also be at a regional level, as is the case with the North-Rhine Westfalia GDI in Germany; or to a group of nations, as with the European INSPIRE initiative. However, SDIs need not be defined by geography, and can be established around a common interest, as with the United Nations SDI.

One of the respondents classifies three levels of SDI (Sorensen 2012), as further discussed in the case example of Abu Dhabi in chapter five. SDI 1.0 refers to practitioners satisfying their need to share data with one another through informal, ad hoc requests. This is similar to what is described earlier with regard to as-needed request for geographic information, which is a prevalent but declining means of data exchange. SDI 2.0 is where constituents each have their own enterprise GIS that relies on internal data as well as external data from their peers that is received by means of web services and other electronic means. Some regions, such as Las Vegas (also highlighted as a case example in chapter five), have achieved this level. SDI 3.0 reaches beyond GIS to include information from other non-spatial decision support systems, as well as beyond organizational bounds to include social media and "big data" from sensors that continuously collect data about the surrounding environment.

Some larger airports have begun to benefit from SDI concepts implemented in their regions, whether labeled as an SDI or not. Sometimes this comes in the form of readily available data sets such as parcels and road centerlines. Other times, the benefit of an SDI is the increased awareness of the benefits of GIS, regardless of whether the goal of exchanging data is fully realized.

SUBSCRIPTIONS

Some airports and public agencies indicated that they subscribe to data by making periodic payments to third parties to gain access to GIS data, and in some cases, to related analytic services. Although not typically thought of as "sharing," because money is exchanged, this is a collaborative method because the interests of many are served by a single provider who has addressed a common need. Examples of subscription data include road centerline and addressing data provided by national or international vendors, flight track information provided by authorized value-added resellers of FAA radar data, and oblique imagery collected by an aerial photography vendor. Often these subscriptions are with private vendors of data, but a number of the more established, non-profit agencies require members to pay a periodic fee to access data. This approach spreads the expense of developing and maintaining the data and the technical infrastructure to disseminate it among many users. Figure 11 shows that such subscriptions are common, but not the norm.

Some commercial vendors have begun to offer hosting services and online software applications to airports and other agencies willing to pay a periodic or usage fee. To maximize their revenue and profit, their offerings can be somewhat general by design so that they are broadly useful. Examples include street centerline data that spans a broad region; imagery that is available for the whole country, or analytic services that can be used by many customers.

These Infrastructure as a Service (IaaS) and Software as a Service (SaaS) models are becoming increasingly common in the cloud, not only for GIS data and services but for office productivity, collaboration, and other software as well. One respondent's organization, for example, is using a cloud-based provider for its airport's e-mail. Such cloud-based resources help airports and agencies reduce the cost of acquiring, administering, and maintaining expensive software and hardware resources. For this reason, cloud-based services have been suggested as a good alternative, especially for smaller airports. The growth of these offerings is indicative of a broader trend toward the use of web services to share GIS data and other resources.

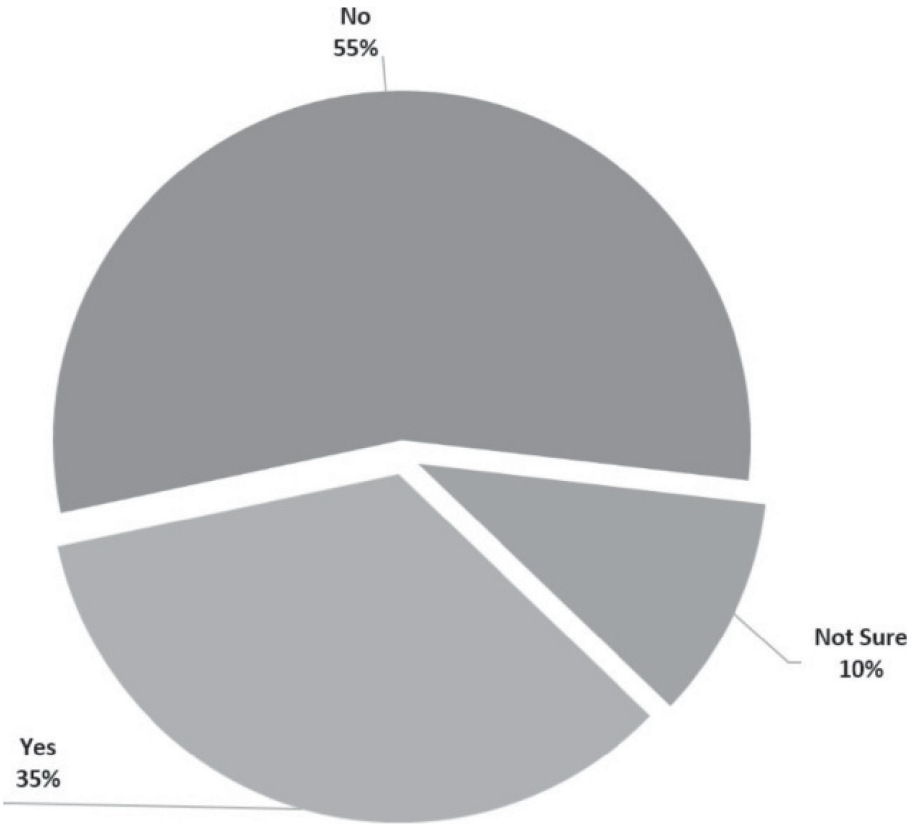

FIGURE 11 Does your organization subscribe to data that are regularly published by other organizations? *Source*: 29 of 44 survey respondents.

ONLINE DATA EXCHANGE

Web-Download/FTP

Placing data on secured or public websites for download by means of FTP is a common way of sharing data with a variety of users. Only a few of the sites identified in this report require an authorized account to download specific data, although some do require a digital acceptance of a license or copyright agreement. No airports interviewed directly offer FTP downloads, although many ask their consultants to set up collaborative sites that use commercial off-the-shelf software to provide data download capabilities to authorized team members working on a specific project or program. Additionally, some airports give data, such as noise contours, runway outlines, or airport boundaries, to the local municipality for download from its secure FTP site. Despite protective measures that can be put in place, FTP sites can expose security vulnerabilities in an organization's network. These vulnerabilities and how to protect against them are beyond the scope of this study, but are suggested for further research.

Web Catalog Services

WCS publish searchable lists of data and relevant metadata. These services typically rely on entries from the data providers that describe the subject, extent, timeliness, accuracy, and intended purpose of the data. No airports and few public agencies identified in this report offer such services, although WCS is an effective way to identify data that is available, and may be relevant to agencies such as the FAA that provide a wide variety of data to a wide variety of users.

Web Map Services

WMS allow providers to publish data in a manner that others can view, query, or incorporate into applications without the need or risk of manipulating the data. The latest version of a data set

is posted and disseminated read-only as it is updated. This eliminates the burden, which many data providers complained about, of making and sending copies to data recipients, who then must periodically request updates. WMS also allow providers to symbolize data in a manner that is appropriate based on the intended use of the data. This not only makes it easier to access but reduces the chances that a recipient will alter the data or create a derivative product in a way the provider would not approve, thus protecting the integrity of the information. Users can immediately integrate meaningful and symbolized data into their desktop, web-based, and mobile applications. No local storage or manipulation of the data is needed because the data are served through the provider's network or the Internet. Advanced WMS users are accessing remote data, geo-processing that data "on the fly," and combining it with local data. Seldom do administrators of these services track specific users or maintain statistics on the number of users who have accessed specific data sets, but this is clearly a growing trend that allows providers to understand who is using their data.

Because of the advantages listed previously, the use of WMS by agencies that disseminate data within their organizations, as well as those who publish data on the Internet, is increasing. Public agencies are using WMS as a means of deploying data to a broad group of authorized regional users or to the general public. The proliferation of GIS-based web services is also supported by vendor-neutral standards published by the Open Geospatial Consortium, which are being adopted by major GIS vendors. These widespread industry standards allow data providers and software vendors to adjust their offerings to a common target, which significantly expands the potential to share data.

Figure 12 shows an example of general airport data made available by Harris County, Texas, and the Houston–Galveston Area Council. Airports are beginning to use WMS as a means of deploying data to off-the-shelf or custom applications they develop for internal use. The FAA has begun to use web services as a means of publishing airport aerial photography and hopes to offer more data by means of WMS in the future. Figure 13 shows an example of FAA aeronautical data made available through a WMS.

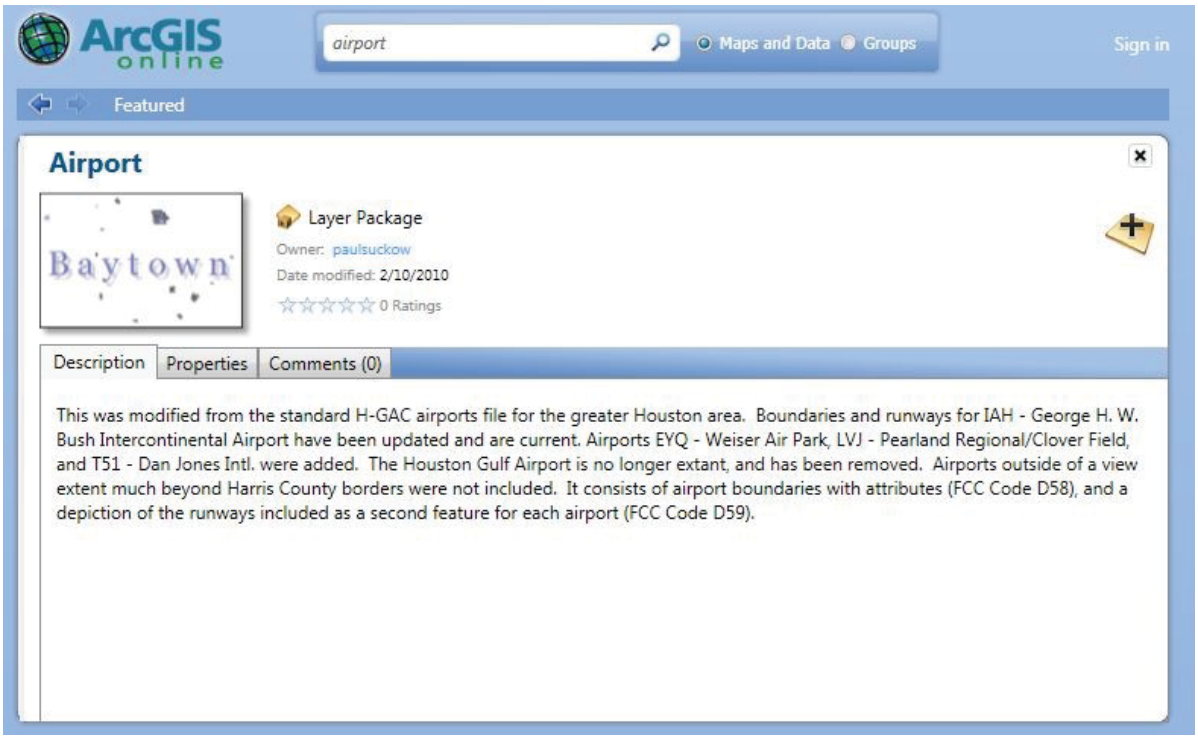

FIGURE 12 Map services made available based on data made available by Harris County and the Houston–Galveston Area Council. *Source*: ESRI (2013).

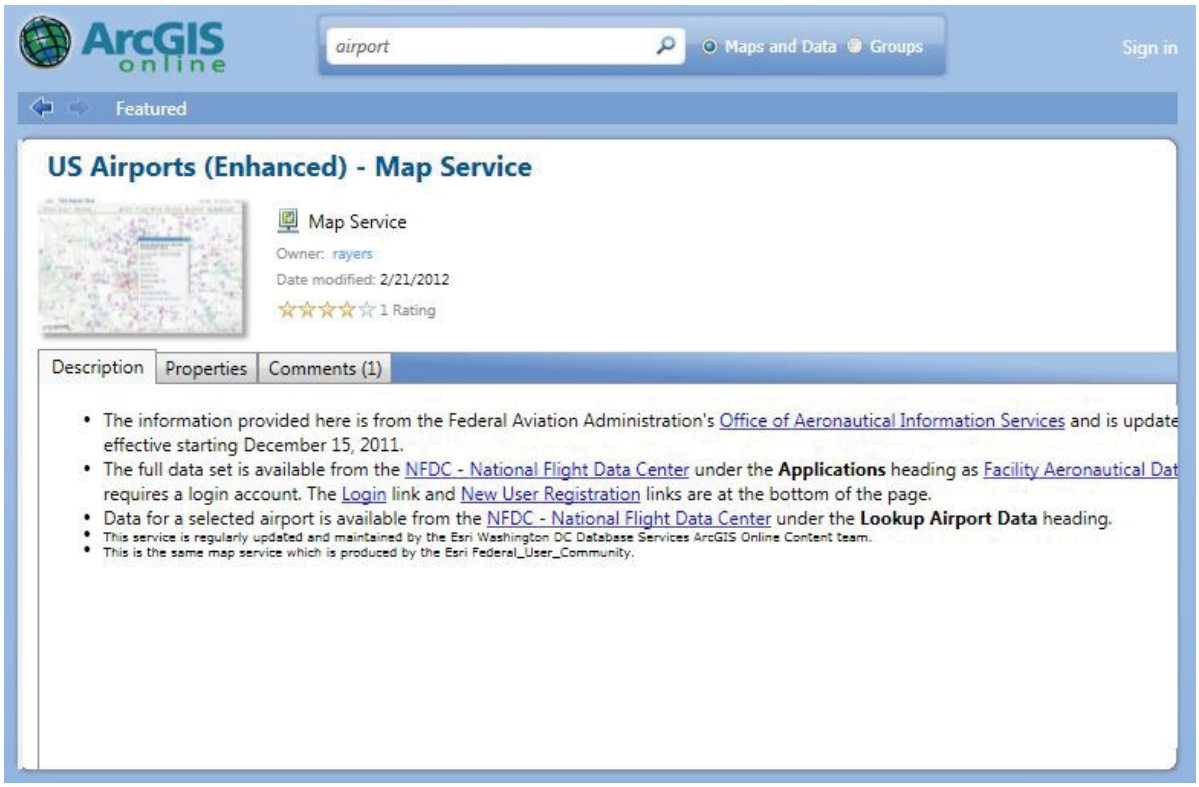

FIGURE 13 Map services made available based on FAA data. *Source*: ESRI (2013).

Web Applications

In addition to FTP downloads, WMS, and other data sharing methods, some public agencies are publishing their GIS data within applications provided by vendors who offer SaaS or IaaS. Often these applications allow authorized users to view, but not necessarily download, information. These interactive mapping applications include basic query, pan, and zoom functions that allow the user to get a good understanding of what data are available to them; those who would like to obtain the source datasets can make requests through defined processes. Intranet versions of these applications, with increased business process specific functions, are also at times available. (An example of such an application is the Savannah GIS MapIt application; see the case example in chapter five.)

CHAPTER FOUR

CHALLENGES TO DATA SHARING AND STEPS TO OVERCOME THEM

Despite the overwhelming desire for more centralized, readily accessible data and the growing range of web-based options to satisfy that desire, many airports and public agencies face challenges that constrain their ability to get the data they need. The reasons can be technical or organizational, although most reported that technical challenges are easier to address and that organizational challenges far more difficult to overcome. Often respondents indicated that they would be willing to pay to develop these data in-house, because it is important to their needs, yet found it difficult to obtain the funds necessary to do so.

Figure 14 indicates some of the more prevalent factors that prevented respondents from getting the data they desire. The "other" category includes references to data quality, accessibility, and concerns over sensitivity. This chapter provides detailed description of the types of challenges that airports and public agencies report facing and the means some have used to overcome them.

ORGANIZATIONAL CHALLENGES

As mentioned earlier, most respondents identified organizational factors as the greatest challenge they face when exchanging data. It is human nature, and often a fiduciary obligation, to prioritize one's own organizational needs over another's. Some individuals also believe that sharing information they possess diminishes their relevance. Barry Wellar suggests that "much of [this attitude] has to do with power, prestige, and empire-building on the parts of individuals and agencies wanting to 'run the show' " (Wellar, p. 42). Airports and public agencies are also governmental organizations that face budgetary constraints, restrictions, protocols, and organizational complexities that do not inherently foster data exchange. Some agencies reported that they felt pressured to recoup data development costs by charging for the information, although the trend is toward providing data for free (Wellar, p. 43) or at a "cost not to exceed the direct cost of duplication" (California Supreme Court 2013, cited later in this chapter). Other agencies have tried, despite the Freedom of Information Act, to withhold data (Sierra Club v. The Superior Court of Orange County 2013, also cited). Some data are, however, considered sensitive or proprietary and cannot be widely shared.

Because of organizational complexities, data exchange is enhanced and more easily accomplished if an airport is a part of a municipal or county agency. This is especially true when resources beyond data, such as software, hardware, and human resources, are also shared. This is likely because of less challenging logistical hurdles or a sense of responsibility among entities within the same organization.

Fortunately, as indicated in interviews with airports and municipalities in this study, there is a clear trend away from a restrictive approach to sharing data because of legal restrictions and imposing fees to a more open approach, making data easily searchable, free, and without restriction. Some agencies are legally required to provide data without restriction (New York State, p. 1). Some are managed by individuals who believe it is their professional obligation to share their resources with peers and with the general public. Others have come to the conclusion that the cost of preparing and disseminating data on request is greater than that of simply publishing it on the web. Whatever the reason, the trend toward open data is growing (as indicated by the increasing number of organizations doing so and the amount of recent literature and discussion on the topic) and it is resulting in a greater volume of information openly available on the Internet.

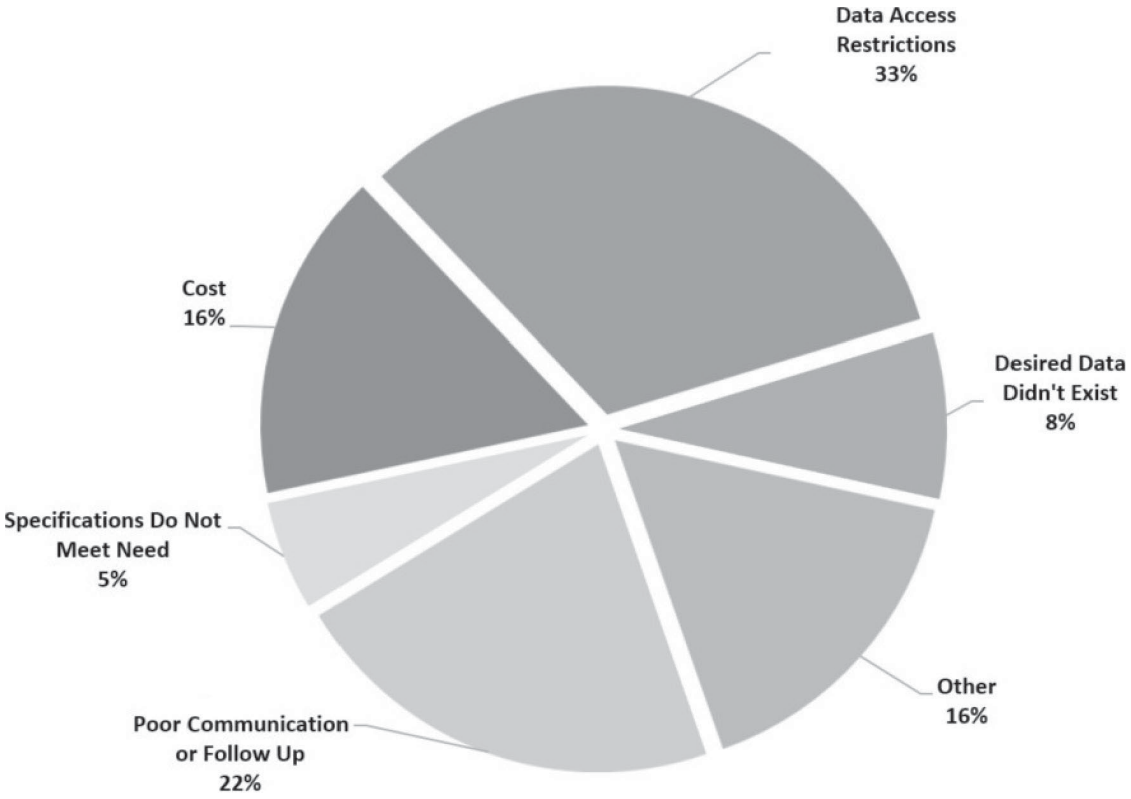

FIGURE 14 What factors have prevented you from getting the data you require? *Source*: 24 of 44 survey respondents.

Open data exchange also frees agencies of the burden of developing and enforcing written agreements that many have (and some still) require. Some states, such as Florida, have determined that data developed using taxpayer money could be made available to the general public on demand. Similarly, the California Constitution states that "the people have the right of access to information concerning the conduct of the people's business" [Article I, Section 3, Subdivision (b)(1)]. Because of these decisions, there is an increasing amount of geographic information and related resources on government websites that can be downloaded by citizens and companies alike—with, at times, restrictions. Some organizations are encouraging the philosophy that data should be shared unless told otherwise, which is the opposite of assumptions in the past.

Several respondents noted that passionate GIS professionals will go out of their way to help private citizens, peers, and colleagues find the resources they need. However, the following are some of the challenges organizations have reported facing, and ways they have overcome them.

Cumbersome Agreements

Although digital and/or written agreements have traditionally been common in data sharing transactions, there is a clear movement away from the cumbersome and time-consuming efforts of generating and enforcing data sharing agreements. This trend was not only identified by respondents to this synthesis and literature reviewed, but found as a part of the review behind *ACRP Synthesis 48: How Airports Measure Customer Service Performance* (Kramer et al. 2013).

Some organizations, however, still see the need for formal data sharing agreements and are taking steps to facilitate the process with standardized agreements. Cy Smith, Oregon GIS coordinator, noted that "in the past, formalization was seen as too difficult and legalistic, but several obstacles have presented themselves over the years that virtually require formalized data sharing agreements between organizations" (Wellar, p. 44). He and his colleagues have therefore taken steps to ease the process of

developing agreements by providing a matrix that helps identify restrictions that can be referenced in standardized data sharing agreements.

A few airports and several public agencies indicated that they have had or still have written agreements that data requesters were asked to sign before information could be shared. In some cases, these agreements took the form of non-disclosure agreements (see the Savannah Airport case example in chapter five). In other cases, a memorandum of agreement or a formal contract was put in place. Some organizations indicated that the cost of developing and enforcing these agreements was greater than the protection they believed the agreements afforded, and in the end decided to make data openly available. Sometimes terms and conditions will be placed on the website where data are available for users to accept, actively or passively, upon download.

Excessive Protection of Sensitive Data

Data security is a technical as well as organizational challenge. It is included in this section because data providers indicated that the organizational challenges of data security are harder to overcome than the technical ones, especially in the post-911 era. Technical challenges of implementing data security can be overcome with modern user authentication, encryption, and other techniques; this is the focus of ACRP Project 05-02, "Airport Cyber Security Best Practices."

Organizational challenges regarding data security include requiring training, consideration of cultural changes, policy adjustments, assessing the tradeoffs between security and accessibility, understanding and weighing technical options, and balancing budgetary constraints.

However, although some data sets warrant high security, others do not (Baker 2004). Sensitive Security Information (SSI) is defined in the Code of Federal Regulations (CFR, Title 49 Part 15.5) as information obtained or developed in the conduct of security activities; and by law, must be protected. Other data, such as utilities mapping, may also warrant an increased level of protection because of the harm that could be inflicted if this information were available to wrongdoers. Many organizations segregate publicly available data from SSI and other sensitive data information that require users to agree to specific terms and conditions through an official channel from publicly available data. Accessing protected data requires users to agree to specific terms and conditions through an official channel. Public data are openly available for search and download. Seldom are additional distinctions made, making administration easier for staff. Data security measures may also apply if licenses, copyrights, or other restrictions have been placed on a data set by vendors or other providers.

Legal Constraints

In some cases, data providers cite legal restrictions, such as confidentiality, copyright, and licensing restrictions, as deterrents to sharing data. In many cases, these constraints are valid and protect sensitive information or the intellectual property rights of organizations that have paid considerable amounts to develop the data.

Public agencies recognize the need to segregate such information from data they freely distribute, and to impose the necessary restrictions so that legal constraints are not violated. This creates a disincentive to data sharing, as the benefit must exceed the added cost of providing it within the legal restrictions in place. Airports report this problem less frequently, primarily because the data they require is either developed in-house or does not carry such restrictions.

In some cases, agencies that limit data sharing based on sensitivity or confidentiality exceed their authority to do so. A few respondents speculated that these restrictions were used as excuses to retain control over data for fear it might not be of a high enough quality, etc. As an example of excessive limitations on data sharing, Orange County, California, asked the Sierra Club to pay $475,000 for data it had requested, and restricted its use and distribution. In 2013, after 51 months and two lower court rulings in favor of the county, the California Supreme Court ruled that Orange County must provide its parcel data to the Sierra Club "in any electronic format in which it holds the information

at a cost not to exceed the direct cost of duplication." Although this case is somewhat unusual, it may be precedent-setting.

Legislation in the state of Florida, however, offers a different example that accentuates an open data philosophy. In 2013, state lawmakers in Florida delivered new policies and laws intended to make government more open, ethical, responsive, and accountable. Title X, "Public Officers, Employees and Records," Chapter 119.01 "Public Records" statutes clearly state that "all records are open for personal inspection and copying by any person. Providing access to public records is a duty of each agency." This statute, along with digital distribution and Internet advancements, has made Florida one of the jurisdictions most advanced in making data readily available to the public.

Not all states have embraced open data laws. Lawyers are therefore left to advise their clients based on a variety of interpretations, often without precedent. It was stated by interview participants that when requested for opinions where data sharing laws are not present, legal counsel tended to default to advising agencies and organizations to prohibit or avoid data sharing because of perceived risk as well as because of traditionally conservative positioning on this general topic. It was also suggested that if equal energy were expended on encouraging data sharing, more constructive exchanges would likely evolve throughout the nation over time.

Lack of Formal Procedures and Policies

Many airports and public agencies responded that they benefitted from written policies and procedures that support data maintenance and sharing. Other organizations, however, have not committed the time or resources to develop such procedures or policies. Some public agencies have benefitted by being a part of larger municipal, county, or state agencies that already have policies and procedures that they can adopt. New York State, for example, has a policy that "encourages public agencies to share in the creation, use, and maintenance of GIS datasets at the least possible cost, while providing citizens, the media, and other data users easy access to this resource" (New York State 1997, p. 1).

Airports are less fortunate in that much of their data needs are unique to aviation operations, making public agency documents less relevant. Airports do, however, have FAA Airports GIS standards which are applicable to their unique needs. Some airports have developed policy and procedures based on the FAA standards, and others have augmented their procedures with relevant details from public agency documents.

Disconnected Organizations

Many airports indicated that they are part of city or county agencies that have GIS data and resources to offer, but only a few of them take full advantage of these resources. For example, numerous cities and counties have enterprise licenses with software and data vendors, but only some agencies are willing to host applications for airports or other constituents in their region.

Several of the airports and agencies interviewed found it easier to identify and obtain data when they come from within their organization, their parent organization, or a peer organization under the same governing body. When the requests crossed organizational boundaries, differing budgets and policies tended to hinder data exchange. Many respondents report overcoming this by developing relationships with peers in other agencies, thus building trust and increasing the willingness of GIS data providers to provide data to colleagues in other organizations.

Limited Staffing

Most organizations indicated that only a few employees are dedicated to data maintenance and/or exhibit production. Additionally, municipal agencies have been hit with budget cuts over recent years that have led to noticeable staff reductions. Extracting and copying data into an acceptable medium often consumes too much time and becomes a barrier to data exchange. Some agencies have found it

easier and less costly to simply make data freely available to those who need it through downloads, WMS, or other means. (This is another incentive for publishing data by means of WMS or FTP sites, as described in chapter three.)

A less technical solution is to rely on assistance from other organizations. Some airports, as noted, "borrow" GIS staff from a municipal or county agency. Although exemplary, these situations of cross-agency labor-sharing are the exception, not the norm.

A Lack of Collaborative Forums

Many regions reported having organized forums that regularly bring together like-minded participants to collaborate and network. The benefits of such collaboration are seen in most of the case examples in chapter five, especially those of Denver, Las Vegas, and Minneapolis. Most of the time, the discussions identify data needs and other common requirements; seldom do they go into detail about specifications or formats. Instead, participants share success stories, develop contacts, and delve into specific requirements outside of these forums. In a few regions, subcommittees have been formed to regularly discuss specific topics of interest.

In most cases, these forums are free to participants; in other cases, the forums are nonprofit operations paid by membership fees. Because they are typically supported by volunteers, these forums may lack participation from senior managers and local political leaders who could implement changes in data sharing policy.

In regions with particularly active and effective forums, there are typically one or two GIS professionals who have championed a data sharing initiative for years and who are credited with establishing and nurturing a culture of collaboration. Individuals with energy and passion can have a significant impact by helping to establish and direct the focus of committees, meetings, and user groups in ways that the regional GIS community finds valuable.

At times, however, GIS professionals indicate that they do not perceive that there is sufficient value in participating in these forums. This appears particularly true of airport GIS professionals, who are increasingly busy and resource-constrained; at the same time, they perceive their needs as being different from others in their region. Some also perceive themselves as having unique needs that can be met internally, without the need to reach out to peer agencies. They therefore elect not to participate; in some cases, management does not support their participation. Some also perceive that participation would generate additional work, or that they would be "giving" more than "receiving." Whatever the reasons, it is clear that airport representatives participate less often in these forums than their peers in nearby public agencies.

Airports do value the usefulness of national conferences that focus on the specific subject of airport GIS. Airports that have sought assistance from city or county agencies have typically been smaller and without adequate funding and/or human resources to develop the GIS capabilities they desired. Those that have utilized the resources of nearby agencies report a cost savings that has justified the effort to collaborate.

Limited Awareness Among Those Who Can Affect Change

GIS advocates and users have reported difficulties in conveying the importance of their recommendations to senior managers and political leaders who could implement changes in data sharing policy. They often have trouble conveying the broader relevance of their message, recognizing that it is detailed and technical. One GIS advocate believes that it is sometimes easier to get support for aerial imagery because it is visual and broadly used, as opposed to detailed vector data and attributes that can support more valuable analysis.

The solution suggested by respondents is for GIS advocates to learn to "market" their ideas to management and political leaders more effectively. Educating these leaders about the benefits of data

sharing and GIS collaboration can be very effective. Summarized recommendations written in a non-technical way and supported by cost/benefit justification have proven to be very useful.

Lack of Executive-Level Champions

A growing number of airports have established GIS manager positions to centralize their GIS data, systems, and human resources. These managers help champion the importance of GIS, synergize resources, and provide a focal point for external data sharing. Individuals in this role are particularly empowered when they report to an executive who supports an open data philosophy (as discussed previously).

An increasing number of states, including Arkansas, New York, and Maryland, have appointed a Geographic Information Officer (GIO) under the governor who has statewide jurisdiction in promoting GIS concepts, coordination, and values, including data sharing protocols. Individuals in these positions can establish policies and standards to promote data sharing. Some GIOs have set up committees to promote GIS capabilities of agencies within the state. They also foster GIS collaboration and data sharing as part of efficiency initiatives within government.

Costly Collaboration and Sharing

Adjusting data to conform to standards, adding relevant or removing irrelevant attributes, and entering metadata so that data can be used by others takes time and is therefore costly. Even when GIS users support data exchange, they still face the challenge of securing and prioritizing already limited resources to enable it. The result limits data sharing or requires recipients to take data as-is and expend their own resources to make any necessary improvements.

The challenge of justifying the cost of data exchange is reduced when the exchange is reciprocal. If by providing data to others, GIS users also receive data that they value, then the benefits of data sharing increase to help justify the costs. Similarly, data providers may be encouraged to share data because it allows them to receive capabilities, services, or other benefits in return. If an equally valuable exchange is not possible, then recipients or governing bodies that represent the interests of recipients must provide the necessary funding. Examples of this have been seen when an agency that requires data provides funding to an airport to collect the data its needs, or when a state or local government provides funding for GIS staff to disseminate data to constituents.

Some data providers offset the cost of sharing data through nominal fees, as is the case with subscription-based and one-time payment plans. Data sets that require payment typically require that the data not be resold or redistributed. Although understood by most users, this restriction does reduce the dissemination and use of the data.

TECHNICAL CHALLENGES

Airports and/or public agencies also face technical challenges when trying to share data. Although modern technology offers many solutions, technical, financial, or organizational constraints render some unfeasible. For each technical challenge identified, the solution(s) some organizations have found successful are reported.

Lack of Consistently Applied Standards

Standards can address the specifications to which data are collected, the structure of the data, or the level of attribution and metadata. However, several examples where identified where information the respondents obtained from another organization was difficult to use because it did not conform to a common standard. In such cases, some airport staff members indicated that they had to adjust the data they receive, whereas others have left the data as is and worked around the differences. Not all the data sets were relevant to the airport; but for some purposes, as when parcels are used to identify

land ownership for sound insulation programs or land acquisition, the data are essential, so these differences can become problematic. Some larger public organizations, such as the Denver area's North Central All-Hazards Region (see the case example in chapter five), have been successful in establishing regional standards that help homogenize data sets, especially those addressing street centerlines and addresses that need to be consistent across municipal, county, or even state boundaries. These standardization efforts are especially beneficial at the regional level where agencies from abutting jurisdictions need to share data with one another.

Some public agencies have also participated in national initiatives to standardize addresses for emergency response purposes. At this level, not only might it be possible to exchange information with nearby agencies but with national emergency response and other initiatives. Unfortunately, national standards developed to support specific categories of data are often underutilized (Wellar 2010).

Information that does not adhere to common standards, or to any standards at all, increases the difficulties of data exchange because data recipients must adjust data to meet their needs or live with the differences. An example of this is the challenge airports have faced when integrating land use data from multiple jurisdictions, as discussed earlier. This consumes time and therefore costs money. Data providers also have expressed concerns that these adjustments may degrade the quality of the data they have provided and that they might be held accountable. (The concern over derivative products is discussed further later in this chapter.)

Airports reported struggling with data consistencies less often than public agencies for two reasons: First, airports rarely if ever need to exchange data with other airports and typically only exchange a few data sets with local public agencies upon request. Such data are often exchanged as-is. Second, the FAA Airports GIS program defines data standards for approximately half of the data sets maintained by larger airports and a larger proportion of the data sets maintained by small and medium-sized airports. Although the required transition to these new standards is not complete (DeLeon and O'Donnell 2012), all airports interviewed are aware of them and many are already moving toward compliance. This movement toward common criteria for airport data is beginning to become a pervasive industry practice.

Unlike airports, public agencies are not typically required to adhere to particular data standards. In some regions, agencies report having adopted a common standard for street centerlines and addressing to facilitate compatibility with neighboring communities. Several public agencies have participated in Emergency 911 initiatives at the state and federal levels that prompted them to comply with broader national addressing standards. Martha Wells of Spatial Focus, Inc., reports "URISA undertook the preparation of an Address Data Standard for the [Federal Geographic Data Committee], and this standard is now nearing full adoption. Many jurisdictions—local, state, regional, and even federal—have been asking for and even using [this] standard" (Wellar 2010).

Figure 15 indicates the factors that influence the definition of standards at airports and public agencies. Most of the time, internal customers and/or management drive the development of standards. Very few agencies reported that their standards are driven by federal or state government, but some indicated that external customers are a factor. A number of airports mentioned adhering to the FAA's Airports GIS Standards, but did not believe that the FAA requirements influenced the development of or updates to the majority of their data.

Poor Data Quality

The evaluation of data quality encompasses positional accuracy, temporality (i.e., time and frequency of update), comprehensiveness, level of attribution, correctness of attribution, presence of metadata, and other characteristics. Data quality requirements vary widely by data set, steward, intended use, project, and organization. Airports typically respond that they have higher requirements for spatial accuracy than public agencies, reflecting the relatively large map scale they require, as well as an engineering perspective that necessitates precision. Public agencies often favor comprehensiveness and consistency, because they must integrate disparate data sets from multiple jurisdictions in order

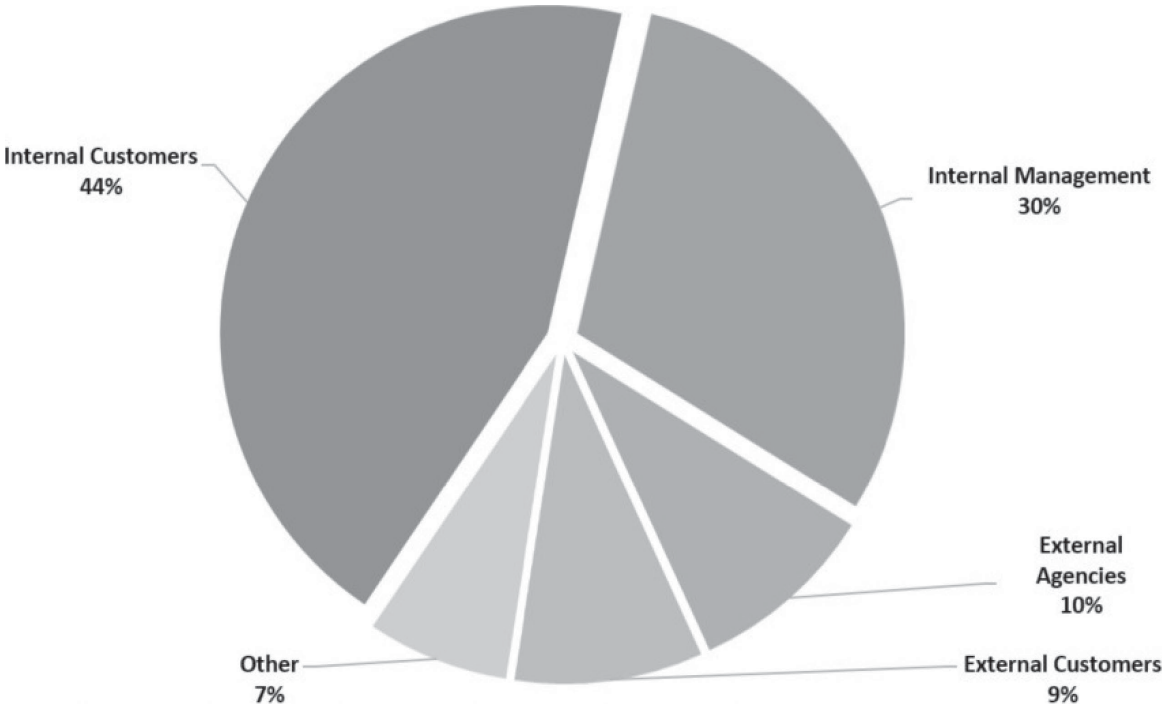

FIGURE 15 Drivers of standards. *Source*: 25 of 44 survey respondents.

to support the regional analysis their users require. The result is that not all data exchanged is of equal quality, and may lack metadata context.

When data are exchanged, receivers typically take what they can get and then adapt the data as effectively as they can to their needs. Metadata becomes critical to the usefulness of data but is seldom available. This increases the cost of using the data, as it must be evaluated and sometimes improved before it can be used. Regardless of the level of metadata, reported best practices suggest that caution be used when applying data from unknown or even known sources.

Out-of-Date Data

One element of data quality that was frequently emphasized by respondents was temporality, or the degree to which data has been kept up to date. Figure 16 shows how often data recipients require data to be updated. Most respondents indicated that they update their data on a project-by-project basis or when it is requested. This approach can work when the requestor and provider are within the same organization and the importance of the request warrants the cost of updating the data. When data are exchanged between organizations, they are often provided as-is. Some agencies, however, reported that core data sets such as road centerlines, parcels, and addresses are continuously updated because of their importance and the number of people that rely on them.

Some data sets are kept more up to date than others. Many larger airports and public agencies update aerial imagery and terrain data annually or biannually. Parcel data are continuously kept up to date by county assessors, but may not be readily accessible in a GIS format. Periodic and widespread use of the data is what drives demand for continuous updates.

One interesting observation shared by an agency was that data published through web services appears to be more up-to-date than that from other sources. The agency's theory is that providers who publish data by means of the Internet do not know who is using it, when, or how often, so they feel obligated to keep it current. As more data providers implement web services, it is like that a trend toward continuous updates versus as-needed revision will develop, resulting in an increase in the temporal accuracy of data.

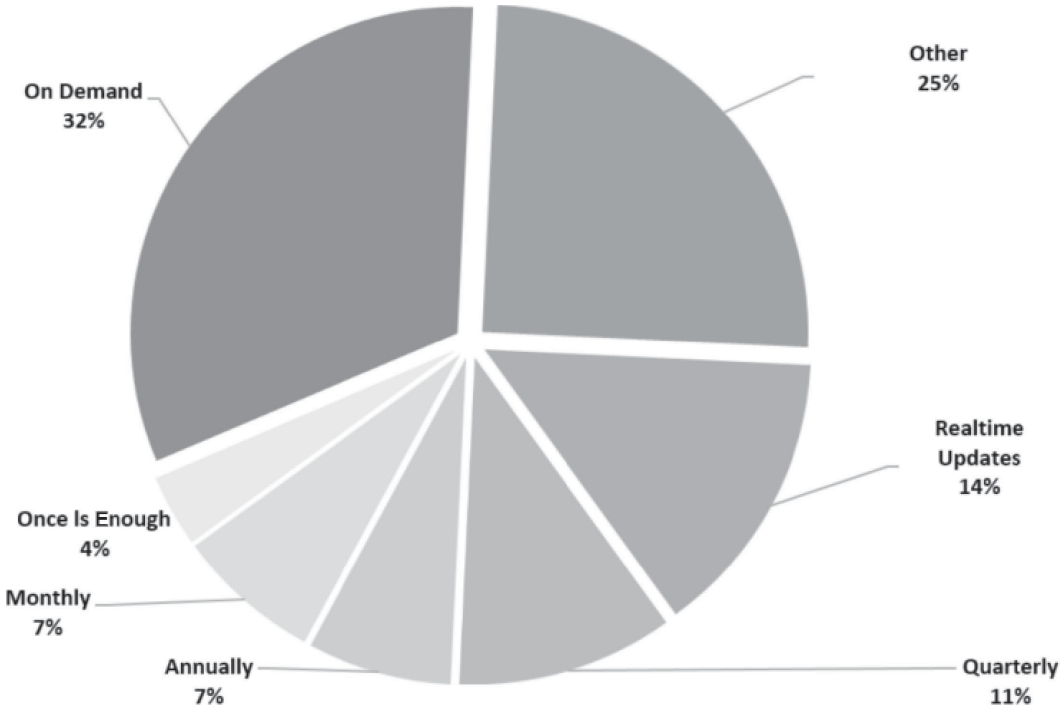

FIGURE 16 How frequently do you require updates of the data you receive from others? *Source*: 28 of 44 survey respondents.

Improper Derivatives

Public agencies often indicated that they need to adapt the data they receive from others to meet the needs of their users. Airports do this less frequently, perhaps because the majority of their data comes from internal sources and has been developed to meet their specific needs.

Some data providers expressed concern that data they share could be inappropriately altered by recipients, thus degrading its quality or violating copyright or licensing restrictions, and make the providers culpable for conclusions drawn from the altered data. Some providers or data originators will allow users to implement and alter the data for their own purposes but prohibit providing the altered data to others, even if they have similar needs. Concerns over liability or accountability for decisions made based on these derivative products have increased their hesitancy to share data. In other cases, data owners fear that derivative products will not be used properly and therefore reflect poorly on their organization or their data.

Conversely, recipients of data have expressed frustration about the need to alter data to meet their needs. This adds cost, especially if the data are periodically updated. They too fear being responsible for degrading the quality of data, especially when it is not within their domain of expertise.

Providing data through web services that restrict ability to alter content; creating metadata that clearly states how data are to be used; and legally restricting inappropriate use of data may be effective responses to this problem.

Lack of Metadata

Metadata provides users with important information about and how to use the data they receive from others; and often such sites protect the provider by defining the limits for use through meaningful disclosures. The Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998) and the International Organization for Standardization's Geographic Information—Metadata standard (ISO 19115) define a variety of metadata elements that support geographic information. Some agencies such as SANGIS (see the case example in

chapter five), recognize the importance of metadata and check all of the data they develop or receive to ensure that it has a minimum level of metadata. Airports have reported that the most important metadata elements, which help them understand how to use the data, include its source, collection method, date of collection, and accuracy.

Despite its importance, many airports and public agencies alike report that they do not receive the level of metadata they need or desire. Many data providers do not populate the metadata when adhering to best practices. One frequently reason cited for not populating metadata is that it consumes time and money after the primary task of developing the data has been completed. Given that data are often developed or updated to meet project specific needs and that most data are developed to meet an organization's internal requirements, it is likely that metadata has less benefit to the primary users of a data set, who likely already know what they need to be able to use the data. Such a lack of metadata, however, seriously degrades the ability to exchange data with external users.

Some data developers believe it is their obligation to populate metadata, but admit that it is seldom done. Evolving metadata standards and, more importantly, tools based on those standards can facilitate the development of metadata. Some of these tools, as well as Extract, Transform, and Load (ETL) software, can automate certain aspects of metadata population. Large programs, such as the FAA's Airports GIS, also collect a variety of metadata at various levels as grants are issued, projects are created, and quality assurance reports are prepared. WCS also make available more metadata than is typically found in data sets that are not published through web services.

Data-Related Differences That Are Difficult to Overcome

There is a wide range of incompatibilities—file formats, coordinate systems, projection, or media—that can make data unusable when it is received. Most of these can be overcome by applying the correct mix of transformations. Following are some of the more common interoperability issues reported by respondents:

- Coordinate Transformations—Airport architects and engineers often use custom Cartesian coordinate systems that align runways with the orientation of the plotted drawing with little account for ellipsoid models or the earth's curvature. Geospatial data in these coordinate systems can be converted to/from standard coordinate systems if the parameters required to support an accurate transformation can be provided and if the skills to apply these parameters within software capable of such transformations are available. These transformations must account for the horizontal and vertical coordinates and ensure that they are accurately referenced to the proper horizontal and vertical datum to the degree of tolerance specified. Inevitably, some inaccuracy is introduced into these calculations, but it is the responsibility of the individual applying them to understand what level of tolerance is acceptable and to report this as a part of the metadata. In some cases, the lack of human resources has presented a challenge when exchanging data.
- Different Format—Geospatial data can be provided in a variety of formats. Although some open standards have emerged, many of these formats are proprietary. Fortunately, proprietary systems and software specific file formats present fewer challenges to data exchange today than they did a decade or two ago. Software vendors will, however, periodically upgrade their underlying data formats or offer new formats to take advantage of emerging technologies. This can create a challenge for other vendors who need to update their software to maintain the ability to read or write to these formats. Extract, Transform, and Load software has emerged over the years to help alleviate the incompatibilities between various formats.
- Cumbersome Media—File sizes, particularly of raster imagery, can be so large that they prevent the efficient exchange of data. External hard drives or DVD stacks are at times necessary for transferring such large data sets. To overcome this, some counties post DVD binders in public libraries. Other counties are taking advantage of WMS, which render data on large servers and send out only what has been requested in a much smaller format.

CHAPTER FIVE

CASE EXAMPLES

Following are specific examples reported by airports and public agencies interviewed that exemplify effective GIS data sharing and resource collaboration. Each example focuses on a specific activity or approach that has been successful for the airports and agencies involved, listed here and detailed below:

- Standards enforced by regulation, along with consistent leadership and committed management (and a bit of perseverance and patience) can drive an industry to share data at a national level.
- A strong precedent for regional GIS data collaboration combined with a philosophy of open data sharing can result in airports and public agencies having ready access to the information they need from each another.
- A philosophy of open data and software can provide airports and other GIS practitioners with significant value at a reduced cost, increasing the ROI of their GIS programs.
- Airports can obtain help from local agencies in developing GIS data to meet FAA requirements and deploy useful applications that leverage these data.
- Common GIS data and application needs can help bring together intra-agency departments to save the overall organization money while leveraging useful data and applications.
- A long-term commitment leads to long-term benefits and collaboration.
- An institutional commitment is needed to establish the standards, procedures, and policies to support broad data sharing.
- Frequent collaborative meetings and coordination among agencies promote the development and deployment of quality data.
- Advanced planning and coordination can allow regional collections of aerial imagery to meet specialized airport and FAA requirements.

For each case example, the airports as well as the public agencies that have collaborated with one another are indicated. These examples are intended to provide ideas that will help others emulate their effective practices.

FAA AIRPORTS GIS—DATA SHARING ON A NATIONAL SCALE

Airports: All NPIAS airports in the United States

Agencies: FAA

Key Finding: Standards enforced by regulation, along with consistent leadership and committed management (and a bit of perseverance and patience), can drive an industry to share data at a national level.

The FAA established the Airports GIS program based on a philosophy of collecting data once and using it many times. At the time, geographic information relevant to airports was being collected by many organizations (often redundantly) and used for a single, limited purpose. Not only was this costing additional money, but discrepancies between various data sets raised questions about quality and integrity. Figure 17 provides a conceptual overview of the FAA Airports GIS.

The Airports GIS program, which one respondent described as one of the largest enterprise GIS initiatives in the world, is working to address these objectives by developing a single, authoritative source for high-quality GIS data depicting airports. The goal is to eventually include data for many, if

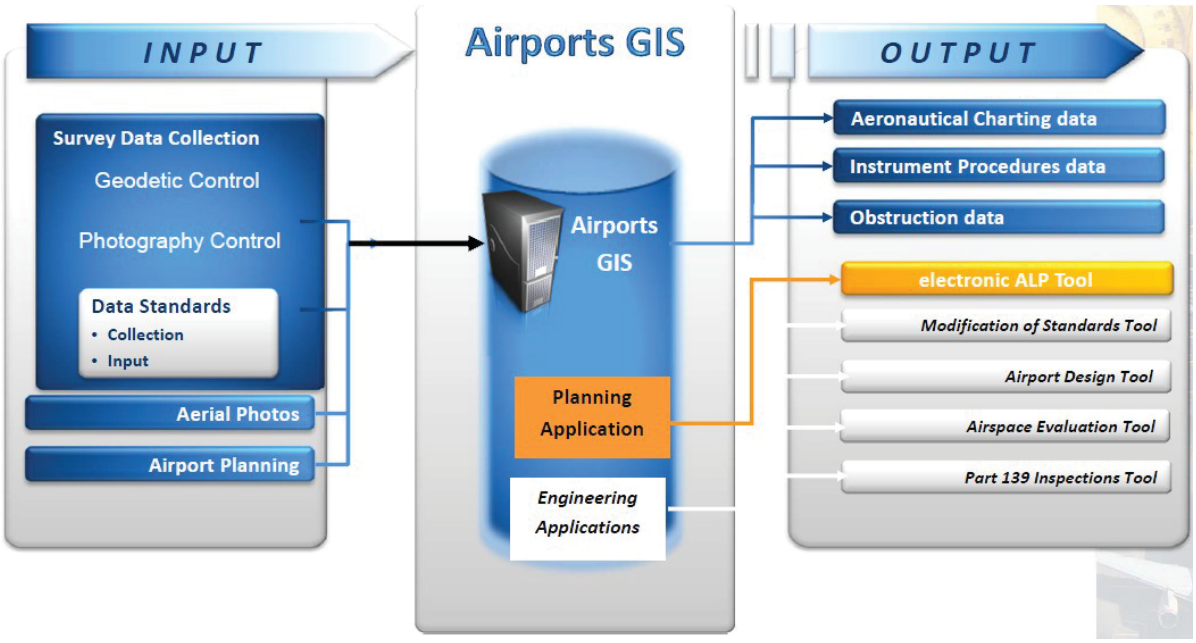

FIGURE 17 Conceptual overview of the FAA Airports GIS. *Source*: McNerney (2012, p. 5).

not all, of the 3,330 airports in the National Plan of Integrated Airport Systems (NPIAS) in a phased approach that is described in the FAA's Airports GIS Transition Policy (DeLeon and O'Donnell 2012).

The program started by documenting standards for establishing geodetic control, collecting remotely sensed data including aerial photography, and submitting GIS data in a common structure and format. Since 2009, airports have been required to provide specific data that FAA considers safety critical in this format. A growing number of airports, starting with the largest, are now being required to submit other planning and as-built data to FAA in this format. The result is a comprehensive base map of GIS data that can be used for a variety of purposes by FAA and other agencies.

Hopefully, data for the program will eventually come not only from airports but from other sources as well. To make this happen, the Airport Engineering Division (AAS-100), which is leading the Airports GIS Program, is reaching out to other stakeholders within FAA as well as to relevant external agencies on topics such as licensing elevation data from the U.S. Geological Survey (USGS) and potentially obtaining information on towers and antennae from the Federal Communications Commission. To help foster collaboration with other agencies, a member of the Airports GIS team participates in monthly teleconference calls with the FGDC.

In addition to receiving data relevant to FAA and airports from other agencies, the FAA has considered providing data to other agencies as well. For example, the National Digital Orthoimagery Program has met with the FAA to see if it can obtain imagery collected by airports. Also, the FAA provides airport data to the Bureau of Transportation Statistics within the U.S.DOT.

This vast amount of data is not only being consolidated into a central repository, but the FAA Airports GIS website (https://airports-gis.faa.gov/?) allows data to be downloaded in CAD and GIS formats. FAA has also begun to offer imagery through cloud-based web image services. Applications starting with an electronic Airport Layout Plan (eALP) viewer are also being developed and made available by means of the Internet. All of these resources are made available to FAA, airport, and consultant users, who have requested and been approved for access.

Although it will take a number of years, FAA has made significant progress, and the benefits of the program are beginning to be seen as an increasing number of users are turning to Airports GIS as the primary source for quality airport information. Some of the airports interviewed expressed that FAA's

standards will continue to elevate the robustness and compatibility of airport data and that the program will encourage data sharing within the aviation industry. If this trend continues, the FAA Airports GIS may likely become one of the largest and most universally beneficial hubs for GIS data sharing and collaboration of its kind.

DENVER—THE BENEFITS OF BROAD REGIONAL COLLABORATION

Airports:	Denver International Airport (DIA), Centennial Airport (APA)
Agencies:	DRCOG, Denver GIS, North Central All-Hazards Region (NCR), City of Centennial
Key Finding:	A strong precedent for regional GIS data collaboration combined with a philosophy of open data sharing can result in airports and public agencies having ready access to the information they need from each another.

The Denver region supports some of the broadest and most active regional collaboration identified by this review. The Denver Regional Council of Governments (DRCOG) facilitates a data consortium, which is an open group of cities, counties, and organizations (including Denver International Airport) that convenes two to three times a year to discuss data sharing and other issues. DRCOG hosts an annual "data summit" focusing on data sharing and plays an active role in the Colorado Code for Communities' annual hackathon—a weekend event that invites "developers, designers, data geeks, leaders, and idea makers to help Denver regional government and civic organizations adopt open web technologies" putting readily available data to use in new and innovative ways. DRCOG also sends out a quarterly newsletter informing regional GIS users about data that is available through its central clearinghouse. One of the more broadly used data collection activities DRCOG coordinates is the Denver Regional Aerial Photography Project (DRAPP), which collects high resolution imagery and distributes it to agencies and organizations in the region—including the airport—that have paid a subscription fee to help DRCOG recover the costs of this valuable resource.

The city of Denver also has an active GIS program (Denver GIS) that hosts a monthly users group meeting covering a broad variety of topics. The city formerly required a data license agreement of users, but this was recently repealed in favor of open data exchange making users "free to copy, distribute, transmit and adapt the data." Ten Denver area counties also participate in the North Central All-Hazards Region (NCR), which was established in response to the governor's Executive Order D013 03 "directing state departments responsible for public safety to adopt a single regional planning map for emergency management and response." The governor's Office of Information Technology also supports a variety of safety and emergency management initiatives and has prompted the development of statewide standards for addressing and roadway mapping.

Denver International Airport (DIA), which is a department of the city and county of Denver, has leveraged and benefited from the data made available by DRCOG and Denver GIS, but the primary source of high-quality data is an FAA Airports GIS eALP Pilot Program data collection project. The airport's GIS program is largely autonomous from the city in terms of software licenses and data collection initiatives, although a positive working relationship is maintained and data are openly exchanged as necessary. Specifically, the airport has used imagery and hopes to receive LiDAR data in the future through continued participation in regional collaborative data collection initiatives coordinated by DRCOG. In the past, the imagery received has not been at the 3-inch resolution the airport requires to support its internal and FAA eALP mapping requirements.

DIA anticipates continued data collection efforts that will include aerial photogrammetry to be conducted every two to three years or, depending on project developments, to meet FAA eALP requirements. The airport also collects sewer utility data from Denver GIS but, like most agencies, has difficulty getting utility data from private utility companies. Conversely, the airport has provided airport boundary, noise contour, buildings, addressing, road segment, and parking lot data to the city and is always willing to share these data upon request. The airport has cooperated with the city's GIS program on an addressing initiative. Airport staff members have participated in DRCOG and Denver GIS meetings to discuss GIS needs in general, but also to make contacts that may help in facilitating future data

exchange. The airport estimates that 50% of its data specifications are influenced by FAA regulations, another 10% by city requirements, and the remaining 40% by internal airport customer needs. Data quality is always a concern for the airport, especially when it comes to information acquired from a third party. In certain cases, although the data are generally good, they have been scrubbed to ensure that the data are usable only for a given purpose. The airport spends most of its efforts maintaining the eALP, utility, and property management data.

Another example of collaboration in the Denver area, albeit at a smaller scale, is seen in Centennial, a relatively new but rapidly growing city. It neighbors, but does not encompass, Centennial Airport (APA), one of the busiest corporate and general aviation airports in the county.

Because of the volume of development in the area, the city regularly needs airport boundary, noise contour, and land use data from the airport. The city would also like to get building and flight track data from the airport; however, this has been a little more problematic because of financial constraints and uncertainty as to from whom to request the information. Most of the data the city obtains about the airport comes through the regional joint area plan. The city would also like to get similar data from nearby Buckley Air Force Base, but this has been even more difficult to obtain. The city and the airport both benefitted from high-resolution imagery captured by the DRCOG with federal agency funds in support of a security initiative related to the 2008 Democratic National Convention. With one GIS staff member but many users of data, the city must actively seek out interagency partnerships in regards to updated data. This approach enables city staff to keep up with the increasing GIS demands. Further data coordination appears to be evolving, given recent state- and city-wide Emergency 911 and other homeland security-related initiatives.

MINNEAPOLIS—A CONTAGIOUS OPEN GIS PHILOSOPHY

Airports:	Minneapolis–St. Paul (MSP)
Agencies:	MetroGIS, Minnesota GIS/LIS Consortium, Minnesota State Geospatial Information Office
Key Finding:	A philosophy of open data and software sharing can provide airports and other GIS practitioners with significant value at a reduced cost, increasing the ROI of their GIS programs.

The Minneapolis–St. Paul area has enjoyed a long history of open GIS sharing, initiated by a few key individuals who established a regular GIS meeting. They infused a culture of active GIS collaboration into the region and raised the expectation that local agencies would share their GIS data and resources. Local political leaders, who valued the benefits GIS could provide, also supported this collaborative environment. Over the years, this collaborative spirit grew to encompass many agencies and initiatives; and GIS professionals who work for these agencies now enjoy close working relationships. There are also a lot of informal user groups that focus on specific GIS needs of their members.

One initiative that has served the GIS needs of many within the region is MetroGIS, an "award-winning, regional geographic information systems initiative" that serves seven counties. MetroGIS offers a repository and dissemination point for many GIS layers developed by its members, including an integrated parcel dataset covering all seven member counties.

The Minneapolis–St. Paul International Airport (MSP) has benefitted by receiving land use, road centerline, and elevation contour data from MetroGIS. MSP also uses aerial imagery and LiDAR made available by MetroGIS as an important reference layer for its sound mitigation program. Conversely, the airport often shares noise contour data with public agencies in surrounding jurisdictions. Aerial photography collected by municipal and state agencies is openly available from WMS published by MetroGIS. Most data sharing is conducted using verbal agreements with no exchange of money.

This open philosophy extends beyond data sharing to include software resources as well as human resources during emergency events. For example, the Metropolitan Airports Commission

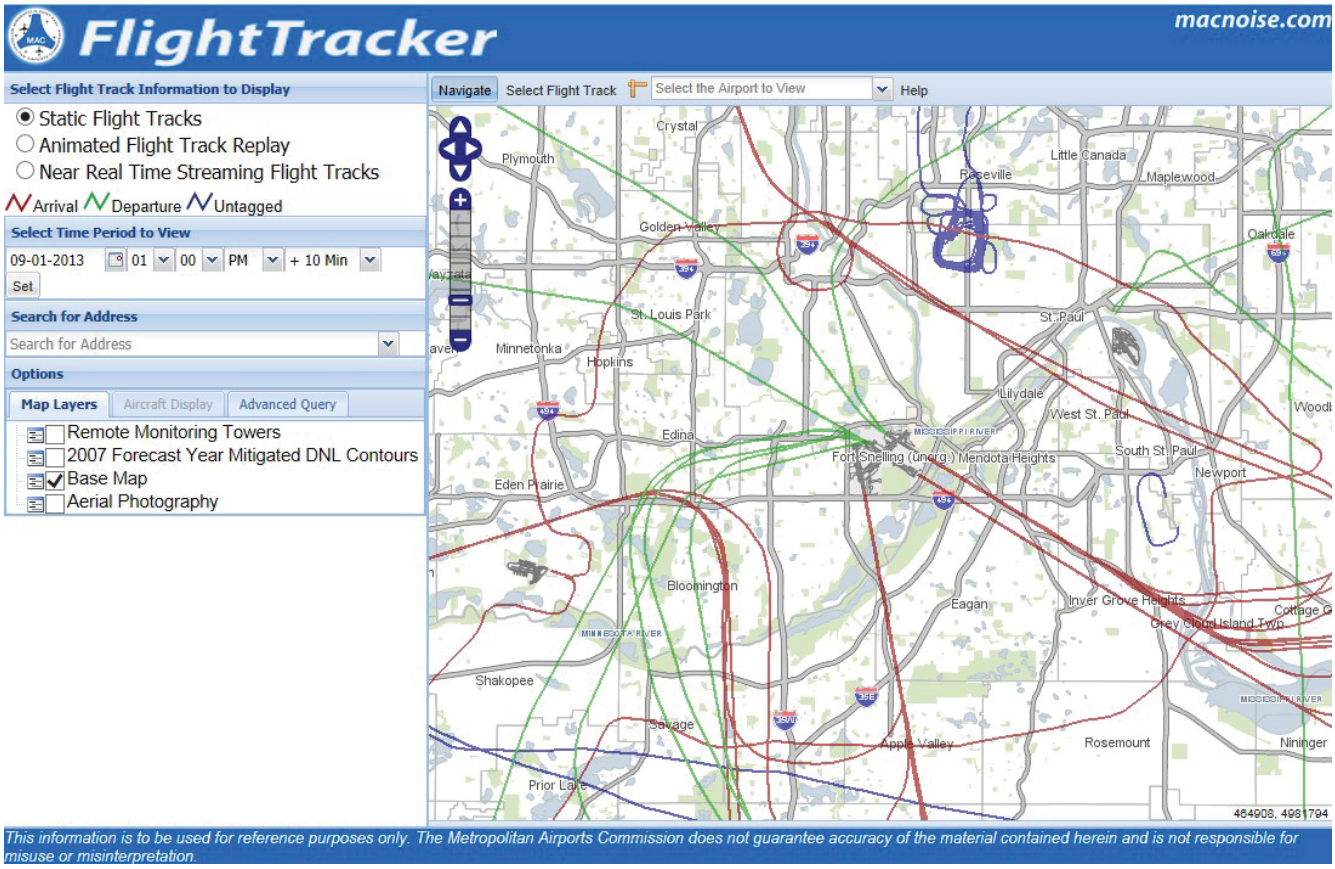

FIGURE 18 Metropolitan Airports Commission's FlightTracker (MAC 2013). *Source*: Metropolitan Airports Commission.

has used Open Source GIS software to deploy an aircraft noise monitoring application accessible to the public (Figure 18). The Application Programming Interfaces (APIs) of these tools make it easy for the airport to add capabilities in increase the value of the data. The airport moved to these open tools because of the familiarity new IT staff had with Linux, and in support of the open source philosophy. As David Bitner, the current chairman of MetroGIS and former MSP airport GIS coordinator, says "When collaboration works, it catches on."

SAVANNAH—A PUBLIC AGENCY HELPING AN AIRPORT MEET FAA REQUIREMENTS

Airports: Savannah/Hilton Head International Airport (SAV)

Agencies: SAGIS

Key Finding: Airports can obtain help from local agencies in developing GIS data to meet FAA requirements and deploy useful applications that leverage these data.

Savannah/Hilton Head International Airport (SAV) and the Savannah Area GIS (SAGIS) have a unique collaborative partnership that provides significant value to the airport. SAGIS is a not-for-profit cooperative of public, private, educational, and other agencies that collects and provides data and services to members on a subscription basis. It is funded primarily by the city of Savannah, Chatham County, and the Metro Planning Commission. SAGIS is focused on providing access to geospatial data in a standardized format and therefore collects and stores a variety of regional GIS data for its members, which, in addition to the city, county, and planning commission, include the County Board of Assessors and public utilities. Although a great deal of the data SAGIS offers comes from members and other sources, some data are created internally. These data are deployed by WMS and a custom portal application called MapIt. There is a free

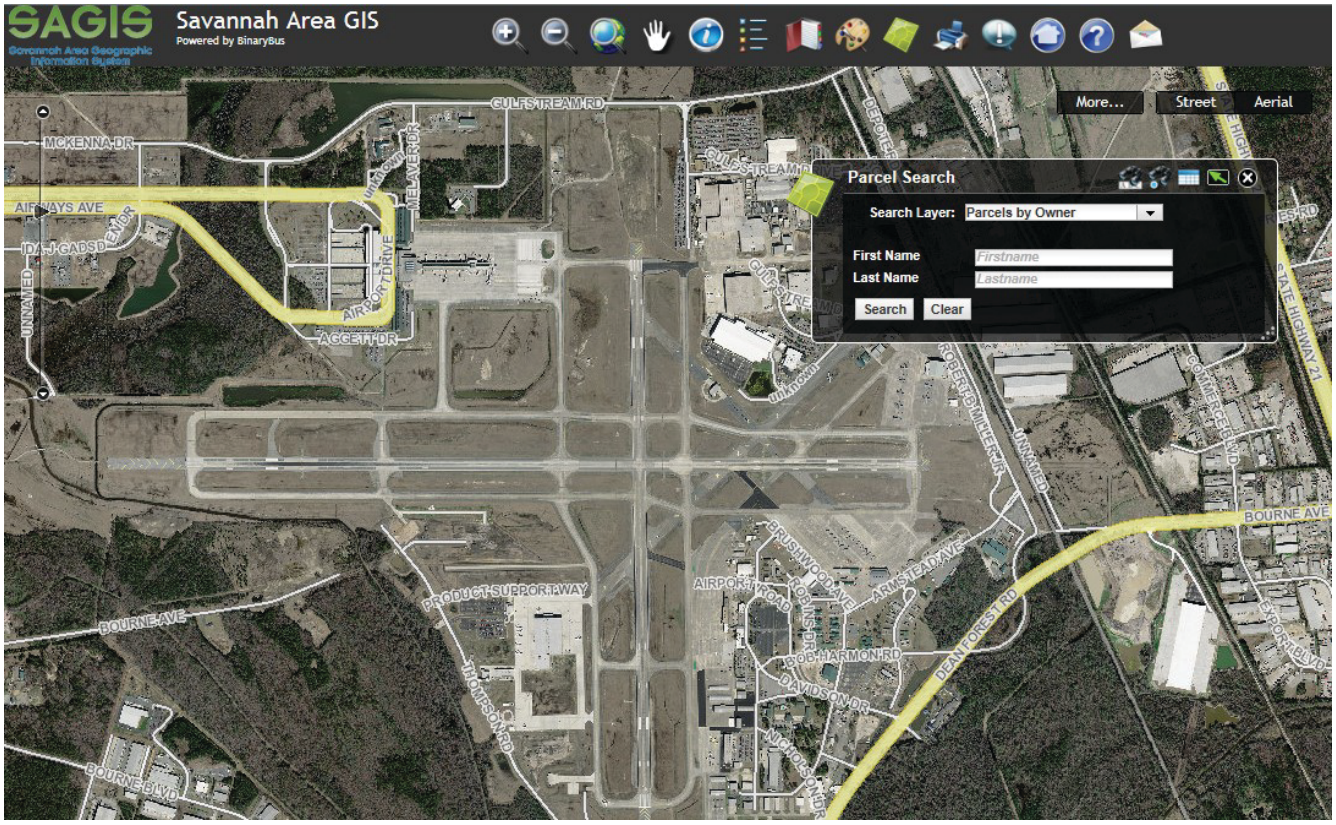

FIGURE 19 MapIt web application showing airport data (SAGIS 2013). *Source*: Savannah Area GIS.

version of MapIt (Figure 19); however, additional data and functionality are provided by MapIt Pro, which is a subscription-based service.

SAV management supported the formation of SAGIS and remains a close working partner. Like many airports, SAV has relied on CAD-based drawings and maps but clearly sees the benefit of GIS. It also wants to begin migrating geographic information to be in compliance with the FAA's Airports GIS requirements. The airport does not have the technical resources to address these needs internally, but its partnership with SAGIS offers the needed resources.

In addition to making its hundreds of standardized data layers available to the airport, SAGIS works with airport engineers to migrate their legacy CAD data and lease exhibits into a GIS format that complies with the AC150/5300-18B. SAGIS is also working with the airport on economic development data and metrics. Once this integration is complete, SAGIS plans to host these data on behalf of the airport within its ArcSDE geodatabase and deploy it by means of WMS and a web-based map portal application.

FORT LAUDERDALE—A COUNTY PROMOTING GIS AS A "UNIFYING TECHNOLOGY"

Airports:	Fort Lauderdale–Hollywood International Airport (FLL)
Agencies:	Broward County
Key Finding:	Common GIS data and application needs can bring together intra-agency departments to save the overall organization money while leveraging useful data and applications.

As an organizational unit of Broward County, Fort Lauderdale–Hollywood International Airport (FLL) has benefitted from resources made available by the county to help establish and expand its

own GIS program. The county provides GIS data and infrastructure in the form of application hosting, network storage, and licenses for ESRI and Oracle software. With the county's support, the airport has been able to advance its GIS program faster than it otherwise would.

The county's GIS activities and staff are located within the Environmental Protection and Growth Management Department, but their focus is enterprise-wide. They host regular meetings between GIS managers from other agencies, such as the airport, to identify common needs and promote data sharing; as well as GIS user group meetings that include local cities and neighboring counties. Measures to ensure that investments in GIS data and applications can meet a broad set of user needs and not just those of a single department are also discussed.

The airport and county regularly rely on one another for data. The airport relies on the county for information essential for a number of its internal business processes, such as hospital or fire station locations needed to support emergency response; parcel and zoning data from the county assessor's office to support airport property management, noise mitigation, and compatible land use planning; and road centerlines and bus routes to support customer service. Conversely, county emergency response personnel use airport data on which gates are "crashable" (i.e., can be deliberately driven through by emergency vehicles) in the event of an emergency. The county hosts aerial data collection data that the airport collects but ensures that the airport can also access the standard 1-foot resolution imagery and digital elevation models updated annually.

Although many airports have found utility data challenging to collect, the airport and the county have worked together to ensure that utility data are collected and managed effectively. The county is responsible for many of the utilities on the airport, although airfield access restrictions require airport personnel to collect some of the utilities data required. These data are exchanged between the airport and the utility department within the county. Utility data from gas and power companies, however, remain difficult to obtain.

Although it is relatively easy to share data between county departments, differing standards, specifications, and formats have presented challenges when data from different sources are integrated. The airport reports having had to adapt the data or adjust its requirements, which in some cases may be so specific that it is hard to use data supplied by others. In the long term, county-wide standards and specifications are needed to alleviate these incompatibilities. Another challenge has been the uniqueness of airport data and the relative complexity of interpreting them. To overcome this, airport staff have sometimes conducted analyses or prepared syntheses to meet non-airport users' needs. For instance, other agencies within the county have requested noise contour data, so airport staff has provided map exhibits that display noise contours.

The airport has access to the same county network as other county departments. This makes it relatively easy for the airport to store its GIS data safely and securely on county GIS servers, leveraging the counties' Esri ArcSDE and ArcGIS server licenses. By hosting its data on county servers, the airport gains access to county GIS applications and related data from other departments. Application development is coordinated, so the resulting tools—for example, mobile GIS applications that support data collection and displays—can be used by other departments that share a similar need. When the airport utilizes federal funds for developing GIS resources, however, care must be taken to avoid diversion of FAA grant monies to non-airport beneficiaries. This is because FAA airport grants come largely from the Airport Improvement Program, which is a federal budget line item authorized by congress for airport purposes and is not to be used for non-aviation purposes.

As Florida has one of the strongest open-records laws in the country, Broward County has established an open policy for data availability. With some exceptions, data can be freely downloaded without formal agreement. Owing to security concerns, however, the county protects the airport data by default unless instructed otherwise. The airport focuses its data protection measures on SSI. Although forward-thinking leadership and visionaries have ensured that data are generally available, promoting a philosophy that "data belongs to everybody" and is a "unifying technology," the information is not always easy to find or available in a common standard. Providing data openly to everyone not only is in compliance with the law, but supports the growth of GIS throughout the region.

LAS VEGAS—EARLY ADOPTERS REAPING THE BENEFITS OF COLLABORATION

Airports: Las Vegas McCarran International Airport (LAS), Henderson Executive Airport (HND), North Las Vegas Airport (VGT), and Jean Sport Aviation Center (OL7)

Agencies: Clark County, NV, regional GISMO

Key Finding: Long-term commitment leads to long-term benefits and collaboration.

Clark County, Nevada, and Las Vegas' McCarran International Airport (LAS), one of five airports within the county's Aviation Department, were early adopters of GIS (in the mid-1980s and 1990s, respectively). Today, the county's GIS Management Office (GISMO), the airport, and other public agencies, as well as private organizations, benefit from a number of centrally hosted GIS data and applications.

Originally, Clark County established a GIS group of 13 agencies to develop consistent parcel data as well as a solid GIS base map. These resources were necessary to support the rapid land development in the region. Many organizations were supportive of the concept, but the county was the most logical one to host it. This group evolved into what is now referred to as GISMO, or the GIS Management Office. GISMO was originally a part of the county's development office, but is now within the information technology department.

Currently, 20 people work in five county departments: GISMO, aviation, comprehensive planning, public works, and building. GISMO staff maintain road centerline and parcel data, while other departments and member agencies maintain other data layers that GISMO hosts. Although a lot of data are available, the pace of land development has hindered staff in establishing regional data specifications and standards. They do, however, have well-attended monthly GIS committee meetings, during which data requirements, specifications, and update needs are discussed.

The data GISMO hosts is provided to members by means of WMS and web applications. One of these applications is the OpenWeb Info Mapper, which is available to the public, as well as more than 200 businesses who find it and the data it provides essential to their business. Departments of the county (including the aviation department) can obtain the data for free, but other users, including public agencies that are not a part of the county and private organizations, pay an annual subscription fee.

LAS is among the agencies that use GISMO's OpenWeb application for a variety of purposes. In addition, the airport's GIS staff has developed applications for planning, utilities, and property management that leverage data published by GISMO via WMS. The planning application in particular incorporates many layers from GISMO's WMS. The airport has relied on such web services for more than five years, which has reduced the data maintenance burden of obtaining copies and then adjusting (e.g., adding and removing attributes) the data to fit their database schema. Parcels, road centerlines, and zoning are some of the essential layers that the airport receives from GISMO. Land use, soil, elevation contours, and Digital Elevation Model (DEM) data are also deployed. Most of the time, the airport is able to use aerial imagery acquired by the Southern Nevada Water Authority, which is a member of GISMO. Only on a few occasions over the last several years has the airport had to acquire its own imagery because of a need for higher resolution.

The remaining data the airport needs it develops internally. This includes aircraft noise impact data, which is provided to and hosted by GISMO for public access. The airport and others within the county would like to have access to better building footprint data, although the airport also requires three-dimensional representations of buildings to help protect airspace from encroaching development. This data set is, however, costly to develop and has not yet been funded. The example shown in Figure 20 relies on Google data, which is not as comprehensive or accurate as the airport desires.

Although both the county and the airport believe their GIS data sharing and collaboration are going well, continued growth of WMS and increased network performance are anticipated in the future. Broader collaboration on safety, security, and emergency management issues is also desired because of the importance of such information to the airport and to its surrounding community.

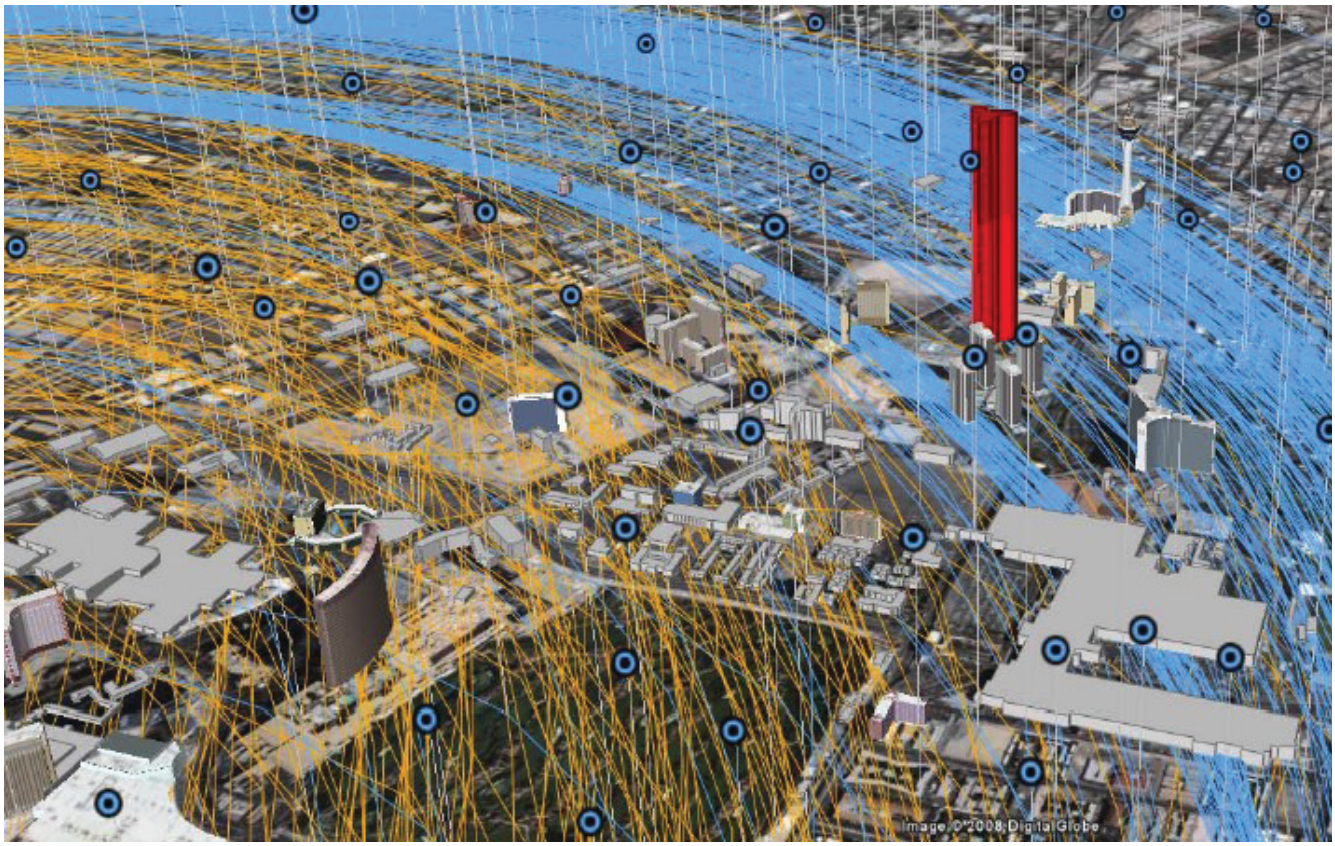

FIGURE 20 Three-dimensional buildings (Google) with flight tracks and proposed structure. *Source*: Bourgon.

ABU DHABI—FORMALIZED COLLABORATION THROUGH AN SDI

Airports:	Abu Dhabi International Airport (AUH), Al Ain International Airport (AAN), Al Bateen Executive Airport (AZI), Delma Island Airport (ZDY), and Sir Bani Yas Island Airport (XSB)
Agencies:	Abu Dhabi Systems and Information Centre (ADSIC)
Key Finding:	An institutionalized commitment is needed to establish the standards, procedures, and policies to support broad data sharing.

In 1992, Colonel (now Major General) Dr. Khalifa Al-Romaithi completed a master's degree thesis describing a national GIS. In 2001, a team formed by H. E. Majid Al Mansouri promoted the development of a common emirate-wide environmental database. From these efforts, a committee of six agencies commissioned a study in 2004 that led to the formation of Abu Dhabi Systems and Information Centre (AD-SIC) and in 2007 the establishment of a SDI for Abu Dhabi. This is now one of many e-government initiatives in Abu Dhabi and is an enabling technology for the emirate's 2030 goals.

The AD-SDI now offers 580 layers that adhere to international standards, and were influenced by local committees of stakeholders and subject matter experts, to agencies and organizations throughout the emirate. The data from more than 50 member agencies and organizations is stored in a centralized data center hosted by Etisalat, the state-run telecommunications provider; and managed by the Abu Dhabi Systems and Information Centre (ADSIC). Members of the AD-SDI are required to sign a service level agreement to ensure data are not used for inappropriate purposes. These data are then published by public, secure, and restricted WMS. A web portal (Figure 21) is available for viewing the data, but many member agencies have developed their own applications that integrate data from the AD-SDI.

The Abu Dhabi Airports Company (ADAC), which operates Abu Dhabi International Airport (AUH), as well as Al Ain International Airport (AAN), Al Bateen Executive Airport (AZI), Delma

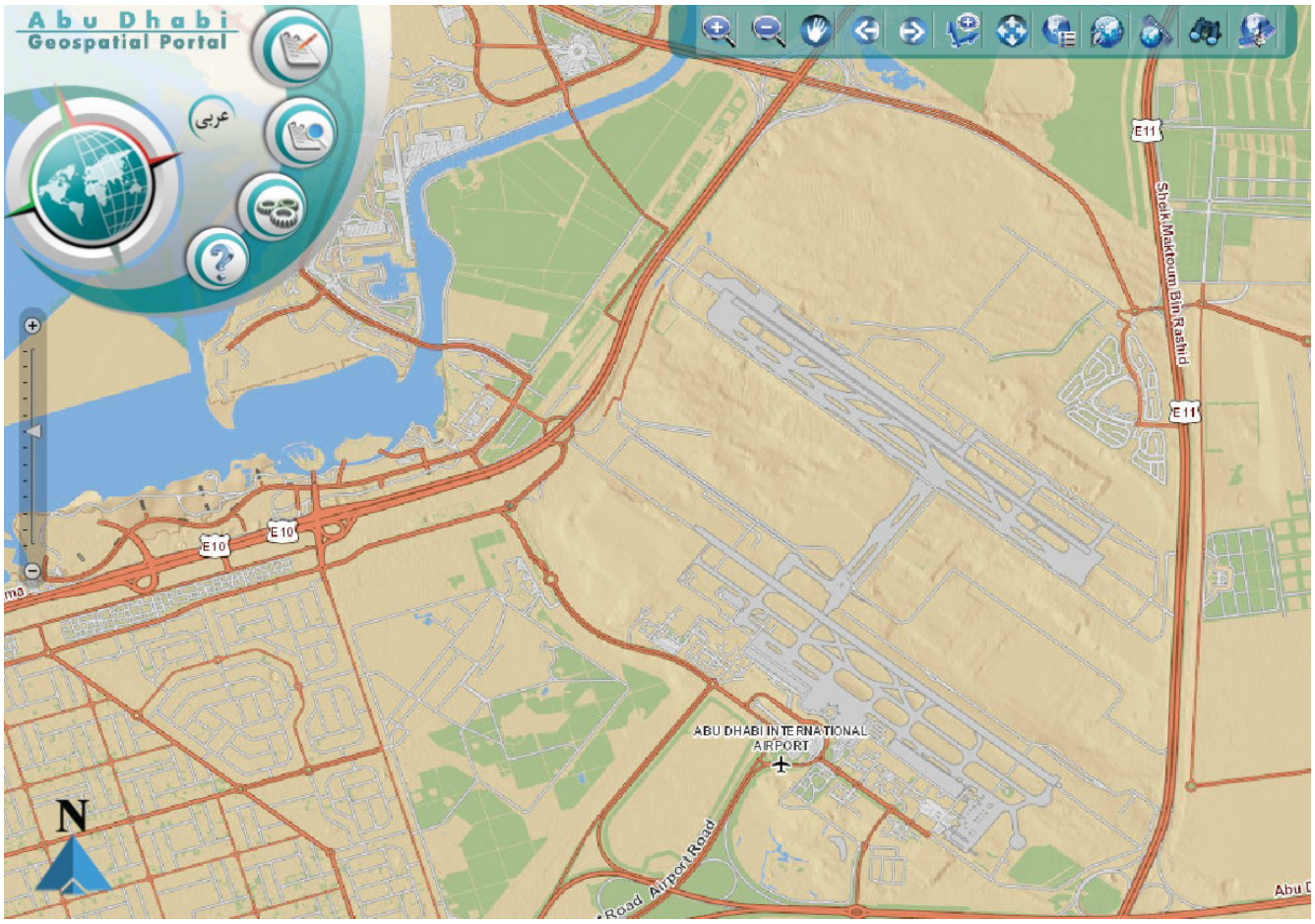

FIGURE 21 Abu Dhabi SDI geospatial portal. *Source*: Abu Dhabi Systems and Information Centre.

Island Airport (ZDY), and Sir Bani Yas Island Airport (XSB), has benefitted by the emirate-wide GIS momentum that ADSIC has built. A few years ago, as ADAC's Enterprise GIS program was getting started (Khater n.d.), the airport signed a service level agreement in order to become a member of the AD-SDI. The airport has since identified more than 30 layers available from ADSIC that are relevant to airport GIS users. These range from reference layers that form a common and consistent base map to "foundational" layers that the airport can link to other GIS and non-GIS databases to address specific airport business requirements. The ADSIC has also provided input to ADAC's GIS Strategic Plan. The airport can also obtain licenses to GIS software by means of an emirate-wide enterprise license agreement signed last year with Esri. Figure 22 shows a map developed to support internal airport operating requirements.

SAN DIEGO—WELL-ESTABLISHED REGIONAL AGENCIES AVAILABLE TO LEVERAGE

Airports:	San Diego International Airport (SAN)
Agencies:	San Diego Geographic Information Source (SANGIS)
Key Finding:	Frequent collaborative meetings and coordination among agencies promote the development and deployment of quality data.

For many years, San Diego International Airport (SAN) has leveraged GIS and CAD data to address a variety of internal needs such as infrastructure planning, development, and maintenance; and given today's challenges, increasingly depends on such information. Geospatial data representing the airport's facilities and assets are available to authorized users by means of an interactive map viewer. This advanced viewer presents the data to users in a 3D format and provides users with

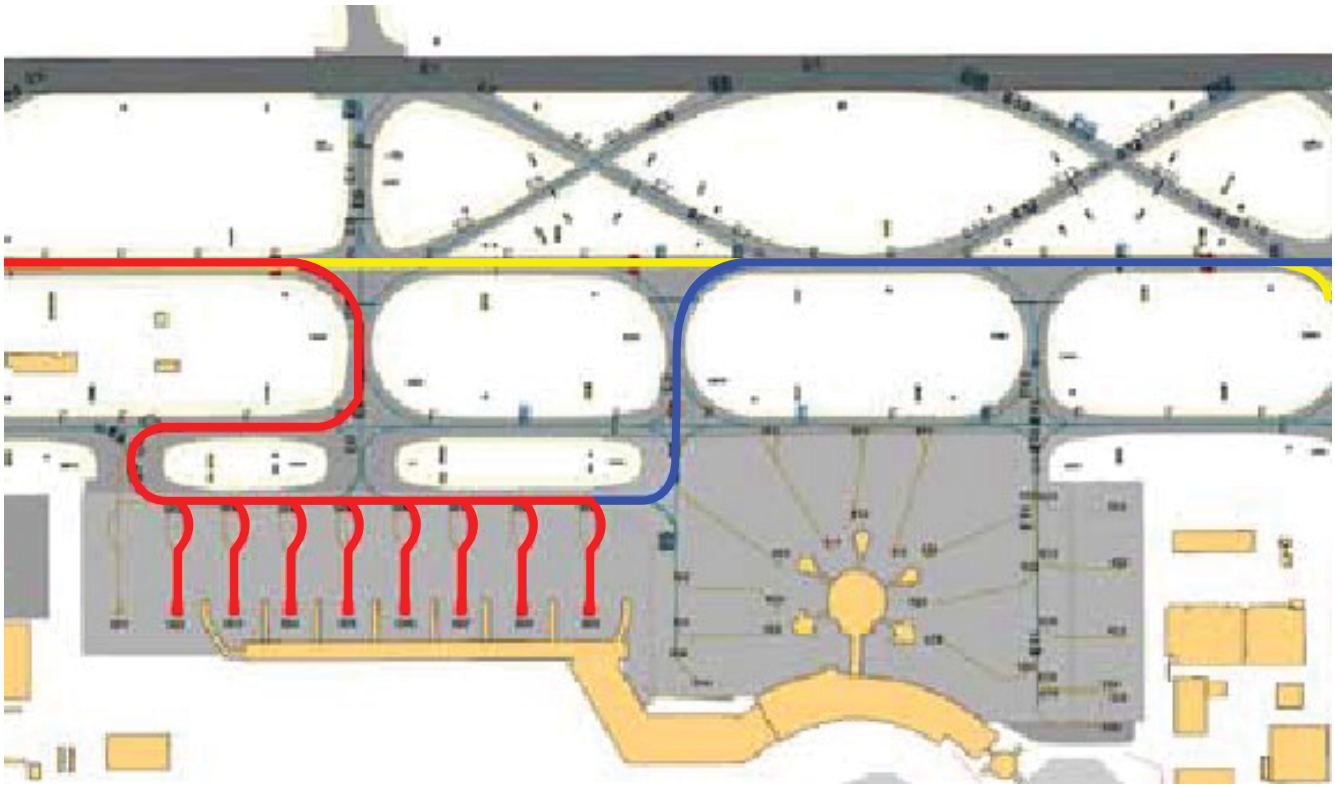

FIGURE 22 GIS implementation at Abu Dhabi International Airport (Khater). *Source*: Abu Dhabi Airports Company.

a variety of customized reports via a link to the Business Objects enterprise reporting system. The underlying spatial data are also complemented by data from the airport's EnterpriseOne (E1) business management system. Externally, the airport has been using GIS to model the noise impact on surrounding communities and to map the locations of noise complaints. The airport has provided a GIS-based application to help local agencies, project applicants, and other stakeholders assess how Airport Land Use Compatibility Plans affect properties near the airport. The airport has also made a GIS-based wayfinding system available to help travelers navigate its busy terminals.

Data sharing, as well as coordination with regional agencies, is especially important to an airport that must grapple with urban density and growth in a narrow geographic area that is also surrounded by tall buildings and waterways. SAN works with its regional organizations to coordinate data needs and data sharing at times when desired data can conform to airport requirements.

Regionally, San Diego is fortunate to have multiple organizations that coordinate forums and data sharing venues. These include the San Diego Geographic Information Source (SANGIS), San Diego Association of Governments (SANDAG), and the San Diego Regional GIS Council. These organizations host numerous monthly or quarterly meetings to discuss high-level data requirements, areas where data quality can be improved, collaborative data collection activities, and sources of new data. From these meetings, technical working groups form to discuss more specific topics.

SANGIS is a joint powers agency established by the city and county of San Diego to maintain the land base map, which is comprised of 17–18 key layers. Core layers that SANGIS maintains directly include parcels, road centerlines, and street addresses. Other layers are provided by various departments within the city or county. These include a basic airfield layout, noise contours, runways, and height restrictions for the airports within the county including SAN. This airport data are made available only to the county and the cities within the county. SANGIS checks all of the data they develop or receive to ensure that it has a minimum level of metadata. Under a memorandum of agreement, these data are then copied onto servers owned and maintained by SANDAG and made available through WMS and web applications.

SANDAG is comprised of 18 cities and counties that serve as a forum for regional decision-making. SANDAG facilitates consensus building and strategic planning, and allocates or obtains resources to support building, engineering, and planning public transportation in an effort to increase the quality of life in the region.

The SANDAG-SANGIS regional GIS data warehouse offers a rich array of resources for the airport and others to leverage, as well as hosting the airport's data—airport approaches, influence areas, zone designation and boundaries, noise contours, height restrictions, and other relevant data—on its website.

SAN's GIS program evolved from San Diego's ports back in 2002 to have more a specialized aviation focus. Since many in the organization came from other municipal departments and regional organizations, past relationships have facilitated data sharing. Data gathered by these external resources is usually of sufficient quality to support the airport's needs.

PORTLAND—COORDINATING AERIAL IMAGERY COLLECTION TO MEET FAA REQUIREMENTS

Airports:	Portland International (PDX), Hillsboro (HIO), and Troutdale (TTD)
Agencies:	Metro
Key Finding:	Advanced planning and coordination can allow regional collections of aerial imagery to meet specialized airport and FAA requirements

The Port of Portland, Oregon, which owns and operates Portland International (PDX), Hillsboro (HIO), and Troutdale (TTD) airports, is collaborating with Metro, an elected regional government entity that serves residents in Clackamas, Multnomah, and Washington counties and the 25 cities in the Portland region, to collect high-resolution imagery that will meet FAA Airports GIS requirements. Since 2003, the Port has received 6-inch color orthophotography from Metro's annual aerial imagery collection. This imagery is used as a visual reference to the Port's GIS and CAD data and supports a variety of airport planning, design, development, operational and maintenance needs. This imagery is also required by many of the public agencies Metro serves.

Over the last year, Port GIS staff have worked with Metro's Data Resource Center, under its regularly meeting Aerial Photo Consortium, to enhance the specifications for the Spring 2014 aerial imagery and LiDAR data collection to better address airport and FAA requirements. One such planned enhancement will increase the resolution of acquired imagery from a 6-inch to 3-inch ground sample distance per pixel, an improvement desired by the airport as well as the city of Portland and other Metro constituents whose end users have become accustomed to on Google, Bing, and other websites. Another planned enhancement, which is unique to airport needs, is the collection of photo control and check points that comply with FAA requirements. Port GIS staff plan to ask consultants experienced with these requirements to educate port surveyors assigned to collect the coordinates and supporting documentation required by FAA Advisory Circulars 150/5300-17 and 18. These coordinates will then be provided to Metro, so that the firm selected for the aerial collection can use them for aero-triangulation and accuracy checks.

Another technical consideration is the airport's need to collect leaf-on imagery to support airspace analysis and obstruction identification. Fortunately, Metro typically collects imagery during leaf-on conditions to support environmental and other needs of its constituents. Approximately every five years, they have collected leaf-off imagery to support other requirements. Although the Port's and FAA's needs for leaf-on imagery will not be an issue, other timing requirements may need to be factored into collection planning. Other technical considerations that must be factored in, but are not anticipated to be issues, include the orientation of the flight lines, side and forward overlap of image frames, the sun's angle at the time of collection, and the degree of cloud cover. Continued collaboration before the flights occur would likely ensure that these technical factors did not present a problem. The LiDAR data that is planned is desired by the airport and other Metro constituents to develop an accurate ground elevation model.

In addition to the technical collaboration described previously, financial support of the aerial collection effort is also being coordinated. Having contributed to Metro's data collection activities in the past, the Port already has a mechanism in place to support this exchange. One challenge the program faces, however, is that not all of Metro's constituents need the enhancements that the Port and other constituents require. The program must, therefore, find a way to distribute the costs and benefits of the enhancements equitably to those who require them while not burdening the rest. In the past, this problem has been overcome by constituents' contributing additional funds. The resulting upgraded product becomes available to others as well. This challenge is also minimized by sharing the unique specifications each constituent has well in advance with the firm that will collect the imagery. This allows the firm to integrate the additional specifications into its normal work flow, sometimes without additional cost.

Beyond imagery and LiDAR, the Port and Metro exchange a variety of other GIS data sets. This ensures that Metro has up-to-date information on the rapidly changing configuration of the airport and that the Port has information on surrounding areas of interest. One data set that is frequently exchanged concerns buildings. To support airspace analysis needs, the Port requires building footprints and heights across multiple jurisdictions. When the Port collects such information, it provides it to Metro, which then integrates it with building data collected by others. Once integrated, this enhanced data set is made available to the Port and the other agencies. The Port also provides runway and taxiway configuration data, which change less frequently but nevertheless are desired by other agencies so that the airport is properly represented on their base maps. The Port also uses parcel and zoning data from Metro and has access to its full library of data through a secure FTP site. Some of Metro's data are also made available to the public by means of an open FTP site. (In the past, these data were exchanged by DVD.) To support emergency management needs, the Port exchanges street centerline, perimeter fence, and entry gate information with Portland fire and police departments.

As the airport moves more toward 3D data to support its internal and FAA requirements, it hopes to share these data with Metro and the city. In the past, concerns about sensitivity constrained such data sharing, but the hope is that this mentality will change and only those data sets that need to be secured will be. This hope of increased data exchange within the region is fostered by a long-standing awareness among regional agencies of the value GIS offers.

CHAPTER SIX

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

CONCLUSIONS

This synthesis was intended to provide a comprehensive understanding of current and effective practice in sharing geographic information and related resources between airports and public agencies. It describes the means by which airports and public agencies exchange information, and identifies challenges many have faced while doing so as well as measures that they have found successful in overcoming these challenges. The goal for airports and public agencies is to identify common needs for data and identify effective ways to address those needs, thus promoting greater data exchange and increasing the amount of useful data airports and agencies have while lowering the costs of obtaining them. The audience for this report is airport planners, designers, engineers, and geographic information systems (GIS) specialists and their counterparts in public agencies.

The report's findings are based on a search of published literature, as well as interviews and survey responses from 44 of 47 organizations that were contacted. Participating organizations included commercial airports and the FAA as well as municipal, county, and state agencies. Organizations were selected that were known to have active GIS programs, or were found through the literature search to exemplify effective data exchange practices.

These respondents indicated that the information data airports and public agencies share with one another is essential. This report identifies the specific data sets each type of organization requires and therefore commonly exchanges with one another, that is:

- Public agencies desire development plans, noise contours, obstruction identification surfaces, flight tracks, building, road centerline, and addressing data from airports;
- Airports desire Navaid equipment, obstruction, and utility data from the FAA;
- Airports desire development plans, land use, parcel, road centerline and segment, building, and addressing information from public agencies.

Interviewees from both airports and public agencies who are actively involved in data exchange generally agree that the benefits of sharing data and other GIS resources exceed the costs. Furthermore, the benefits become more pronounced as the trend toward open data exchange, in some cases legally mandated, continues; and the costs of data sharing shrink as web-based technologies advance and become more prevalent. The following are the key benefits and costs of GIS data sharing and collaboration between airports and public agencies that were identified in this study.

Benefits and Costs of Data Sharing and Collaboration

Benefits

- Lower cost of data collection and maintenance
- Reduced redundancy in creating and maintaining data sets
- More current and complete data received from the source
- Assurance that the best copy of the data is available when needed
- More efficient government and increased stewardship.

Costs

- Staff time spent preparing and fulfilling requests for data
- Costs of hardware and software required to establish a data repository
- Time spent and travel costs of attending collaborative forums and meetings
- Lack of control or influence over shared data resources or derivative products
- Legal liability, both real and perceived.

This synthesis indicates that there is an obvious movement toward open data exchange and leveraging technology through web-based services that make it easier to find, identify, obtain, and use information available from other organizations. Recipients can often find the data they desire through a simple web search, then directly incorporate or integrate them into their native environment for analysis and decision-making. They can also deploy data to other users by publishing data to public locations or incorporating the data into applications they develop. No longer is there a need to periodically request updates; the user is now able to pull data on demand. Conversely, data providers no longer need to spend time and money extracting and copying data to fulfill requests or worry about the liability of inappropriate derivative products. While a traditional personal exchange of data on physical media is still prevalent, the clear trend is toward a more anonymous web-based identification and exchange of data by means of a strong spatial data infrastructure. The following are ways airports and agencies report effectively sharing data:

Effective Reporting of Sharing Data and Collaboration

- Online data exchange
  - Web catalog services (WCS)
  - Web feature services (WFS)
  - Web map services (WMS)
  - Web image services
  - Web applications
- Collaborative forums
- Spatial data infrastructure.

Participants in the survey expressed that to take advantage of the most effective ways of sharing data, as well as other resources (e.g., human, software, and hardware), airports and public agencies need web-based or desktop applications that can access and integrate web services. Although many data providers offer such viewers, they are often generic and not specifically designed to meet the recipient's specific needs. Additionally, web-based viewers often allow data to be viewed but not necessarily downloaded, therefore requiring users to contact hosting agencies or data owners to obtain copies. Commercial off-the-shelf software vendors also provide web-based or desktop applications that can make use of such data. Increasingly, they, and public agencies such as the FAA, are meeting the increased demand for business process specific applications and deploying applications designed to meet airport requirements. As this trend continues, airport managers and staff will need to worry less about finding and obtaining data and be able to focus more on analyzing and making decisions based on information from a variety of reliable sources (so long as metadata are available to better qualify the data).

Although the trend toward web-based data and applications is accelerating, airport managers and staff generally support and are comfortable with these new technologies; and those agencies that openly share their data and resources are better positioned to benefit from resources provided by others.

In addition to investigating how airports share data with public agency GIS systems, this report may help airports and public agencies overcome the challenges identified and implement the effective GIS data sharing and collaboration methods others already enjoy.

Despite an urgent and growing need to exchange data with one another, interview participants reported that few airports or public agencies are taking full advantage of the resources available.

There are many reasons for this gap, but participants in the study suggested that the greater challenges are organizational rather than technical ones, many of can be addressed relatively easily by applying newer technologies, especially web or "cloud"-based options. The following are the primary challenges hindering data exchange between airports and public agencies identified by study participants.

Challenges That Hinder Effective Data Exchange

Organizational

- Cumbersome agreements
- Excessive protection of sensitive data
- Legal constraints
- Lack of procedures and policies
- Disconnected organizations
- Limited staffing
- Lack of collaborative forums
- Limited awareness among those in position to affect change
- Lack of executive-level champions
- Cost of collaboration and sharing.

Technical

- Lack of consistently applied standards
- Poor data quality
- Out-of-date data
- Improper derivatives
- Lack of metadata
- Data-related differences that are difficult to overcome.

Participants also expressed that challenges to effective data exchange and collaboration are the result of traditional ways of identifying and requesting data, as well as traditional attitudes that favor restricted access or the imposition of fees. Many data requestors rely on personal contacts to find and request data as needs arise. They often need to follow up, and sometimes are confronted with restrictive legal agreements or concerns about data sensitivity or security. When the information is received, it often needs to be altered to meet recipients' needs. This not only costs time and money but increases concerns among providers about degraded quality or inappropriate use of their data.

Some states and regions have made significant advancements in coordinating data and resource sharing through official avenues. In some cases, state laws and policies have been established to support initiatives that have allowed sharing to evolve to the next level. Furthermore, some states have created a geographic information officer (GIO), directly responsible to the governor, to provide leadership in geospatially related topics, including policy and data and other resource sharing. Case examples in this report detail specific relationships and transactions through which agencies and organizations support each other's geospatial sharing initiatives, including not only data but also staff, policies, etc.

Clearly, despite the initial challenges, all forms of sharing have proven beneficial to parties willing to engage and participate, even for those who seemingly give more than they receive. Once these challenges and costs are understood, protocols can be established to share data more efficiently. Although the need to ensure data security will at times create a slowdown, diligence will continually need to be exercised to ensure trusted and sound sharing practices. GIS proponents on both the airport and public agency sides have ensured continued coordination and forward momentum that may encourage those considering embarking on this path.

SUGGESTIONS FOR FURTHER RESEARCH

This synthesis reviewed the need for and current practices of sharing geographic information and related collaborations between airports and public agencies. As this review was carried out, several related topics were identified that could benefit by additional research. These include:

- ***Definitions of and protocols for handling sensitive and proprietary information—***Many, but not all, airports and agencies interviewed are familiar with the concept of Sensitive Security Information (SSI) or how such data should be handled. Fewer have written policies and procedures for identifying and handling SSI. Research into best practices and prudent methods of handling SSI would benefit the airport industry and help protect data and the nation's aviation infrastructure. It is suggested that this research go beyond SSI to investigate data that is not SSI but could be used to do harm if made available without restriction. How to protect proprietary rights when exchanging data is also an important topic that needs to be covered.
- ***Integration and dissemination of FAA data to airports—***Several of the airports interviewed noted that they find it more challenging to identify and obtain data from the FAA than from other public agencies. They also point out that often the data from the FAA is also essential to satisfy FAA's own Airports GIS program requirements. FAA understands this issue and has been working to identify, integrate, and consolidate the vast and sometimes redundant data that it has relevant to airports. Although the FAA is addressing this challenge internally, additional research on how civil aviation organizations in other countries or agencies in other industries have overcome similar challenges may be helpful. Respondents to this study indicate that a catalog of FAA data sources guiding airport staff and their consultants to resources would be beneficial. Guidance on data sharing and exchange, especially as it relates to NextGen, would also be helpful.
- ***Use of cloud technologies at airports—***Cloud- or Internet-based data, software, and hardware is a rapidly growing resource for airports and most industries. A primer on what options exist, their costs, security concerns, and other factors would help airport managers and information technology staff leverage the potential of cloud-based resources.
- ***Building information modeling—***Building Information Modeling (BIM) is a rapidly emerging technology that airports are using for planning, design, and construction. Many are also looking to use this rich data to support ongoing operations and maintenance. A primer on BIM, the standards that exist, methods of using and exchanging the data, the costs/benefits of implementation, and a list of resources would help airport managers and staff take advantage of this emerging technology.
- ***CAD, GIS, and BIM integration—***Computer-aided design (CAD), GIS, and BIM data are all used to develop, analyze, and visualize geographic information at airports as well as at public agencies and other organizations. How to exchange data between these platforms, and how to maintain one master set of data that can be used by these different types of software, remains an issue for many. An investigation into effective practices of exchanging such data and guidance that airports and other organizations can use to implement such practices is suggested.
- ***Costs, benefits, and returns on investment that can be realized with an airport GIS program—***Many airports have some form of GIS within their organization. Other airports are hindered by the investment required to purchase software and hire technical support. There are clear short- and long-term benefits to putting a GIS in place that at times need quantification to help justify. It is suggested that further research be conducted to quantify both tangible and intangible benefits and returns from an investment in a GIS program. This research could also identify ways in which airports have funded their GIS programs and constraints they face, such as federal limitations on how airport grant monies are spent.
- ***Establishing public collaborative forums—***This study identified the importance of collaborative forums in identifying and exchanging data between airports and public agencies. Although some effective practices and challenges to setting up such forums were identified, additional research could stimulate additional collaboration, stimulating additional data exchange. This research ideally would identify the options that exist and highlight examples of successful implementations.

- ***Awareness and training material on the open data movement—***Many types of organizations in various jurisdictions have benefitted from open data, meaning data that is freely available without restriction or charge. Although this trend has provided obvious benefits and reduced data collection costs, many managers are hesitant to employ them because of concerns over liability, costs, and other constraints. Education, particularly for senior managers and public policymakers, could increase awareness of the benefits of open data sharing and appease concerns by providing successful mitigation strategies.

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GLOSSARY

The following terms have been used in this report and are defined here:

Airport Layout Plan (ALP) A scaled drawing of existing and proposed land and facilities necessary for the operation and development of the airport.

Building Information Model (BIM) A digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle, defined as existing from earliest conception to demolition.

Cloud computing Accessing and making use of computing resources including data, applications, software, and hardware in a broad network such as the Internet, but sometimes a large organizational intranet.

Commercial off-the-shelf (COTS) software Software that is available from a commercial vendor that can be installed and used without significant customization.

Computer-automated design (CAD) A computer-based system for the design, drafting, and display of graphical information (Esri).

Coordinate Transformations Calculations that transform the graphical elements of geographic information from one coordinate system to another.

Data set A grouping of similar feature classes that share a common function or purpose.

Enterprise GIS A geographic information system that is intended to meet the needs of and promote collaboration between the organization's divisions.

Extract, Transform, and Load (ETL) A class of software that is design to extract data from one of many formation, transform it in some manner such as changing its coordinate system or format, and load it into another format or location.

Feature class A collection of geographic features with the same geometry type (such as point, line, or polygon), the same attributes, and the same spatial reference. Feature classes can be stored in geodatabases, shape files, or other data formats. Feature classes allow homogeneous features to be grouped into a single unit for data storage purposes.

File Transfer Protocol (FTP) A digital protocol that allows the transmission of files between computers over a network.

Geographic information Geospatial data along with related attributes, and metadata.

Geographic Information Systems (GIS) An integrated collection of computer software and data used to view and manage information about features, analyze spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analyzed.

Geospatial data Information about the locations and shape of features and the relationships between them, usually stored as coordinates and topology.

National Spatial Reference System (NSRS) A consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States and is designed to meet our nation's economic, social, and environmental needs.

Non-governmental organization (NGO) A non-governmental organization, also often referred to as "civil society organization" or CSO, is a not-for-profit group, principally independent from government, which is organized on a local, national, or international level to address issues in support of the public good (United National Rule of Law). These represent regional councils of government, multi-agency consortia, and non-profit organizations.

Open GIS Consortium (OGC) An international voluntary consensus standards organization, originated in 1994. In the OGC, more than 400 commercial, governmental, nonprofit, and research organizations worldwide collaborate in a consensus process encouraging development and implementation of open standards for geospatial content and services, GIS data processing, and data sharing.

Orthorectification The process of correcting the geometry of an image so that it appears as though each pixel was acquired from directly overhead. Orthorectification uses elevation data to correct terrain distortion in aerial or satellite imagery.

Public agencies Organizations funded and managed using public (i.e., tax payer) funds including municipal, county, state, or federal agencies, as well as, non-profit consortia of one or more such agencies.

Raster data A graphical representation of data where cells are provided one or more specific values. An example is an aerial imagery where each cell or pixel is given a value for red, green, and blue.

Remote sensing The collection of data without coming into direct contact with the subject. Examples of remotely sensed data that airports and public agencies alike use include aerial imagery, LiDAR, and subsurface utilities detection.

Rich Site Summary (RSS) A web-based protocol for publishing periodic updates of information to which the receiver has subscribed in a common format so that these updates can be read by and incorporated into a variety of software and devices.

Sensitive Security Information (SSI) Information obtained or developed in the conduct of security activities.

Shape Files A common geospatial vector data format developed and used primarily with Esri GIS software. It is developed and regulated by Esri as a (mostly) open specification for data interoperability among Esri and other GIS software products.

Software as a Service (SaaS) Software that is owned, delivered, and managed remotely by one or more providers.

Spatial Data Infrastructure (SDI) A coordinated series of agreements on technology standards, institutional arrangements, and policies that enable the discovery and use of geospatial information by users and for purposes other than those it was created for (Kuhn 2005).

Standard A set of well-defined criteria, rules, and guidelines that provide a common framework for communication and interoperability.

Web Catalog Service (WCS) A web service that returns a listing and relevant metadata about geographic information that is available.

Web Image Service (WIS) A web service that returns an image of raster data such as an aerial photograph.

Web Map Service (WMS) A web service that returns an image of a map.

APPENDIX A
SURVEY QUESTIONNAIRE

Following is the questionnaire that was used to collect information from 44 of 47 organizations contacted (these are listed in Appendix B). In some cases, more than one individual from each organization was interviewed. In a few cases, respondents filled out this survey online. In most cases, the online questionnaire was used as a guide and means to record responses when conducting a phone interview. Following is the questionnaire that was used.

SURVEY QUESTIONNAIRE

The objective of this survey is to investigate how airports share GIS and related data with public agencies and, conversely, how public agencies share data with airports. This study will research current and effective practices for such data exchange and synthesize the findings into a report that will be published by the Airport Cooperative Research Program, which is administered by the Transportation Research Board under the National Academies of Science. The study is being conducted by consultant investigators that were selected by a panel of industry experts. We would appreciate your assistance.

Are you willing to participate in this study?

1. Yes, please contact me to schedule a date and time to talk
2. Yes, I don't have time for a phone interview but I'll answer questions on-line
3. I'm not the right person to speak with about this subject
4. No, I don't have time
5. No, I prefer not to participate
6. Other:

Please suggest a few dates and times over the next few weeks that you can spend 30–45 minutes with us on a phone interview

Would you like to answer some of our questions now or prefer to wait until we contact you?

1. Not now, I'll answer your questions when we talk
2. I'll provide some answers now and then expand on them when we talk

For what type of organization do you work?

1. Commercial Airport
2. General Aviation Airport
3. City/Municipal Government
4. County Government
5. State Government
6. Federal Aviation Administration
7. Other Federal Agency
8. Other:

What is the 3 digit location identifier for your airport?

What is the name of your organization?

What is your FAA routing code?

What level of GIS does your organization have?

1. Enterprise level actively used by 2 or more departments
2. Used by more than 2 end users within one department
3. Used by analysts/technicians to prepare maps for our staff and management
4. One person uses it
5. We don't have it, but we plan to
6. We have no plans to get it
7. Other

Do you or your colleagues use CAD software and data?

1. Yes
2. No
3. Not sure

Is data exchanged between the CAD and GIS software in your organization?

1. Yes
2. No
3. Not sure

How is CAD/GIS interoperability achieved?

Has your organization provided or received geospatial information (i.e., GIS, CAD, Imagery, LiDAR, or other mapping data) from another organization or agency?

1. Yes
2. No, but we would like to
3. No, we don't see a need to
4. I'm not sure

How do you find out about data available from other agencies (select all that apply)?

1. Word of mouth
2. Meetings
3. Conferences/conventions
4. Newsletters
5. E-mail broadcasts
6. Internet searches
7. Other:

How frequently do you meet with other organizations with which you do or would like to share data?

1. Daily
2. Weekly
3. Monthly
4. Quarterly
5. Annually
6. As needed
7. Not yet
8. Not necessary

Which local organizations, cooperatives, forums, or meetings do you regularly participate in to promote GIS knowledge and data sharing?

When you meet with other agencies to discuss data sharing, what topics are discussed (select all that apply)?

1. High level requirements
2. Detailed technical specifications
3. Data quality
4. Legal matters such as confidentiality or data use restrictions
5. Standards
6. Other:

Please describe any cooperative agreements your organization has with other organizations and what data sets are covered.

Please rank on a scale from 1 to 10 (where 1 is not at all and 10 is all the time) the following:

	Rank
I am able to easily find data I need from third party sources (e.g., municipalities, clearing houses, etc.)	
I use a lot of free data available on line and also available to the public	
I am able to develop the data I need to support my projects or fulfill state/federal reporting requirements	
Developing data within my organization is costly and at times prohibitive	
I do not have quality concerns over data I obtain for third parties	
I or my staff find that there are cooperatives and forums in my area that allow me to network with other GIS data users and providers	
I or my staff actively participate in cooperatives and forums in my area to promote networking and data sharing	
I have ample funding to acquire or develop the data I need	
I feel that analysis and conclusions are compromised based on the quality and completeness of my GIS data	
I believe there is valuable data available from local or other government that I am unable to obtain due to unexplainable reasons	
File formats or data conforming to certain standards is important to my department	
I find myself often times being behind in keeping my data updated	
Data duplication and redundancy is a problem in my organization	

Please indicate the name(s) of the organization(s) you have provided remotely sensed data to or received remotely sensed data from. If multiple, please indicate what types of organizations (e.g., multiple counties).

	Provided to	Received from	Wanted from	Internal Use only
Aerial Imagery				
Satellite Imagery				
LiDAR				

Please indicate the name(s) of the organization(s) you have provided elevation data to or received elevation data from. If multiple, please indicate what types of organizations (e.g., multiple counties).

	Provided to	Received from	Wanted from	Internal Use only
Contours				
DTM/DEM				

Please indicate the name(s) of the organization(s) you have provided GIS/CADD data to or received GIS/CAD data from. If multiple, please indicate what types of organizations (e.g., multiple counties).

	Provided to	Received from	Wanted from	Internal Use only
Airfield				
Airspace				
Asset Management				
Cadastral				
Cultural Resources				
Environmental				
Events				
Geodetic				
Interior				
Life Safety				
Navigational Aids				
Other				
Pavement				
Seaplane				
Security				
Structures				
Surface Transportation				
Utilities				

Please indicate other types of non-data resources you have shared with another agency.

	Provided to	Received from	Wanted from
Software			
Hardware			
GIS Analysts			
CAD Technicians			
Surveyors			

Does your organization purchase or subscribe to data sets? If so, which ones?

Is there data that you would like to get from another agency but cannot?

1. Yes
2. No

Which data sets are you missing that you believe can be provided by another agency. What is the name of those organizations. Note: we will not share information you provide with them, but may research or interview them without mentioning your name. If you prefer we do not contact them, please let us know.

What factors have prevented you from getting the data you require (select all that apply)?

1. Data access restrictions
2. Cost charged for the desired data
3. Technical specifications that do not meet our needs
4. Poor communication or follow-up
5. The data we desire doesn't exist
6. Other:

Please expand on what TECHNICAL challenges you have faced in obtaining desired data from other agencies.

Do you find data redundancy and discontinuity between similar data sets to be a challenge? For example, is it sometimes hard to know where the best data for a certain asset or topic may be?

Please expand on what ORGANIZATIONAL challenges you have faced in obtaining desired data from other agencies.

What data sets are the hardest to obtain?

In your opinion, what could change to make it easier to share (give and receive) data with external organizations?

What steps have you taken to overcome challenged to data sharing that have worked or didn't work?

	Successful	Unsuccessful	Other
Signed non-disclosure or other agreement			
Followed up by phone/e-mail			
Followed up in person			
Sought senior management help			
Adjusted our needs to their specifications			
Asked or paid for them to adjust their specifications			

Please expand on the steps you have taken (whether successful or not) in overcoming the challenges of data sharing.

Please rank the following aspects of data quality based on their relative importance to you. Only fill in those that are relevant?

- Accuracy (<1 foot) _____
- Accuracy (1–5 feet) _____
- Accuracy (>5 feet) _____
- Timeliness (1–3 months) _____
- Timeliness (6–12 months) _____
- Timeliness (1–2 years) _____
- Comprehensiveness _____
- Level of attribution _____
- Metadata availability _____

What quality issues have you experienced with data you have obtained from others (please indicate the type of data that has been problematic)?

What specifications do you require of the data you receive from others?

What portion of your data specifications and/or technical requirements is driven by federal or state regulation?

1. All
2. Most
3. Half
4. Few
5. None

How frequently do you require updates of the data you received from others?

1. Once is enough
2. Real-time updates
3. Weekly
4. Monthly
5. Quarterly
6. Annually
7. As needed
8. Other:

In what format do you require (or desire) data provided by other organizations (please check all that apply)?

1. ESRI Shape Files
2. ESRI Personal
3. ESRI File Geodatabase
4. AutoCAD DWG
5. Microstation DGN
6. LiDAR LAS
7. GeoTIFF
8. MrSID
9. JPEG2000
10. Comma Separated Value (CSV) text
11. Geographic Markup Language (GML)
12. RDBMS format (Oracle, SQL Server, etc.)
13. Other:

Are your data needs and specifications changing due to internal or external factors? If so, please explain.

What key GIS or related data sets do you maintain?

Of the key GIS or related data sets you maintain, do any rely on data or other inputs from another organization? If so, please explain.

If the data you desire from others is not available to you (for any reason), would you pay to develop it yourself?

1. Yes
2. No

Please explain.

How many people in your organization use the data you receive from other organizations?

1. 0
2. 1
3. 2–5
4. 5–10
5. 10–50
6. 50 or more

What percentage of the total people in your organization use data collected from other organizations?

How critical is the data you collect from other organizations to people within your organization?

1. Essential
2. Very helpful
3. Nice to have
4. Not essential
5. Other:

Do people within your organization need to modify the data received from other organizations in any way before they can use it?

1. Yes
2. No
3. Not sure

How do they modify the data?

What mechanisms does your organization use to exchange data with other organizations?

1. CD/DVD
2. Thumb/USB drive
3. E-mail
4. FTP
5. Web (map) services
6. Other:

What improvements can be made in the data you provide to or receive from other organizations to make it more usable to you or they?

Have you or your organization entered into written agreements to govern the exchange and use of data?

1. Yes
2. No
3. Not sure

What types of agreements have you or your organization been party to (check all that apply)?

1. Non-disclosure
2. Contract (not involving money)
3. Contract (involving money)
4. Memorandum of Agreement
5. Verbal agreement
6. Other:

Can you recommend another colleague that may help us with this study?

First Name

Last Name

Phone

E-mail address

Would it be OK to contact you with follow up questions?

First Name

Last Name

Phone

E-mail address

Thank You!

APPENDIX B

LIST OF SURVEY RESPONDENTS

The following organizations responded to the survey by either completing the questionnaire (a copy of which is provided in Appendix A) or by agreeing to a phone interview during which the questionnaire was used as a guide and means to record the information provided. In some cases, multiple individuals from a single organization were interviewed.

Type	Organization	City	State	FAA Region
Airport	ATL (Hartsfield—Jackson Atlanta International Airport)	Atlanta	GA	ASO
Airport	AUH (Abu Dhabi International Airport)	Abu Dhabi	UAE	n/a
Airport	BFI (Boeing Field/King County International Airport)	Seattle	WA	ANM
Airport	DEN (Denver International Airport)	Denver	CO	ASW
Airport	DFW (Dallas/Fort Worth International Airport)	Dallas	TX	ASW
Airport	FLL (Fort Lauderdale/Hollywood International Airport)	Fort Lauderdale	FL	ASO
Airport	HPN (Westchester County Airport)	White Plains	NY	AEA
Airport	LAS (McCarran International Airport)	Las Vegas	NM	ASW
Airport	MSP (Minneapolis-St Paul International/Wold-Chamberlain Airport)	Minneapolis	MN	AGL
Airport	PDX (Portland International Airport)	Portland	OR	ANM
Airport	PHL (Philadelphia International Airport)	Philadelphia	PA	AEA
Airport	PHX (Phoenix Sky Harbor International Airport)	Phoenix	AZ	ASW
Airport	PWM (Portland International Jetport)	Portland	ME	ANE
Airport	SAN (San Diego International Airport)	San Deigo	CA	AWP
Airport	SAV (Savannah/Hilton Head International Airport)	Savannah	GA	ASO
Airport	SFO (San Francisco International Airport)	San Francisco	CA	AWP
Airport	SJC (Norman Y. Mineta San Jose International Airport)	San Jose	CA	AWP
Airport	TRK (Truckee-Tahoe Airport)	Truckee	CA	AWP
City-Municipal	City of Centennial, Colorado - GIS	Centennial	CO	ASW
City-Municipal	City of Denver - GIS	Denver	CO	ASW
City-Municipal	City of San Mateo - GIS	San Mateo	CA	AWP
County	Broward County Florida - GIS	Fort Lauderdale	FL	ASO
County	Clark County - GIS	Las Vegas	NV	ASW
County	Cook County, Illinois - GIS	Chicago	IL	AGL
County	Fairfax County, Virginia - GIS	Arlington	VA	AEA
County	Orange County, Florida - GIS	Orlando	FL	ASO
County	San Mateo County, California - GIS	San Mateo	CA	AWP
County	Volusia County, Florida - GIS	DeLand	FL	ASO
County	Westchester County Department of Public Works and Transportation	White Plains	NY	AEA
FAA	FAA AAS-100	Washington	DC	n/a
FAA	FAA APP-400	Washington	DC	n/a
Other	Atlanta Regional Commission	Atlanta	GA	ASO
Other	dbSpatial, MSP—Environmenal, MetroGIS	Minneapolis	MN	AGL
Other	Denver Regional Council of Governments (DRCOG)	Denver	CO	ASW
Other	Esri, Inc.	Redlands	CA	AWP
Other	GPC-GIS (AD-SDI)	Abu Dhabi	UAE	n/a
Other	Metro	Portland	OR	ANM
Other	Ohio State, Formerly with Chicago Transit Authority	Columbus	OH	AGL
Other	R.W. Armstrong and Associates (a CHA Company)	Cleveland	OH	AGL
Other	San Diego Geographic Information Source (SanGIS)	San Deigo	CA	AWP
Other	Savannah Area Geographic Information System (SAGIS)	Savannah	GA	ASO
State	Metropolitan Airports Commission	Minneapolis	MN	AGL
State	New York Department of Transportation - GIS	Albany	NY	AEA
State	Not Disclosed	Boston	MA	ANE

Abbreviations used without definitions in TRB publications:

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