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ACRP

Web-Only Document 37

Research Roadmap in the Area of Airport Operations and Maintenance

Narrative Research Roadmap Report

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Contractor's Final State of the Industry Report for ACRP 11-02/ Task 29
Submitted November 2018

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Executive Summary

The Airport Cooperative Research Program (ACRP) undertakes high-quality, applied research projects to improve practice in the airport industry. The ACRP relies on input and cooperation from industry stakeholders, such as airports, air carriers, trade associations, consultants, and state and local government officials, for both the development of research problem statements, and to serve on project panels to direct the research. While there is no shortage of research needs for the airport industry, there is often a lack of time for practitioners to thoughtfully translate their challenges into research ideas and problem statements. In addition, most practitioners do not have a complete picture of all the existing, ongoing and planned research from ACRP, the Federal Aviation Administration (FAA) and academia. As a result the ACRP undertook the development of several research roadmaps to provide a vehicle for industry to collaborate in identifying future research needs and knowledge gaps. The research roadmaps will help ACRP to direct research funding towards areas of greatest need, and ensure the consistent supply of relevant problem statements.

ACRP project 11-02/Task 29, “Research Roadmap in the Area of Airport Operations and Maintenance” outlines the key research gaps and areas of interest for airports in the field of operations and maintenance (O&M) over the next five years. The roadmap was developed through a review of relevant research and broad stakeholder engagement with industry practitioners. The research ideas generated as part of this project are organized into nine high-level themes, which represent the main categories of challenges facing airports in this field presently and over the next several years. While both operations and maintenance subjects are designated as their own research areas within the ACRP program, the roadmap takes a coordinated approach and combines the two in both the report and the visual representation. Based on the result of the outreach and literature review, forty-two research ideas were generated and categorized into nine high-level themes, including:

-  Continuity of Operations
-  Financial Resources and Procurement
-  Facility and Operational Modernization
-  General Asset Management and Maintenance
-  Integrating Advanced and/or Disruptive Technologies
-  Safety and Security
-  Sustainability and Resiliency
-  Unmanned Aerial Systems / Vehicles
-  O&M Workforce

The research ideas are further categorized into twelve sub-topics. The ideas contained in the research roadmap are spread out over a wide variety of themes and sub-topics, because O&M stakeholders interviewed stressed that the nature of their work requires them to consider each of these topics in developing their approach to conducting their day-to-day duties. Other disciplines are often assigned the responsibility for developing solutions to the challenges that airport operators and maintainers encounter (e.g., planners, design teams, construction, information technology professionals and airport procurement specialists). As such, these other disciplines may ultimately take the lead in developing some of the roadmap ideas into problem statements, and conducting the research identified in this roadmap. Although many of the roadmap ideas align closely with multiple traditional ACRP research areas, O&M personnel should be included to ensure that their perspectives are considered, and how the actions and decisions of one group affect those across the organization.

As airports modernize, the need to collaborate and coordinate their activities across virtually all disciplines has become apparent, particularly with the outsized role that new technologies are playing in this industry and depicted in the roadmap. Research associated with the ideas contained in this roadmap will benefit from the insights that airport executive leadership and human resource executives can provide, given the role that they play in integrating the efforts of all airport personnel and stakeholders.

An overview of the themes and the roadmap development process is described in Section 1. A description of the Literature Review process, sources identified and a high-level summary of findings are described in Section 2. The resulting research ideas were prioritized based on a set of key criteria, stakeholder input and research team analysis, which are described in Section 3. The high-level issue themes, sub-topics and specific research ideas are described in Section 4. Final observations of the research team are included in Section 5. Accompanying products to the roadmap are included in the appendices and on IdeaHub.

The completed “Research Roadmap in the Area of Airport Operations and Maintenance” consists of the following products:

- Narrative Research Roadmap report (this document: *ACRP Web-Only Document 37: Research Roadmap in the Area of Airport Operations and Maintenance*)
- Appendix B. Graphical representation of the roadmap (the static version is available in Appendix B; an interactive version is available on ACRP’s website at [https://public.tableau.com/profile/acrp#!/vizhome / ACRPRoadmapOperationsMaintenance_0/ACRPOperationsMaintenanceResearchRoadmap](https://public.tableau.com/profile/acrp#!/vizhome/ACRPRoadmapOperationsMaintenance_0/ACRPOperationsMaintenanceResearchRoadmap))
- Appendix C. Research Ideas Database ([separate Excel file](#))
- Narrated PowerPoint presentation describing the roadmap and related products ([a separate PowerPoint presentation](#))

1 Introduction

The Airport Cooperative Research Program (ACRP), is a research program of the Transportation Research Board (TRB), which is in turn part of the National Academies of Sciences, Engineering and Medicine (NAS). The ACRP, now over a decade old, is an “industry-driven applied research program that develops near-term, practical solutions to problems faced by airport operators” (TRB, 2018), and is sponsored by the Federal Aviation Administration (FAA). The ACRP was developed to investigate problems not currently being addressed by other federal research programs, and has developed a reputation for excellence in research since its inception in 2006, largely attributable to its focus on collaboration with industry stakeholders.

ACRP relies on input and cooperation from industry stakeholders, such as airports, air carriers, trade associations, consultants, and state and local government officials, for both the development of research problem statements, and to serve on project panels to direct the research. Over the past twelve years, ACRP has published (and/or in the process of developing) well over 400 research reports, synthesis reports, legal digests and web-based tools based on the interests and input of industry practitioners.

1.1 Project Background

The airport industry has always faced a variety of challenges, problems and opportunities for improvement in the field of operations and maintenance. Some of the challenges have persisted over time and others are new, arising and resolving over time with the continued evolution of technology, practices, materials, and the changing needs of airport stakeholders. In order to maintain a steady supply of high quality research ideas to address these challenges, the ACRP has undertaken the development of five year, strategic research roadmaps in several topic areas. One such is ACRP Project 11-02/Task 29, “Research Roadmap in the Area of Airport Operations and Maintenance”. As stated in the Request for Proposals, a “research roadmap outlines a research agenda that will guide the development of problem statements flowing into ACRP and can provide answers to current questions, reduce uncertainties, and provide a sound approach for future research projects”.

The objective of this project is the development of a 3 to 5-year, prioritized research roadmap that identifies gaps in knowledge and research ideas in the area of airport operations and maintenance. The research roadmap will enable industry stakeholders to develop problem statements and assist the ACRP Oversight Committee (AOC) in selecting projects for funding. The research roadmap will be designed for broad distribution via the internet, and will integrate with ACRP’s online platform for the collaborative development of research statements, the IdeaHub.

The Operations and Maintenance (O&M) Research Roadmap considers the main airside and landside challenges relevant to airport practitioners today, as well as challenges expected to emerge over the next several years. It identifies several high-level themes as well as a number of sub-topics in order to categorize individual research ideas. The intent is for the individual research ideas to serve as starting points to be developed into complete problem statements over the next five years. The roadmap provides the reader with an understanding of the main topics of interest in this field, how the ideas relate to one another, and how the research ideas address overarching industry goals and objectives.

In order for this roadmap to accurately reflect the needs of industry and address the key challenges in the fields of operations and maintenance, two critical components were required. First, a thorough review of existing and planned research in these areas was completed to understand what information is currently (or soon to be) available, and where knowledge gaps exist. The ACRP and other TRB cooperative research programs have conducted a number of relevant studies in these topic areas over the past several years, which were reviewed. In addition, the FAA has a significant body of research relevant to airports which was surveyed. Other governmental agencies, trade associations, the academic community were all useful sources of information. The roadmap builds off of these existing sources to ensure that there is no duplication of efforts in future ACRP research.

Second, a robust stakeholder engagement effort was critical to capture the current and emerging challenges for airports of all sizes in the areas of operations and maintenance. During the development of the roadmap, a diverse set of airport practitioners, consultants, service providers, airlines, researchers and government officials were

contacted and interviewed, in order to gather information about issues of concern. The roadmap is a reflection of the common themes and ideas generated during the stakeholder engagement process.

The primary audience for this research roadmap includes ACRP leadership and staff, airport management and staff, airlines, consultants and regulators. The expected outcome of this project is a strategic research plan that can be used to develop impactful research projects over the next several years.

1.2 Integration with ACRP IdeaHub

The need for a consistent supply of high-quality research ideas fueled the development of ACRP's research roadmap projects, but also provides the foundation for another strategic initiative of ACRP, IdeaHub. IdeaHub is the recently launched online platform for problem statement development that allows users to effectively collaborate on ideas, vote on preferred research topics, and follow the process from start to finish in a transparent manner. Both IdeaHub and the research roadmaps share a common goal of identifying current and emerging challenges in the airport industry, and converting these challenges into problem statements to effectively guide future research spending.

The development of the research roadmaps occurred in parallel with the launch of IdeaHub. While both initiatives share the same objective (feeding the research idea pipeline), IdeaHub is geared towards collecting problem statements for current issues and challenges while the research roadmaps look further into the future to identify continuing and emerging trends the industry.

One key observation that the research team made during the development of the research roadmaps is that many emerging challenges span multiple areas of an airport's business objectives and operations. The team identified a corresponding need for cross-cutting, collaborative research projects. In fact, many ideas that were generated during the development of the O&M Research Roadmap could easily fit on other roadmaps, such as Policy and Planning, Environmental, and/or Design and Construction. IdeaHub provides an easy means for effective and continuous collaboration between practitioners that previously may not have interacted in the former, more one-dimensional problem statement development process. IdeaHub is a tool for stakeholders to view and develop research ideas from outside their own area of expertise, creating an impetus for collaboration. The hope is that this will result in research projects that span multiple disciplines – reinforced by the content of the research roadmap.

1.3 Roadmap Development Process

The O&M Research Roadmap was developed over several months, and is based on two main sources of information: a review of existing and ongoing research (or literature review) and an extensive stakeholder outreach process. The literature review provided the research team with an understanding of the key issues in this field that have been examined to date. This provided a foundation for developing an initial set of high-level topics and example research ideas that were used as basis for discussion with industry stakeholders. The literature review process and results are described in Section 2. The stakeholder outreach process involved discussion in a variety of formats with numerous participants across the industry, in both large and small group settings. The stakeholder process and participants are described in Section 3.

1.4 Roadmap Products

ACRP Project 11-02 Task 29 includes four products: the Narrative Report (this document); Visual Research Roadmap; Research Idea Database; and the Narrated PowerPoint presentation.

1.4.1 Visual Research Roadmap

The Visual Research Roadmap is an interactive version located on ACRP's website, with a static version included as Appendix B in this document. The Visual Roadmap is designed to convey a lot of information quickly to the user. It allows users to see the distribution of the research ideas over a five-year timeline, organized by high level theme and sub-topic, and to understand the relationships between the themes and topics. By hovering over each

research idea icon on the Visual Roadmap, users can read the research idea title, background information and objective.

1.4.2 Research Idea Database

The Research Idea Database is a searchable Excel file containing all forty-two ideas generated during the project. The database can be filtered by a number of categories, including high-level theme, sub-topic, keyword, related research (existing or ongoing research), idea rank (based on overall prioritization score) and by related ACRP Idea Hub tag. The ACRP Idea Hub has approximately 30 topics identified as “tags” that practitioners can select when entering a research idea or problem statement into the portal. Tags include subjects such as sustainability, human resources, customer experience, airport planning, etc. The Idea Database includes relevant Idea Hub tags for each research idea to further demonstrate the multi-dimensional nature of the knowledge gaps.

The Database is described in Appendix C.

1.4.3 Narrated PowerPoint Presentation

The Narrated PowerPoint presentation provides readers with an overview of the project, the roadmap development process and instructions for how to read the Visual Research Roadmap.

2 Review of Existing Research

The research team reviewed existing, on-going and planned research from a variety of sources. The most prolific source of research relating to the area of airport O&M is the Airport Cooperative Research Program (ACRP) itself. In addition to projects in ACRP, the research team searched the other TRB cooperative research programs for related research such as the Transit Cooperative Research Program (TCRP). The second largest source of research the team reviewed was from the International Facilities Management Association (IFMA). Next were federal agency research and their associated research partners, particularly the Federal Aviation Administration (FAA). The FAA conducts a significant amount of research, both directly, through their Technical Center, and indirectly, through university centers of excellence. Many lines of business within FAA have their own research roadmaps, including the Office of Airports, the Air Traffic Organization, and the Office of Environment and Energy. The research team reviewed the most recent National Aviation Research Plan (NARP) and the National Plan of Integrated Airport Systems (NPIAS) as well as other documents.

The research team also conducted a search for relevant publications from industry trade organizations and other relevant sources, such as:

- Airports Council International- North America [ACI-NA]
- American Association of Airport Executives [AAAE]
- Airport Consultants Council [ACC]
- International Facilities Management Association [IFMA]
- National Safe Skies Alliance Program for Applied Research in Airport Security [PARAS]
- RTCA NextGen Advisory Committee [RTCA NAC]

Relevant publications from trade organizations and federal agencies serve as a means for identifying the main goals of the respective organizations and what they consider as priorities and research gaps in the industry (not necessarily limited to O&M issues).

The research team did not observe an abundance of applicable, publicly available research from the academic community beyond the scope of research conducted through ACRP.

The research team logged and categorized over 100 resources that have some applicability to this issue area, and organized the publications by high-level topic and specific topic areas. This assisted in the identification of areas that have been well covered by existing research and areas that have not.

2.1 Transportation Research Board

Unsurprisingly, the ACRP program is the richest source of existing information in the areas of airport operations and maintenance. Out of 103 total publications reviewed, ACRP accounts for 82. The ACRP Research Fields 9: Maintenance and 10: Operations were a particular focus of the research team, though publications from all other research fields were reviewed for relevant products, and included in the database when applicable. ACRP Research Field 9: Maintenance contains 17 research projects that are either published, in progress or planned. ACRP Research Field 10: Operations contains 26 projects completed or anticipated. All ACRP publications (reports, synthesis reports, impacts on practice, etc.) were considered if they had a nexus to either operations or maintenance topics. Many of these are listed under other research fields, such as Research Field 2: Environment, and Research Field 4: Safety, due to the interrelated nature of many topics.

We focused the bulk of our search and subsequent review on projects published in the past five to six years, but noted the topics covered by older research in the spreadsheet. If an older (pre-2011) research product currently exists for an idea that was raised during the stakeholder outreach process, the research team evaluated the existing resources to determine if an update would be appropriate.

The research team categorized ACRP research topics by high-level topic areas to organize the resources and to help identify some overarching trends in existing research. Overall, the distribution of existing ACRP sources we reviewed include:

- Overarching Operations and Maintenance topics – 17 publications
 - Subtopics for publications in this category include: commercial ground transportation, fueling infrastructure, pavement maintenance, general guidance / maintenance best practices, winter and irregular operations and evolving trends
- Safety related topics – 15 publications
 - Subtopics for publications in this category include: airside operations, communication and coordination, management systems, wildlife, and winter and irregular operations
- Sustainability related topics – 12 publications
 - Subtopics for publications in this category include: energy efficiency and renewable energy, fueling infrastructure, general guidance and/or implementation tools, pavement, new and evolving trends
- Integrating Advanced Technologies and IT-related topics –11 publications
 - Subtopics for publications in this category include: emergency operations, general guidance and/or implementation tools, Building information modeling (BIM), new and evolving trends, and pavement
- Financial Resources or Procurement related topics – 9 publications
 - Subtopics for publications in this category include: curbside/roadway, replacement or renewal of assets, transportation network companies (TNCs), and resources to support O&M
- Asset Management related topics – 6 publications
 - Subtopics in this category include: general guidance and/or implementation tools, energy efficiency and renewable energy, fueling infrastructure, and operational efficiency
- Continuity of Operations – 5 publications
 - Subtopics in this category include: general guidance and/or implementation tools, resources to support O&M, and winter and irregular operations
- Operational Demand Management topics – 3 publications
 - Subtopics in this category include: NextGen, operational efficiency, and safety

The following topics each had 2 publications: Climate Change and Severe Weather, Facility and Operational Modernization, Workforce, Unmanned Aerial Vehicles, and Emergency Operations.

Interestingly, certain aspects of several research ideas raised by stakeholders are covered by other ACRP research areas, including advanced digital technologies, sustainability and workforce development. This once again highlights the need for multi-dimensional research that reflects the rising integration of activities within and across traditional airport divisions.

Overall there is an impressive body of research available from ACRP and the other TRB cooperative research programs O&M. The high-level topic area with the greatest number of resources is the “Overarching O&M” category followed closely by “Safety” related topics. This is not surprising given that in the first several years of ACRP existence the focus was on low-hanging fruit in terms of developing fundamental guidebooks and best practice documents covering topics such as preventative maintenance at airports and pavement maintenance.

Safety is the top priority for all stakeholders in the aviation industry, so it is also not surprising that a substantial number of publications address this issue. Topics covered include safety and risk management, safety

management systems, ramp and apron safety practices, wildlife hazard management and airfield separation for example. This continues to be a top priority of the FAA, airports and airlines moving forward.

Sustainability is another topic that has been well-covered by ACRP. Although many of these research projects originated in the Environmental Research Field of ACRP, they have a clear nexus to airport O&M, such as alternative fuel use in airport fleets, energy benchmarking, stormwater management, impacts of sustainability on O&M, and a sustainability rating system. Sustainability has served as a catalyst for establishing collaboration and coordination of activities across all disciplines of an airport.

Integrating new and advanced technologies was a central theme during stakeholder discussions on the roadmap, and it has been of interest to airport practitioners for the past several years, evidenced by the number of projects in this category. This is a broad topic represented by a number of subtopics, both in the existing literature as well as the proposed ideas for the database. Existing research that was organized in this category include topics such as building information modeling (BIM), integrating software into airport operations, IT systems at airports, and integrating TNCs into airport infrastructure for example. Despite the existence of several publications addressing emerging technologies, the field is so broad and constantly evolving, warranting inclusion of a number of topics on the roadmap in which ACRP research could be of benefit.

One common concern raised by stakeholders during the outreach process is the ability to attract, retain and train qualified employees in/to the airport sector. While there is some existing research on this topic, this is a knowledge gap that ACRP can address going forward since it will benefit disciplines beyond O&M as well.

2.2 International Facilities Management Association

The International Facilities Management Association is a global association of facility management professionals, with over 24,000 members in over 100 countries (IFMA, 2018). Within IFMA, there are 16 different industry-specific councils, including one for airports. While there are characteristics of airports that make them unique from other types of facilities, there are also many similarities. Thus most of the issues addressed by IFMA are relevant to airports. IFMA conducts original research on topics of interest to their membership, and also undertakes studies of industry trends, hot topics, tools and educational materials. As a result, the research team found a number of helpful resources published by IFMA, in addition to holding fruitful discussions with their staff and members of the IFMA Airport Council.

The research team reviewed several relevant documents, accessed through the IFMA knowledge library and obtained from IFMA staff. We focused our search on the publicly available material (mainly research documents and white papers), as the full library of materials for purchase was quite extensive. The most relevant publications were included in the literature review database.

The IFMA *Facility Management Outlook 2016: Trends, Issues and Forecasts* document outlines emerging trends in facility management and categorizes them into three main categories: business, cultural, and technological issue areas. Many trends that they identified mirror emerging themes in this research roadmap project. Some relevant trends that they characterize include the importance of embracing data and technological changes in facility maintenance, identifying labor market changes, and maintaining pace with rapidly changing workplace technology. The document stresses the need to train and retain a multi-skilled, multidisciplinary workforce that is equipped to work across roles and departments, while breaking down the idea of independent or isolated business units.

Welcome to the IoT [Internet of Things] Era is another publication by IFMA that is relevant to this roadmap as strategies for integrating IoT into airports is of particular interest in the industry. The IoT will enable new ways of operating and delivering services including maintenance, placing facilities management professionals on the frontlines of this technological transition. According to the findings of the IFMA, the top five IoT applications related to building systems and physical infrastructure include building automation, energy management, maintenance, security and physical access and safety – all of which are especially relevant to airports. Another relevant observation from the publication is related to data and network security concerns as a hurdle to IoT adoption, which has been echoed in stakeholder outreach during the development of the roadmap.

According to an internal membership survey, IFMA members are particularly interested in research products that address benchmarking for facilities O&M issues, as well as best management practices. To the extent that ACRP

can integrate the development of benchmarking tools into future research products, the organization will find there is an appetite not only with the airport industry, but more broadly across the transportation industry stakeholder community.

2.3 Federal Aviation Administration

The FAA submits their National Aviation Research Plan (NARP) to Congress annually, outlining their strategic research plan and vision for the National Airspace System (NAS). The most recent version of the NARP available is from 2016 (2017 and 2018 are currently being combined and reformatted, and not yet published). In the FAA's 2016 NARP, the agency outlined three central principles that guide their research and development (R&D) portfolio: 1) Improve aviation safety; 2) Improve efficiency; and 3) Reduce environmental impacts. The FAA planned to invest \$400 million in fiscal year 2017 on research programs (FAA, 2016) across its various lines of business based on these three overarching principles. The R&D funding is distributed across several divisions or accounts within the FAA, including approximately \$167 million in Research, Engineering and Development; \$189 million in Facilities and Equipment; and \$46 million in the Airport Improvement Program (AIP). The NARP was primarily used throughout the course of this project to confirm if the FAA is currently funding research ideas generated by the stakeholder outreach process, and to identify areas that are not being funded by FAA, making them appropriate for ACRP funding.

Other FAA resources identified and reviewed by the research team include publicly available meeting minutes of the Research, Engineering and Development Advisory Committee (REDAC). The REDAC is comprised of representatives from airports, airlines, manufacturers, and academic community. REDAC meets biannually to review FAA's research portfolio and provide input on how the agency should prioritize future research and development spending. This source provided further insight into research currently underway by the FAA.

The research team reviewed FAA documentation specifically related to NextGen as well as their research plan and prioritization regarding the implementation of NextGen technologies (FAA, 2012). The team consulted documentation intended to inform items in the FAA's Advisory Circular pipeline, and industry trends. For example, the FAA's Report to Congress on the "National Plan of Integrated Airport Systems (NPIAS) 2017-2021" outlines the amounts and types of airport development projects eligible for Airport Improvement Program (AIP) grant funding over the next 5 years. The report highlights that AIP-eligible projects are expected to increase at small hub airports, while decreasing somewhat for large and medium hubs. A recent focus on capacity-enhancing projects is waning while there is growing interest in terminal development and rehabilitation projects. Recognizing broad trends was useful in identifying high-level topics for the roadmap. As the focus shifts from airfield to terminal projects, there is an intensifying interest on customer and passenger experience with respect to terminal and facility design – which we would expect to translate into increased O&M needs with regards to terminals and landside facilities.

Given that Unmanned Aerial Systems (UAS) were raised as an issue of interest and concern by several stakeholders, the research team also reviewed research projects funded through the FAA's Center of Excellence for UAS research, the Alliance for System Safety of UAS through Research Excellence (ASSURE). Key research focus areas for ASSURE include: air traffic integration, particularly of fixed-wing UAS; airworthiness; control and communication (specifically the development of appropriate control and communications link between aircraft, pilot and controllers); technology to enhance detection and collision avoidance; human factors; UAS pilot training, and; low-altitude UAS operations safety.

Finally, the research team noted that the FAA-funded National Safe Skies Alliance, Inc.'s Program for Applied Research in Airport Security" (PARAS) has an ongoing project titled "Guidance for Integrating UAS into Airport Security" (expected publication 2018). PARAS publishes relevant guidance for airports relates to security topics. Some of the UAS research ideas generated during the stakeholder engagement process overlap with areas of research conducted by PARAS and ASSURE, but are not identical. Given the great interest in UAS from our industry, ongoing coordination between ACRP, PARAS and ASSURE on UAS topics in the future will be beneficial.

2.4 Trade Associations

The research team reviewed publications from major airport industry trade associations. Guidance was based on two relevant publications, ACI-NA's "Airport Infrastructure Needs: 2017-2021" report and Airport Consultant

Council (ACC)'s "Trends in U.S. Airport Development: A Summary Look at Future Trends and Opportunities". Both reports were published in 2017, and contain an overview of industry development needs for the next five years. These reports align with the results found in the 2017 NPIAS Report from FAA in their findings that terminal development or rehabilitation projects and other types of building infrastructure (parking, rental car facilities, etc.) will likely dominate in the near term as capacity projects (runways, taxiways) slow down. This information was useful as the research team engaged in conversations with stakeholders to understand their priorities, and how O&M needs associated with new and/or rehabilitated facilities can be addressed by ACRP research.

In addition, RTCA's Tactical Operations Committee "Improving Awareness, Planning and Execution of Airport Construction" (March 2016) guidance document was consulted to refine research ideas related to the challenges airports face in construction projects, and corresponding research gaps. The RTCA report highlights some additional needs of the industry, including a construction compendium to assist with education and awareness, and better coordination of complex construction projects. While this research may be more appropriate for the FAA to undertake than ACRP, and perhaps on the surface more applicable to the Design and Construction Roadmap, it highlights the need for ensuring continuity of operations during construction projects. This is a major theme identified by the stakeholders consulted for O&M roadmap input. RTCA has also taken the multi-dimensional approach to research tasks requested of them by the FAA. By including multiple disciplines and considering how all relevant stakeholders are affected by a certain issue, the organization can develop better, more robust solutions.

Finally, the research team conducted a cursory search of American Society of Civil Engineers (ASCE) and the American Institute of Architects (AIA) materials; however, their materials require membership or paid access and therefore are not included.

2.5 Other Stakeholders

Through the stakeholder outreach process, we were directed to a 'lessons learned' document developed by San Diego International Airport. The document, *The Rental Car Center Knowledge Transfer*, features lessons learned during the process of centralizing rental car facilities into a single Rental Car Center. While the document focused on the design and construction process, there were lessons learned that apply to O&M as well. Success factors include streamlined operations associated with a consolidated rental car center. Independently operated shuttle busses were replaced by a much smaller fleet of shuttle busses managed by a 3rd party facility operator, reducing emissions and increasing operational efficiency. The project team planned to train owners and tenants on maintenance of facilities before opening day and provide Building Operation & Maintenance (O&M) Manual to the 3rd party operators and Airport Authority. This mirrors the feedback the research team received in regards to the need for training third parties that work in the airport environment.

2.6 Research Gaps

The research team categorized the reviewed resources based on high-level themes and sub-topic in order to organize the plethora of research publications and identify trends. The categorization was somewhat subjective as several topics could conceivably have been placed in more than one high-level category, however the purpose of organizing the existing research ideas into high level topics was mainly to aid the research team in identifying broad trends and knowledge gaps.

After conducting the literature review and stakeholder outreach process, the research team identified several research gaps. This section provides a short summary of research gaps discovered in both the literature review process and concurrent stakeholder engagement process (topics are discussed in more detail in Section 4).

With advancements in technology, automation, and the ever-increasing connectivity of devices, systems and components (i.e. the "Internet of Things" [IoT]), we found a knowledge gap regarding updating and integrating technologies at airports, for example in designing and monitoring smart buildings, using BIM for maintenance and security, integrating new technologies and software with older IT systems, and preparing for autonomous vehicles. The roadmap refers to "advanced technologies" as those that enhance existing processes and capabilities, whereas "disruptive technologies" refers to those that can or will result in significant changes to operations, processes, services and capabilities, i.e. they will displace or force fundamental changes to existing processes and providers.

Advanced and disruptive technologies can also play a role in improving collaborative decision making between stakeholders including the FAA, airlines and airports. This will also have an impact in reducing delays and ensuring continuity of operations which is another high-level theme identified for inclusion on the roadmap.

Topics considered under the continuity of operations category in existing research include planning for small airports, guidebooks for ensuring continuity during winter and irregular operations, and practices to ensure operation of facilities during maintenance and repair. As airports are handling more passengers, and airline fleet updates have resulted in fewer spare aircraft and fuller planes, ensuring that continuity of operations and minimizing delays/ recovery time remains critically important. Some existing resources could benefit from an update, making this is subject a focus of attention during the outreach process.

Sustainability and resiliency are two issues that have been addressed by many existing resources, but came up often in the course of the roadmap development. These issues have largely been addressed by ACRP through the lens of the Environmental Research Field. However, sustainability and resiliency topics influence and are impacted by many other disciplines. As such, the ideas included on the roadmap that are in the Sustainability and Resiliency category include developing guidance on maximizing the impact of airport resiliency planning and advanced building automation and energy management systems through the integration of other airport disciplines. ACRP is in the process of developing an Environmental Research Roadmap which may also capture these topics. However, they are also included here because they impact airport O&M and illustrate the cross-disciplinary nature of many of these project ideas.

The existing research reviewed contains a number of research projects that address UASs, primarily through the FAA's ASSURE Center of Excellence and PARAS. While UAS represent a new and disruptive technology, the intense interest in this subject and the broad reach of impacts to an airport from UAS operations justifies this area being considered a high-level theme. UAS represent unique challenges and opportunities to airports, and our understanding of the impacts on airports, specifically operations and maintenance, is evolving.

As described above, safety is of paramount importance to the aviation industry. Airport O&M personnel have a significant role in ensuring the safe and secure operation of the airport environment. This importance is reflected in the existing body of research, both from ACRP and FAA. Given the priority of safety and security to airport operators and maintainers, these themes are reflected in the roadmap.

In addition, the stakeholder outreach process illustrated a widely recognized need for guidance on recruiting and retaining quality employees in the airport industry. Succession planning is critical for all business areas of the airport. Although not limited to operations and maintenance, ensuring a consistent pipeline of talent is critical to the development, operation and growth of our nation's airport system. Of particular importance is the need for a modern workforce that is capable of addressing the more sophisticated, complex and connected airport operating environment, and understanding how to use new technologies (and remain flexible for future changes).

2.7 Review of Existing Research Conclusion

Numerous resources were reviewed during this phase of the research roadmap development process. The bulk of the relevant resources came from ACRP, as expected. Although many of the research topics addressed by the roadmap are covered in some way by prior research, some of the projects are out of date and technological advances often necessitate a second look. Sources and documents from the trade associations and FAA, and particularly from IFMA, served as references for ensuring that research ideas generated as part of this project are not duplicative and achieve alignment with industry priorities. The research team, as intended, treated the database of resources as a living document for the duration of the stakeholder engagement process, and additional sources were added to the spreadsheet as they were identified.

3 Idea Identification and Prioritization

This section describes the stakeholder outreach process used to identify additional research ideas, and the methods used to prioritize the topics.

3.1 Stakeholder Engagement and Idea Identification Process

The research team completed outreach to key stakeholder groups to identify research gaps, and to solicit specific input on possible future ACRP research projects to be conducted in the area of airport operations and maintenance. The research team sought out representatives of stakeholder groups that could effectively identify knowledge gaps from a cross-discipline perspective, and identify emerging topics that will impact airport O&M, even if those challenges are not traditionally considered within the O&M field.

The stakeholder outreach process included multiple forms of communications: large group webinars, individual and small group teleconferences, and in person meetings as well as conference and committee presentations.

At the outset, many stakeholder conversations were introductory in nature. During these events, the research team provided a briefing on the project, including: the purpose and objectives of the roadmap; the preliminary topics and themes identified through the review of existing research and prior industry knowledge; and how the roadmap will integrate with ACRP's IdeaHub. The research team held several of these introductory briefings, and subsequently scheduled follow-on outreach meetings or calls designed to get a more in-depth understanding of stakeholders' research needs.

The research team made a concerted effort to gain a broad view of the field by engaging with a number of stakeholders from groups that identified as having an interest in and/or ability to contribute to the research roadmap. In total the research team conducted approximately thirty outreach activities (webinars, interviews, meetings, teleconferences and conference presentations) to groups ranging in size from one to over fifty participants, including the following groups:

- ACI-NA Committees: Operations and Technical Affairs Committee (including the Facilities & Maintenance, and Construction and Project Delivery working groups) Small Airports Committee, Business Information Technology Committee, and the Environmental Affairs Committee Sustainability working group
- AAAE Committees: Operations, Safety, Planning and Emergency Management (OSPEN) and Facilities and Technical Services (FATS) Committees
- ACC Committees: Advocacy and Finance & Project Delivery; Engineering; Terminal and Facilities Planning and Environment; and Security Committees
- FAA Office of Airports Planning & Programming, Office of Airport Safety & Standards, Airport Engineering
- The Volpe National Transportation Systems Center
- TRB Aviation Subcommittees: Airport Terminal and Ground Access, Committee Research Coordinators Council, Environmental Impacts of Aviation, and the Airfield and Airspace Capacity and Delay Committees
- National Association of State Aviation Officials (NASAO) staff and individual members from FL, MA and LA
- International Facilities Maintenance Association (staff and airport members)
- RTCA (formerly the Radio Technical Commission for Aeronautics) staff
- ACRP researchers on related projects
- Airline representatives
- Individual airport representatives from a range of airport sizes and locations
- Individual consultants

In general, the research team found that the stakeholders largely concurred with the high level topics identified through the literature review and our own understanding of the topic areas. The research team developed or collected over seventy individual research ideas through the literature review, stakeholder outreach and IdeaHub entries. This input was consolidated and refined, and categorized into the high level themes and specific sub-topics. We also added an additional, higher level of organization for each idea in the Research Idea Database (as a result of stakeholder input) in order to demonstrate how the ideas aligned with one of three overarching industry and FAA goals: 1) Enhancing customer / passenger travel experience; 2) Ensuring a safe and secure air transportation system; and 3) Enabling capacity enhancement and growth.

As previously discussed, the research team is also developing ACRP 11-02/Task 30, “Research Roadmap in the Area of Design and Construction of Airport Facilities and Infrastructure”. Since both projects are on a concurrent schedule, much of the stakeholder outreach was conducted for both projects simultaneously. This resulted in several benefits. In some cases (particularly for small airports or trade association staff) the relevant stakeholders for each roadmap are the same individuals. Therefore it was helpful to discuss both roadmaps at the same time to be efficient with participants’ time. For smaller airports in particular, staff often are responsible for multiple duties and therefore are able to provide input on both roadmaps. By holding discussions on both roadmaps simultaneously, the research team was able to identify topics that are cross-cutting and thus should appear on both roadmaps.

Two prominent and oft-repeated examples of cross-cutting topics are the rise of connected technologies (i.e. the “internet of things” [IoT]) and the attraction, retention and development of airport staff. Both issues are important to airports and span the needs of multiple departments. While not all outreach was dual-purpose, it did produce some interesting findings, aided in identification of common themes and created efficiencies for both the research team and participants.

The stakeholder outreach process resulted in a number of contributions to the roadmap, including: 1) confirmation of the research team’s findings from the literature review on high-level themes of interest; 2) contribution of additional research ideas to the database; and 3) identification of high priority issues that cross ACRP topic areas.

3.2 Research Prioritization Overview

To assist in the categorization and prioritization of research ideas, the research team conducted a literature survey to determine the process by which other industry organizations have prioritized research projects, and the guidelines and methodologies that they have developed for evaluating potential projects. One important finding is that most research organizations have not adopted a single, consolidated prioritization methodology. Instead, they apply a set (or sets) of key principles when evaluating research ideas. This allows the organization(s) to prioritize research projects based on their unique needs or interests. The research team has adopted a similar approach for the research roadmap, whereby we have identified a set of key principles for evaluating ideas that mirror ACRP’s own set of criteria for evaluating submitted problem statements.

3.2.1 Prioritization Criteria

The research team identified a set of key prioritization criteria. The prioritization of research ideas is both subjective, based on the knowledge and experience of research team and Project Panel members, and objective where possible (for example is the idea duplicative). The research team developed a simple scoring mechanism for each prioritization criteria based on the process ACRP uses to rank submitted problem statements. The methodology was then applied to each research idea through a survey of Project Panel members. The methodology is intended to serve as a high-level screening tool for determining priority of ideas relative to one another, and not to indicate a specific year in which the research should take place. The scores from each criteria were added up for each idea, and used to rank order the research ideas relative to one another.

1) Avoidance of Duplicative Efforts

This criteria was applied to ensure that the proposed research ideas have not been, nor are currently being addressed by ACRP or other research institutions. Ideas that are duplicative will not be included in the roadmap unless the information in existing sources is out of date and an update is warranted.

2) Applicability

This criteria refers to the approximate portion of the airport industry that could potentially benefit from the results of the research. Some ACRP research projects have been geared specifically to small airports for example, while others have been more applicable to large airports in practice. This criteria recognizes the importance of ACRP selecting research projects that are not so narrowly tailored as to be beneficial to only small sub-sets of airports.

3) Timeliness

This criteria addresses the timeliness of the research problem, essentially determining if sufficient data exists to conduct research, or if additional time is necessary for impacts of the problem/challenge to be understood. For example, the number of autonomous vehicles in use at airports currently is very limited, so there may not be enough data to examine their impact on airport operations and maintenance needs for several more years.

Research ideas that address a current or urgent challenge to the industry and for which data exists rated higher in this category than research ideas which were not as urgent or was too new of a challenge to have sufficient data available to conduct research.

4) Understandable and Implementable

This criteria is based on what ACRP has in their own prioritization criteria, and refers to whether or not the research idea is understandable and logical. This criteria also addresses whether results will be implementable (i.e. the research is applied and is likely to result in information, data, or a tool that can be used by the aviation industry).

5) Collaboration and Coordination

Lastly, based on feedback from stakeholders, it is clear that a number of their interests are cross-departmental or multidisciplinary (for example, the interconnectivity of building systems and components, or the “internet of things”). At the same time, stakeholders identified a need to attract the interest of airport executive leadership to these cross-departmental research needs, as airport leadership have the responsibility for and the authority to empower their organizations to work collaboratively as opposed to strictly independently. This criterion was added to the prioritization scheme because it reflects this need and involves assessing whether or not the research addresses the integration of cross-departmental issues.

3.3 Application of Prioritization Methodology

Based on the application of the scoring methodology described in the previous section, the assessment of the research team and the Project Panel, the list of ideas for inclusion in the roadmap was refined and prioritized. The database represents our best understanding of the challenges and issues of interest in the area of airport O&M in the present. While the high-level themes are not anticipated to change over the next five years, individual research ideas may change, rise or fall relative to each other in priority. Additionally, new research ideas will arise and others may become irrelevant as conditions and technology change. The prioritization methodology can likewise be updated over time as new information becomes available.

4 Research Topics

Airports today face a plethora of O&M challenges. While many challenges are similar from airport to airport, many also reflect individual characteristics of each airport and their surrounding communities. For example, one common challenge for many airports in the United States (and indeed for transportation infrastructure overall), is the age of their facilities. A significant proportion of our nation's airports are between 40 to 60 years old. Additionally, many airports are growing quickly and handling larger volumes of passengers than their facilities were designed to manage.

The normal wear and tear on airport infrastructure is amplified by the continual and rapid evolution of technology, as well as the frequently changing landscape of aviation security. As a result, our nation's airports are struggling to keep up with the space and technology requirements of today, and need significant investments in their infrastructure to meet both current and future needs.

After a comprehensive review of existing research, ACRP's IdeaHub and stakeholder outreach, the research team identified over forty research ideas for inclusion on the roadmap. Each research idea is categorized into one of nine high-level themes, or categories, of O&M challenges for airports in the U.S. The high-level themes include: 1) Integrating Advanced and/or Disruptive Technologies; 2) Operations and Maintenance Workforce; 3) Safety and Security; 4) Continuity of Operations; 5) Sustainability and Resiliency; 6) Facility and Operational Modernization; 7) Unmanned Aerial Systems; 8) General Asset Management and Maintenance; and 9) Financial Resources and Procurement.

As these categories are broad, each research idea is further categorized into one of twelve sub-topics, including: 1) Building Information Modeling (BIM); 2) Collaborative Decision Making (CDM); 3) Curbside, Roadway and Vehicles; 4) Emergency Response and Crisis Preparedness; 5) General Aviation; 6) General O&M Guidance / Implementation Tools; 7) Integrating Advanced or Disruptive Technologies; 8) Joint Operations; 9) Operational Efficiency; 10) Replacement or Renewal of Assets; 11) Airspace Safety/Wildlife/Obstructions; and 12) Winter and Irregular Operations (IROPS).

Integrating Advanced or Disruptive Technologies is both a high-level theme and a sub-topic. This reflects the rapid pace of technological change and adoption within the airport and aviation industry, and the integral nature of airport IT systems to all areas of operations and airport lines of business.

Each high-level theme is described below with the list of research ideas categorized within that theme listed beneath. High-level themes are listed from those with the greatest number of research ideas in that category to the fewest. The individual research ideas are listed in order from highest to lowest priority based on the criteria described in section 3. The working title and objective for each research idea is included below (full background information for each idea is contained in the accompanying database, Appendix C). Next to each research idea (in parentheses) is the corresponding sub-topic.

A research idea contains a working title of the research project, a brief background section with a description of the challenge or knowledge gap (i.e. why research is needed), and what the research would seek to accomplish (objective). A research idea is less descriptive than a fully developed problem statement. The research ideas represent a mixture of topics generated from stakeholder outreach and meetings, the literature review, research team experience and entries from IdeaHub (some of these ideas have already been entered into IdeaHub).

4.1 Integrating Advanced and Disruptive Technologies



Terminal buildings and airport facilities are built to last decades, whereas the pace of technological change is exponential. Airports need to keep pace with new technologies and software, but this is difficult to do with aging systems and facilities, and limited maintenance budgets. Research is needed on how to modernize and maintain facilities to take advantage of emerging technologies, as well as how to integrate new technologies into old facilities and seemingly incompatible software programs (i.e. how to build or retrofit "smart buildings"). This is a multidisciplinary topic that involves airport planners, finance, IT, designers and contractors.

Airports need to understand emerging and disruptive technologies and services that are impacting the industry and how to adapt. Airports have experienced this with the rise of Transportation Network Companies (TNC) such as Uber and Lyft, redefining the way that passengers choose to arrive and depart from our nation's airports. These new entrants into the commercial and private vehicle domain on the arrival and departure curbs has increased the demand of an already taxed piece of airport real estate. A related example of an emerging disruptive technology is the advent of autonomous vehicles, on both the landside and airside. While autonomous vehicles were considered an emerging trend early in the stakeholder engagement process, this was ultimately rolled into the overall category of integrating new and advanced technologies.

Other IT-related topics include Building Information Modeling (BIM) programs and their use for operations, maintenance, security, planning, etc., as well as the emerging connectivity capabilities of systems and components through the Internet of Things (IoT). Both topics have received recent attention from ACRP and IFMA, and there is a real need to investigate the possible operational performance benefits of these technologies. These areas are of great interest to the industry and the roadmap anticipates follow on research is warranted.

- **Internet of Things (IoT) Standards for U.S. Airports (*Sub-topic: Operational Efficiency*)** – IoT technologies hold promise to provide many benefits to US airports and airlines, including the increase in operational performance, reduction in operational cost, increase in workflow management and increase in customer experience during air travel. IoT will also enhance cooperation between US airports and airlines and increase operational efficiencies for both parties, for example during irregular operations. The purpose of this research idea will be to propose, develop and encourage the use of IoT standards among U.S. airport industry stakeholders.
- **Modernizing Management Models for Commercial Ground Transportation (*Sub-topic: Curbside, Roadway and Vehicles*)** – The purpose of this research is to develop comprehensive high-level guidance regarding each major aspect of managing commercial ground transportation. The primary considerations include planning and forecasting demand and asset needs of service providers; Public Safety Code requirements; organizational structure review to ensure effective management of the activity as well as operational oversight and code enforcement; capital planning and associated debt service as well as operations and maintenance expense recovery, and; customer service support requirements at passenger terminal curbside and terminals.
- **Guidance on Data Integration for Real-Time Collaborative Decision Making (CDM) (*Sub-topic: Collaborative Decision Making*)** - Airports, Airlines and the FAA are identifying the benefits of real-time data sharing to facilitate CDM regarding other operational, security, and safety areas of the airport. However, there is no guidance on how to efficiently and effectively achieve real-time data sharing, nor common standards for facilitating the integration of disparate software platforms in order to allow for real-time data sharing. The objective of this research idea is to develop guidance on how the various parties can make use of their existing system software platforms and data exchange programs to enable real-time data sharing for airport-wide CDM. This idea is related to the research idea "Establishing Real-Time Decision Making", but focuses specifically on how to technically enable data sharing.
- **Smart Buildings: Performance Monitoring Systems and Centralizing Dashboards for Building Health and Resiliency (*Sub-topic: BIM*)** - The objective of this research idea is to identify technology solutions for automating building systems, and best practices for integrating these solutions into both new and existing airport IT systems and software.
- **Establishing Real-Time Collaborative Decision Making (*Sub-topic: Collaborative Decision Making*)** – Airports are comprised of a multitude of service providers who support one another in providing a safe, efficient and effective transportation system. The advent of computer-based, networked systems have enabled all service providers to develop highly automated and precise service delivery mechanisms which are highly vulnerable to disruptions of other service providers' delivery mechanisms. This has created a need to have real time situational awareness across all service providers, as well as a capability to collaborate in real time. The objective is to produce guidance on how airports and other stakeholders can develop a holistic approach to collaborative decision-making across the airport enterprise.

- **Guidebook to Assess Real-Time Operating Status of Non-Airport Controlled Assets (Sub-topic: Joint Operations)** - Develop a guidebook describing how airports and their tenants can make use of their existing system software platforms and aftermarket, “off-the-shelf” technologies for sensing and reporting system status. This will enable other airport service providers to integrate this information into their existing system software platforms to obtain the real time operational status of the systems that they are dependent upon for effectively delivering their services to their customers.
- **Guidebook on Integrating Commercial Space Operations into Airspace and Airport Operations (Sub-topic: General O&M Guidance or Implementation Tools)** – The objective of this research idea is to produce a thorough overview of the emerging commercial space market and its implications for airports and air traffic. The research should include launch and reentry operations and cover emerging markets such as commercial crew operations to the International Space Station, space tourism, and fast point-to-point travel. The guidebook should address integrating flight operations with existing air traffic.
- **Comprehensive Planning Guidance for Airport Curbside Roadway Design and Operations in the Era of Autonomous Vehicles (Sub-topic: Curbside, Roadway and Vehicles)** - Develop planning and operational guidance for ground transportation assets and associated service offerings, with particular focus on services associated with terminal curbsides and adjacent parking/staging facilities, in anticipation of the advent of autonomous as well as connected vehicle technologies.
- **Smart Airports and Connected Vehicle Technology (Sub-topic: Curbside, Roadway and Vehicles)** – The objective of this research idea is to evaluate the potential impacts to airport operations of connected vehicle technologies, including vehicle-to-vehicle and vehicle-to-infrastructure communications, considering both airside and landside impacts.

4.2 Operations and Maintenance Workforce



Workforce development and retention is a topic of great interest to all lines of business within the airport industry. ACI-NA, AAAE and ACC have all highlighted the need to attract new talent to airports as the current workforce of baby-boomers becomes eligible to retire. In addition to developing a pipeline of new talent to the field, airports need to train and develop their existing workforce to adapt to new technologies, work across silos and be more efficient. While this subject is not limited to O&M professionals, it is a challenge that came up during several of the stakeholder outreach activities, and is therefore included on the roadmap despite it applying across other areas of ACRP research.

The list of selected problem statements for 2019 includes two human resources related topics, including ACRP 06-06 "Cultivating Talent in the Airport Environment" and project 06-07 "Building Academic Programs to Cultivate Future Airport Industry Professionals". These projects may meet some of the needs described in the research ideas below, however as the requests for proposals have not yet been developed the level of focus on O&M workforce specifically is unknown at this time.

- **Guidebook on Professional Development and Retention for Airport Operations and Maintenance Personnel (Sub-topic: General O&M Guidance or Implementation Tools)** - Attrition, workforce development, and fostering the next generation of airport leaders are critical issues for airports of all sizes and all departments within airports. Along with many other professions, the number of airport employees who are baby boomers and eligible to retire in the near future is significant. In addition, the pace of technological change is exponential and airports rely more than ever on advanced digital technologies. This research project would result in a guidebook on professional development and retention best practices, as well as strategies to attract and train new employees in airport operations and maintenance fields.
- **Guidance for Integrating Airport IT Professionals with Other Departments to Implement New IT and Software Systems (Sub-topic: Integrating Advanced or Disruptive Technologies)** – Airport maintenance departments and IT departments are often not effectively integrated so as to ensure proper identification of line maintenance diagnostic/repair responsibilities to rapidly respond to, test and restore system

functionality prior to engaging an IT technician. Alternatively, inter-departmental integration might consider the embedding of IT technicians into the maintenance departments in order to provide timely and holistic support. The objective is to conduct a synthesis of best practices and/or develop guidance on how to effectively approach the IT-related diagnostic and restoration needs of systems maintained by airport maintenance departments.

- **Guidebook for Effective Transition from Construction of Assets to Operation and Maintenance (Sub-topic: Operational Efficiency)** – The objective is to develop guidance that will inform capital asset, new/replacement/renewal project managers on how to ensure that maintenance departments are capable of properly maintaining the assets and taking over assets on day 1 of project completion.
- **Primer on General Aviation Airport Management (Sub-topic: General Aviation)** - General Aviation airports that are owned and operated by municipalities are often managed by staff that serve in more than one capacity, or have a background in fields other than aviation. There is a need for basic GA airport management training and information for non-aviation professionals. The objective of this research is to develop guidance and training materials designed for new GA airport management who do not have an aviation background, and which can also serve as a primer for community leaders who serve in an airport oversight role.
- **Guidebook for Recruitment, Training and Technological Literacy in Airport Staffs (Sub-topic: Integrating Advanced or Disruptive Technologies)** – While similar to the idea above, this research idea is not limited to operations and maintenance staff, or only in-house staff. Virtually all airport departments are identifying new ways to improve their effectiveness and efficiency through the use of Information Technology. However, adopting new technologies normally result in organizational changes and restructuring of business practices that take time as well as other resources in the form of manpower and money. Many interviewees indicated that the adequate budgets and buy-in from other departments are not secured prior to acquisition of new software platforms. One of the challenges is identifying what core capabilities that airport staff, as well as outsourced service providers need to possess in order to succeed in the new technologically-enabled work environment. These core capabilities are an important part of the recruitment process for new employees as well as the onboarding of outsourced service providers. This research would result in guidance that identifies both challenges as well as best practice approaches regarding the recruitment, training and retention of the modern technologically-enabled airport workforce.
- **Airport Operational Training and Education for Outsourced Workforce (Sub-topic: Integrating Advanced or Disruptive Technologies)** – Airport-wide service providers report on the lack of education, training and capability of outsourced workforce employees in terms of both accidents, human-error, equipment/aircraft damage, and the inability to achieve operational performance goals. Research is needed to identify approaches that will enable outsourced workforce personnel to conduct themselves in an informed, safe and effective manner when placed in an airport work environment. The objective is to develop guidance on how to educate, train outsourced workforce personnel to ensure that they can perform their respective jobs in a safe, efficient and effective manner in the now highly interdependent and integrated world of airports.
- **Developing Training Programs with a Unionized Workforce (Sub-topic: Integrating Advanced or Disruptive Technologies)** - The rapid pace of technological change at airports necessitates constant updating of training programs and plans. Airports often employ unionized workers who have certain requirements and processes for developing their own training and skill requirements for union membership. There is a need for guidance on how airports and unions can work collaboratively to develop more flexible training plans to address new technologies. The objective is to develop guidance on how to work with union leadership in communicating training needs and upcoming / emerging technologies in their training plans and programs.

4.3 Safety and Security



Moving people and goods safely is the primary objective of the airport industry and thus ensuring the safe operation of aircraft and vehicles at airports is paramount. At the same time, the rise in the frequency and severity of terrorist attacks at international and domestic airports is an urgent challenge for our industry, both on a local and global scale. Airports are seeking solutions to better prepare for and prevent these attacks, and respond to regulatory changes.

Both safety and security issues have been addressed by ACRP, in research fields other than operations or maintenance and by the National Safe Skies Alliance. However safety and security are still front of mind for the airport and industry practitioners interviewed during the stakeholder outreach process. As a result, the research ideas listed below are important to both airport O&M personnel but are also cross-disciplinary topics which could appropriately appear on more than one research roadmap.

- **Evaluating Common Safety and Security Standards Across General Aviation Airports (*Sub-Topic: General Aviation*)** – Non-certificated airports do not have the same safety and security standards that Part 139 airports do, but there is a wide range of standards and level of rigor in enforcing certain standards at GA airports across the country. This can create confusion amongst operators and makes it difficult for GA airports that do adhere to certain standards to enforce them. Research is needed to evaluate the safety and security needs of GA airports and whether common core standards are warranted. The objective of this research is to conduct a survey of practice regarding application of safety, security and operating standards at GA airports in the U.S., provide an analysis of the utility and possibility of updating common standards of practice.
- **Development of Joint Operations Centers (*Sub-Topic: Joint Operations*)** – Rapidly evolving global security threats requires a joint / coordinated response from the range of public safety and security agencies across the country and with airports. DHS, the FAA and airports have all recognized the need for real-time communication and collaboration across agencies on a continuous basis. This will enable effective integration and interoperability with existing operations centers to ensure agility and resiliency across organizations. The research objective is to develop guidance on how to develop a concept of operations and design of a Joint Operations Center.
- **Evaluation of Wildlife Hazard Management Plan Outcomes (*Sub-Topic: Airspace Safety / Wildlife/ Obstructions*)** – Nationally, the true effectiveness and performance of implemented airport Wildlife Hazard Management Plans has not been objectively and systematically evaluated. This proposed line of research will examine Airport Wildlife Hazard Management Plans, their implementation, and ability to successfully meet the wildlife management (and conservation) expectations and in consideration of the goals of the sponsoring airports and airport users. The objective is to provide guidance regarding airport wildlife management that is based upon a holistic review of the goals/objectives of both federal and state regulators of safeguarding flight operations, as well as regulators who are charged with safeguarding wildlife and the environment.
- **Ensuring Building Information Modeling System Data Security (*Sub-Topic: Building Information Modeling*)** – In order for BIM to be valuable to facilities and maintenance (i.e. achieve intended benefits such as ROI on investment, high level of equipment availability, etc.), the data must be pushed out to tablets, phones, and devices in the field. This creates a data security risk and airports need to ensure secure two-way data exchange. The challenge is how to satisfy data security requirements across stakeholder file servers and systems. The objective of this research idea is to develop guidance and best practices on data security from both within the airport and outside the airport industry.
- **Utilizing Advanced BIM Modeling for Safety, Security and Emergency Management Operations (*Sub-Topic: Building Information Modeling*)** – Use of advanced technology such as cameras for mapping or virtual/augmented reality for security personnel or first responders to utilize when responding to emergencies. An example is if a security camera is out of use due to smoke etc., responders would still be aware of the layout of the building. Research on systems that could provide relevant, virtual information that can give a varying audiences what they need to secure the space. The objective of this research idea is to develop guidance or case studies on the use of BIM data for safety and security purposes, the

capabilities, benefits, risks and potential problems can be explored. Use of case studies outside the aviation industry is encouraged.

- **Immigration Regulatory Changes and their Impacts on Airport Operations (*Sub-topic: Emergency Response and Crisis Preparedness*)** – Recent changes to immigration regulations have impacted airports due to the operational and security challenges of demonstrators, and the needs of stranded passengers. This project would look at legal, operational, communications and passenger service issues associated with these types of disruptions.

4.4 Continuity of Operations



The economic expansion that has occurred since the 2008-2009 downturn has translated into increased passenger numbers and busier airports. While the number of operations at many airports may be constant or lower than prior peaks, changes in fleet mix (larger aircraft) and higher passenger loads means that there are more passengers moving through airport facilities. In addition, as airlines have adjusted fleets and schedules so that there are fewer spare aircraft and empty seats on planes to accommodate passengers in the event of a delay or cancelled flight.

As airports have become busier, they have to adjust their operations and infrastructure to meet this demand. As described in the NPIAS and publications from ACC and ACI-NA, there is a focus on renovating, updating and /or building new terminals and landside infrastructure to accommodate the loads. Many airports in the U.S. are decades old and were not built to handle the passenger traffic volume experienced today. The construction to update facilities also has a big impact on airport operations.

It is not surprising therefore that the high-level issue of ensuring continuity of operations, for example during periods of disruption whether it be weather, systems failures, security incidents, new construction projects and/or major maintenance projects etc., and having the ability to rapidly recover from such incidents, were two common themes. Once again, the research ideas in this topic area highlight the need for information technology platforms that enable shared-situational awareness to facilitate Collaborative Decision Making real time

- **Optimizing Airfield Snow Removal (*Sub-topic: Winter / Irregular Operations*)** - Research best practices focused on managing the resources at airports to optimize the number of runways and taxiways that can be kept open during winter storms. The guidelines should include using process optimization to reduce variation caused by unpredictable weather events and computer simulation analyses to optimize the number of equipment needed, resources required, and optimize the best deployment pattern for the snow removal equipment.
- **Ensuring Continuity of Operations during Adverse Weather (*Sub-topic: Winter / Irregular Operations* –** The objective of this research project is to develop guidance on the planning parameters, as well as best practices and approaches for maintaining continuity of operations over extended periods. Primary factors to consider include passenger needs, workforce availability, as well as equipment availability and resupply of consumable resources, and coordination with metropolitan planning organizations, transit, etc. The intent of this project is to update lessons learned since publication of past related ACRP projects.
- **Maintenance and Renewal of Assets During Limited Non-Operating Hours (*Sub-topic: Operational Efficiency*)** - The objective of this research idea is to develop guidance to assist airports in identifying the best practices and approaches to both inspecting and maintaining airfields (both movement areas and non-movement areas), in order to minimize disruptions during operational hours. Additionally, to identify how to conduct necessary repairs in an expedited manner during operating hours, and how to conduct preventative maintenance as well as extensive repairs during non-operating hours.
- **Continuity of Airport Operations and Maintenance: Ensuring Redundancy during the Design and Construction Process (*Sub-topic: Operational Efficiency*)** – The objective of this idea is to develop guidance on building redundancy into facilities during the design and construction process, and its importance in maintaining continuity of operations during periods of system failure. Additionally, to provide guidance on how to effectively achieve a continuity of operations in the event that systems that support operations of passengers, tenants or other service providers becomes inoperable.

- **Busing Resources for Aircraft Emergencies and Transportation Outages (*Sub-topic: Emergency Response and Crisis Preparedness*)** – The purpose of this research is to determine the best practices for providing and contracting for backup transportation within an airport for the following situations: aircraft emergencies (where passengers must deplane an aircraft and be bused to the terminal), planned and unplanned outages of alternative intra-airport transportation systems such as trains, and transporting passengers and staff off-airport in the event of airport closure for security reasons for example.

4.5 Sustainability and Resiliency of Infrastructure



Sustainability and resiliency are two related topics that have been of great interest to the airport industry over the last several years. The extensive list of sustainability and resiliency related ACRP projects is a testament to that interest. Although the majority of these projects are products of the environment field, there is an opportunity to consider these topics through the lens of O&M of airport facilities.

Climate change and extreme weather are two challenges within this theme area that airports currently face. Resiliency planning is important for natural disasters as well as man-made events. Airports must decide the extent to which they intend to invest in infrastructure resiliency measures in the face of imperfect data, making it difficult to justify when funding is already tight.

Airports may also be faced with expectations from their community to operate in a less impactful manner. The trend towards adopting more sustainable building practices, using more sustainable materials and improving conditions for workers has increased in the past several years. More airports are realizing efficiency gains and cost savings by incorporating sustainability into their facility management and operational procedures. This is evidenced through continued interest by airports in the U.S Green Building Council's LEED rating system (for existing buildings as well as new construction), FAA's grant funding for sustainable management and master plans, and the more recent arrival of the Institute for Sustainable Infrastructure's Envision rating system for infrastructure. The USGBC continues to roll out new rating systems as well, which may or may not be appropriate for airports, such as PEER (Performance Excellence in Electricity Renewal), WELL (a certification system designed for the built environment measuring impacts on occupants human health and well-being) and Parksmart (a program of sustainable practices in parking structures).

For those airports that have not developed guidelines or protocols for how to incorporate sustainability however, it can be a daunting challenge to know where to start and what initiatives, practices or programs are right for their facility. For those airports that have already made strides in this area, a number of questions remain about the best way to track performance and monetize the benefits, and how to take advantage of new technologies to operate in a more sustainable manner, and ultimately to be more efficient and save money.

This theme is particularly important as the industry will make significant investments in new and rehabilitated terminals and buildings over the next five years. Some research ideas in this area on the roadmap include:

- **Integrating Airport and Community Resiliency Planning (*Sub-Topic: Emergency Response and Crisis Preparedness*)** – The rise in Severe Weather Events (e.g., hurricanes, tornadoes, high winds) as well as the effects of rising sea levels, and changing weather patterns (e.g., periods of extended drought) have caused significant flooding and damage to many regions across the United States. Airports have begun to examine what can be accomplished on airport to make airport infrastructure more resilient to the effects of such weather activity. The objective is to develop guidance on how airports can engage their local communities in Integrated Resiliency Planning.
- **Advancing Building Automation and Energy Management Systems (*Sub-Topic: Integrating Technology or Disruptive Technologies*)** – This idea addresses two unmet needs that require future research regarding advanced building automation and energy management. The first is the identification of the cost of integrating these systems into the existing software platforms in order to realize the return on investment potential of the new software. Second, new software platforms are capable of replacing legacy systems in other areas of specialization at an airport. However, they also require the redevelopment of existing work flow processes and the training of airport staff in departments that will be making use of these new systems. The objective of this research is to develop a guidebook of best practices that have been used to

effectively integrate new software platforms into both legacy software systems and existing work flow processes of the airport department activities they are intended to support.

- **Evaluation of General Aviation Airport Financial Needs Considering Regional Risks and National Categorization (*Sub-Topic: General Aviation*)** – Regional natural disaster threats add a layer of complexity to the determination of the value or role of a General Aviation (GA) airport in the event such a disaster should occur. Research is needed to evaluate these regional risks and how they would impact airports in that region. Specifically, the research would examine the role of GA airports in the event a regional disaster renders other airports in the region inoperable for a time. The objective is to develop a resource for GA airports to understand their risks from regional disaster threats and role in recovery. The guidance would also inform and educate state departments of transportation the FAA as they update to the classification report, update their system plans and understand the financial needs of GA airports.
- **Selecting and Implementing the Right Certification or Rating System (*Sub-Topic: Operational Efficiency*)**– As existing rating and certification systems are updated (LEED for campus / multiple buildings, EPA Energy Star) and newer sustainability rating systems emerge (Envision, PEER, WELL), information is needed for airports to determine what the cost savings or unintended consequences are from an operations and maintenance standpoint. This will help airports determine which rating or certification system, if any, is right for their project / facility. The objective of this research idea is to produce guidance for selecting and implementing the most applicable sustainability certification or rating system for airport projects and facilities.

4.6 Facility and Operational Modernization



This topic aligns closely with the Integrating Advanced and Disruptive Technologies theme, as the modernization of facilities necessitates the acquisition and incorporation of new technologies. Likewise, the integration of new technologies into existing facilities updates their operation and function. Considering that the bulk of airport capital projects over the next five years are focused on terminals and landside facilities (according to the NPIAS), this subject was frequently mentioned by stakeholders in both the operations and maintenance and design and construction roadmap outreach efforts. Modernization of airports can include both physical assets as well as processes and management models. Airport policies and procedures need to be updated as the industry experiences changes, for example in passenger ground transportation options. The following three specific topics are included in this category:

- **Integrating New Technologies into Aging Infrastructure (*Sub-topic: Replacement or Renewal of Assets*)** - Develop a guidebook on how to evaluate, select, and implement information technology-enabled capabilities into aging systems that have not yet reached the end of their useful life. The intent is to assist airports to enable more efficient and effective use and restoration of operationally critical systems for the remaining lifespan of the old infrastructure, while minimizing the costs for systems that will need to be replaced.
- **Guidebook on Revising Curbside-Roadway Operations and Demand Profiles to Address Changing Needs (*Sub-topic: Curbside, Roadway and Vehicles*)** - The advances in autonomous as well as connected vehicle technologies has the potential to create entirely new ways of transporting people and goods throughout society. Associated with this is a rapidly transforming service environment as passengers, existing service providers and new-entrants to the marketplace begin to make use of these new technologies. The objective is to develop revised curbside-roadway operations and demand profiles (for all major users of such infrastructure) for use by airport planners and Commercial Ground Transportation Managers.
- **Management Models for Commercial Ground Transportation (*Sub-topic: Curbside, Roadway and Vehicles*)** – The objective is to develop guidance that enables commercial ground transportation managers to understand the evolving industry and the likely impacts to existing commercial ground transportation management models, as well as guidance on how to effectively revise/refine the existing management model to meet the needs of the marketplace.

4.7 Unmanned Aerial Systems / Vehicles



Unmanned aerial systems or vehicles (UAS / UAVs), having been developed, deployed and matured over the years by the United States Armed Forces, are in high demand by both recreational users as well as commercial users. The FAA currently estimates that the number of UASs operating in the United States will rise from 2.5 million in 2016 to 7 million by 2020. While the FAA is responsible for controlling all aircraft operations and maintaining the safety of the National Airspace System (NAS), there are other challenges as well as opportunities created by UASs that directly affect airport operations and maintenance. These fall into the following broad categories which are not intended to be exhaustive:

- **Integrating UASs and Emergency Response (Sub-Topic: Emergency Response and Crisis Preparedness)** – The objective of this project is to develop guidance that identifies UAS capabilities that enhance emergency response capabilities as well as how to integrate these systems, and their capabilities into airport emergency response plans and operations.
- **Airspace Right of Way (Sub-Topic: Airspace Safety/ Wildlife/ Obstructions)** - This research idea involves a thoughtful examination of airspace and recommendations on how to de-conflict relevant stakeholders, in terms of operating aircraft and UAS, using airspace 400-1000 feet would be useful. The objective is to develop practical, usable, efficient, and fair methods for clarifying use of operational airspace near to the ground.
- **Protecting Airport Operations from UASs (Sub-Topic: Airspace Safety/ Wildlife/ Obstructions)** - UASs are demonstrating wide ranging capabilities that can enhance the effectiveness and efficiency of diverse applications that provide great benefit to users. Enhanced mobility, high precision flight tracks, pre-programmed routing to enable safe day/night use, are just a few of the capabilities of UASs. However these same capabilities along with a small profile, agility, capability of flying autonomously and in coordinated "swarm" operations, also creates a threat to security when operated by a "bad actor". This project would develop guidance that identifies existing means to detect, interdict and defeat nefarious UAS activities so as to preserve a safe and secure airport operating environment.

4.8 General Asset Management and Maintenance



While the topics described above sort research ideas into high-level categories and subtopics, several research ideas generated during the roadmap development process were more general in nature, and did not fit neatly into one of these categories. These remaining ideas have merit and practical application in the area of airport operation and maintenance, apply to specific knowledge gaps, and were thus included under a separate category for general asset management and maintenance.

- **Guidance for Airport Tree Removal (Sub-Topic: Airspace Safety/ Wildlife/ Obstructions)** – The objective of this research project is to develop a synthesis of current best practices regarding airport tree removal, including guidance on how to streamline the environmental review process.
- **Summary of Practice for Automated Pavement Condition Surveys (Sub-Topic: Replacement or Renewal of Assets)** - Pavement condition data is a critical component of all pavement management systems. The accuracy and validity of pavement condition data is very crucial to many activities conducted by airports and local agencies. The objective for this synthesis project is to document agency practices, challenges, and success in conducting automated pavement condition data collection surveys. The guidance may showcase successful practices, integration of automated data collection into pavement management systems, and efforts needed for reporting pavement condition.
- **Integrated and Comprehensive Management of General Aviation Airport Maintenance Operations (Sub-Topic: General Aviation)** – The objective of this research project is to craft flexible but comprehensive and coordinated GA airport infrastructure maintenance operations programs and protocols. This will achieve the purpose of infrastructure preservation cost savings, cost deferrals and extend the useful service life of

existing infrastructure. The guidebook could outline methods and means of comprehensively integrating the management of most all airport maintenance operations.

4.9 Financial Resources and Procurement



Financial resources are always a limiting factor for airports as they strive to do more with less – for example dealing with the diminished purchasing power of the Passenger Facility Charge (PFC), and capital needs that exceed what is budgeted in the Airport Improvement Program funds (AIP). The availability of funding for airport projects is of great interest to many stakeholders, but airports are somewhat limited in their ability to expand access to capital. Airports must determine priorities, and understanding the true cost of projects, actions and operations is important – as well as understanding how new technologies can result in cost savings and further efficiencies. Research on innovative financing models such as public-private partnerships is included on the Design and Construction Research Roadmap, however two ideas for this category include:

- **Understanding the Economic Benefits and Needs of General Aviation Airports (*Sub-Topic: General Aviation*)** - The economic benefits to communities are well understood for large hub airports, but less so for smaller and GA airports. It can be difficult to quantify the economic benefits of general aviation to their communities during budget shortages. Guidance is needed for GA airports to develop a value proposition and show return on investment for airport needs. The objective is to develop guidance on how to demonstrate direct and indirect economic benefits of GA airports for community leaders in support of obtaining required operations and maintenance budget needs.
- **Consequences of Delayed Maintenance of Airport Assets (*Sub-Topic: Replacement or Renewal of Assets*)**– The objective of this research project is to present a process for quantifying the consequences of delayed maintenance of airport assets, from a financial standpoint as well as other variables like time out of service. It will cover asset preservation policies, maintenance and budget needs, and the analysis of delayed maintenance scenarios, using case studies from within and external to the airport industry as appropriate.

5 Conclusion

During the roadmap development process, it was clear that the significant impact of new technologies on the airport industry, in O&M but also more broadly across all business areas of the airport is a reoccurring theme. An illustrative and oft-cited example of the impact of new technologies on the industry (and airports are not unique in this regard), is the rise and integration of transportation network companies (TNCs). TNCs have revolutionized urban and suburban transportation options, including how passengers and employees get to and from our nation's airports. This technology has led to many significant changes at airports, including curbside design and configuration, service provider relationships (contracts with TNCs versus taxis and limousine services for example), and revenue models (i.e. declining parking garage income). A decade ago, Uber did not exist, and now the service is available in every U.S. major city, serving 146 U.S. airports (Uber, 2018). As a result, airports have had to quickly transform their operations, facilities and infrastructure to accommodate this radically changing sector of the transportation sector within a few short years.

Autonomous vehicles are another advanced and potentially enabling/disruptive technology with implications for airports, both on the landside and airside. The rise of connected devices, systems and individual components into integrated building management systems is continuing to expand as well. Airports will need guidance on how to effectively select and integrate new technologies, which is important not only during the design and construction phase of airport development and procurement but also results in lasting impacts on the operation and maintenance of these facilities for decades. New and advanced technologies will impact airports across all lines of business, and adapting to them will require a collaborative approach. The industry is beginning to take a more holistic view of adapting to these types of challenges, and therefore the industry's research program needs to do so as well.

As exciting as groundbreaking new technologies are however, there are a number of other topics that speak to airport industry goals and objectives that require research attention over the next five years. As the research roadmap demonstrates, there are opportunities for advancement of our collective knowledge in practice as it relates to O&M for more efficient operation of facilities, better customer service and passenger experience, enhanced safety, and more sustainable and resilient infrastructure at our nation's airports.

The roadmap is not intended to cover every possible topic of interest, nor can it accurately predict the changes that will occur in the airport industry. However, it does represent the industry's understanding of the challenges that exist today, and those that are expected to continue and emerge in the near future. While the specific research ideas may change, the roadmap serves as a foundation to support the overarching goals of our industry, which are to ensure a safe and secure air transportation system, improve customer service, and enable the sector's continued growth into the future.

6 References

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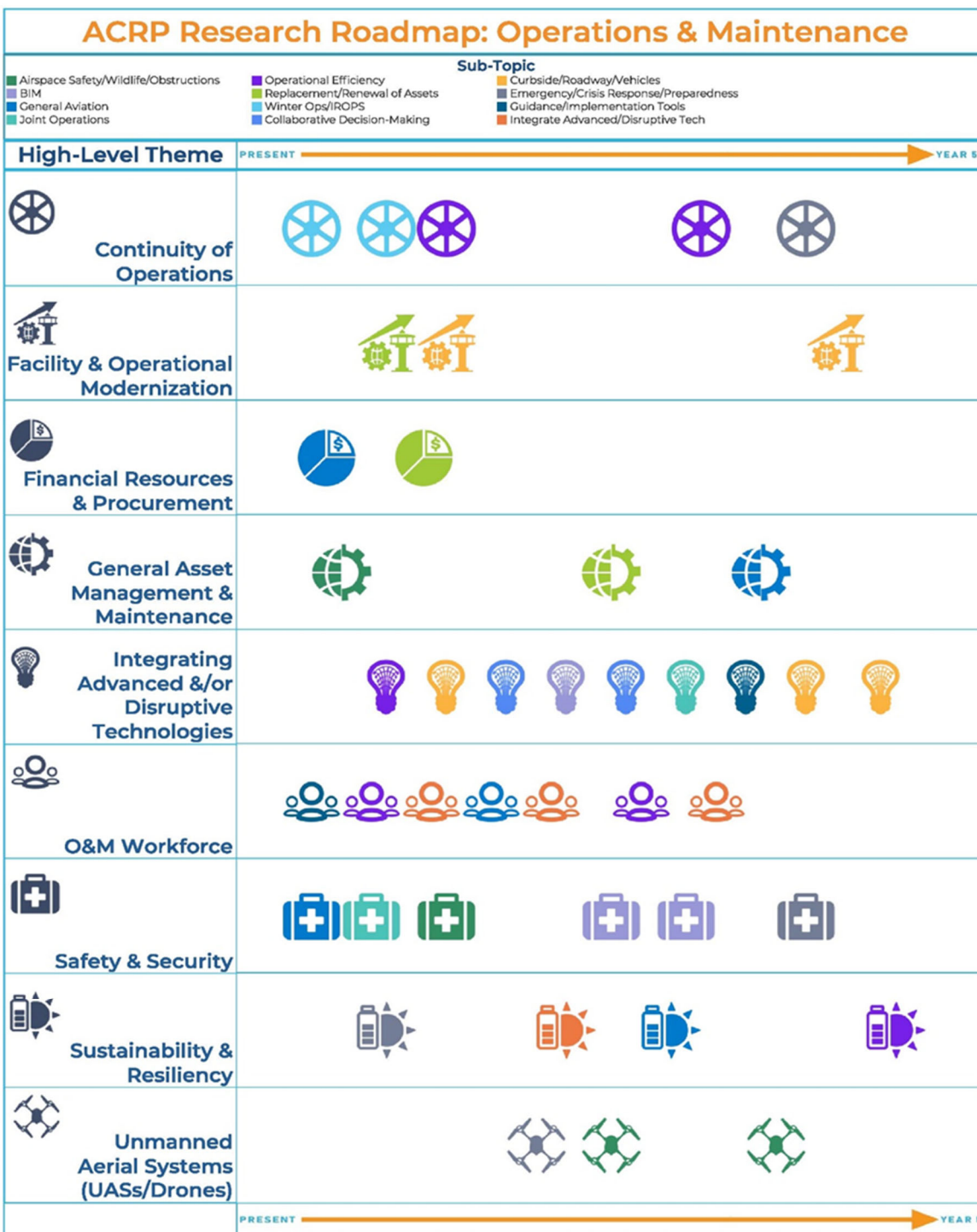
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Appendix A Acronyms

A4A	Airlines For America
AAAE	American Association of Airport Executives
ACC	Airport Consultants Council
ACI-NA	Airports Council International – North America
ACRP	Airport Cooperative Research Program
AOC	ACRP Oversight Committee
ATO	Air Traffic Organization
BIM	Building Information Management
EOC	Emergency Operations Center
FAA	Federal Aviation Administration
FM	Facilities Maintenance
IFMA	International Facilities Management Association
IoT	Internet of Things
IROPS	Irregular Operations
NARP	National Aviation Research Plan
NAS	National Academy of Sciences, or National Airspace System
NPIAS	National Plan of Integrated Airport System
O&M	Operations and Maintenance
PARAS	National Safe Skies Alliance Program for Applied Research in Airport Security
PM	Preventative Maintenance
REDAC	Research, Engineering and Development Advisory Committee
RTCA	Radio Technical Commission for Aeronautics
TNC	Transportation Network Companies
TRB	Transportation Research Board
USGBC	U.S. Green Building Council
UAS / UAV	Unmanned Aerial System / Unmanned Aerial Vehicles

Appendix B Visual Research Roadmap

The interactive version of the Operations and Maintenance Research Roadmap is available online at https://public.tableau.com/profile/acrp#!vizhome/ACRPRoadmapOperationsMaintenance_0/ACRPOperationsMaintenanceResearchRoadmap. A static version of the Roadmap without these features appears below.



Appendix C Research Idea Database

The Research Idea Database is a searchable Excel file ([provided as a separate file](#)) containing all forty-two ideas generated during the project. The database can be filtered by a number of categories, including high-level theme, sub-topic, keyword, related research (existing or ongoing research), idea rank (based on overall prioritization score) and by related ACRP Idea Hub tag. Below is the list of columns and content contained in the database.

- Column A contains the idea identification number for tracking purposes. This number does not reflect the rank or prioritization score of the idea.
- Column B contains the prioritization score for each idea, based on rankings from the Project Panel and the research team across the set of prioritization criteria. The idea with the highest prioritization score is assigned a rank of 1. The idea with the lowest prioritization score is assigned a rank of 42. Several ideas received the same *score*, and were accordingly assigned the same priority *rank*. The ranking scheme therefore skips numbers to reflect this. For example, if two ideas both achieve the highest possible prioritization score, they would both be assigned a rank of 1. The idea with the next highest score would be assigned a rank of 3 (2 is skipped).
- Column C includes information on which overarching, general industry and FAA goals (Safe and Secure Air Transportation System; Capacity, Growth and Efficiency; and Customer Service and Travel Experience) each idea addresses.
- Column D contains the high-level theme of each individual idea, while Column E contains the sub-topic.
- Column F contains the working title of the research idea.
- Column G contains the background information for each idea, and provides context and justification for the research.
- Column H contains the research objective for each idea.
- Column I lists related research projects, both completed and ongoing, for additional background information.
- Column J lists all related ACRP IdeaHub tags.