

AIRPORT
COOPERATIVE
RESEARCH
PROGRAM

ACRP

Web-Only Document 40:

Airport Design and Construction Narrative Research Roadmap

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Contractor's Final Report for ACRP 11-02/Task 30
Submitted March 2019

The National Academies of
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TRANSPORTATION RESEARCH BOARD

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COOPERATIVE RESEARCH PROGRAMS

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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.

The ACRP Project 11-02/Task 30, “Research Roadmap in the Area of Design and Construction of Airport Facilities and Infrastructure” outlines the key research gaps and areas of topics of interest for airports in this field over the next five years. The roadmap was developed through a review of relevant research and broad stakeholder engagement efforts with industry practitioners. The research ideas generated as part of this project are organized into seven high-level themes that represent the main areas and challenges of interest to airports in design and construction. While design and construction are designated as their own research areas within the ACRP program, this roadmap takes a consolidated approach and combines the two in both the report and the visual representation.

Based on the results of the outreach and literature review, 40 research ideas were generated and categorized into seven high-level themes (listed in descending order from the theme with the greatest number of research ideas to the least):



Customer Service



Integrating Advanced and/or Disruptive Technologies



Project Management, Delivery and Finance Models



Safety and Security



Sustainability and Resiliency



General Design and Construction



Workforce Development

The research ideas are further categorized into twelve subtopics: 1) Passenger Experience; 2) Integrating Technology and Data; 3) Finance and Revenue Development; 4) Alternative Approaches to Project Delivery

Mechanisms; 5) Sustainable Design and Construction; 6) Innovative Approaches to Security / TSA Operations; 7) Construction Best Practices / Guidance and Tools; 8) Modernizing and Retrofitting Airport Facilities; 9) Construction Materials; 10) Accommodating Changing Demographics; 11) Curbside, Roadways and Vehicles; and 12) Unmanned Aerial Systems

The ideas contained in the research roadmap represent a wide variety of themes and subtopics, many of which would also be appropriate for research roadmaps in other ACRP fields. As airports modernize, the need to collaborate and coordinate their activities across virtually all disciplines is important, which is evidenced by the multi-dimensional nature of the ideas in the roadmap. Research associated with the ideas contained in this roadmap will benefit from insights of airport executive leadership, operators, maintainers, planners and human resources executives, in addition to design and construction experts, given the role they play in integrating the efforts of all airport personnel.

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, subtopics 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 online at ACRP's website.

The completed Research Roadmap in the Area of Design and Construction of Airport Facilities consists of the following products:

- Narrative Research Roadmap report (this document)
- Graphical representation of the roadmap (static version in Appendix B, interactive version available on ACRP's website)
- Research Ideas Database (separate Excel file labeled Appendix C)
- Narrated PowerPoint presentation describing the roadmap and related products

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”¹ 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 is 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 design and construction. 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 30, “Research Roadmap in the Area of Design and Construction of Airport Facilities and Infrastructure”. 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 project.s”

The objective of this project is the development of a five-year, prioritized research roadmap that identifies gaps in knowledge and research ideas in the area of design and construction of airport facilities. 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 Design and Construction 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 research themes and subtopics, in order to categorize individual research ideas. The intent is for the research ideas included in the roadmap to serve as resources for industry practitioners developing problem statements over the next five years. The roadmap provides the reader with an understanding of the main topics of interest in the field of airport design and construction, how the ideas relate to one another, and how the research ideas address overarching industry goals and objectives.

¹ Transportation Research Board website, accessed March 10, 2018. <http://www.trb.org/ACRP/ACRP.aspx>

In order for this roadmap to accurately reflect the needs of industry and address the key challenges in the fields of design and construction, 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 has 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 as well. The roadmap development process considered the existing sources to avoid 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 design and construction. 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 an online platform for problem statement development. IdeaHub 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 guide allocation of funding.

One key observation that the research team made during the development of the research roadmaps is that many emerging challenges span multiple areas of airport operations, which call for cross-cutting, collaborative projects. In fact, many ideas that were generated during the development of the Design and Construction Research Roadmap could easily fit on other roadmaps, such as Policy and Planning, Environmental, and/or Operations and Maintenance. In recognition of this, IdeaHub provides a mechanism for users to categorize their research idea(s) by selecting from multiple different "tags"². Ideally the research roadmaps and IdeaHub will act as tools to enhance collaboration between stakeholders on the development of problem statements.

1.3 Roadmap Development Process

The Design and Construction Research Roadmap is based on two main sources of information: a review of existing and ongoing research 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

² There are approximately 30 topics that IdeaHub users can select from to categorize their research ideas, which are called tags. Tags include subjects such as sustainability, human resources, customer experience, airport planning, etc. When a user first enters an idea in IdeaHub, they are prompted to select a primary research area, and can then select multiple other tags to further categorize their topic. The intent is for practitioners to more easily categorize multi-dimensional topics and to more easily search for ideas of interest. The Idea Database accompanying this project includes suggested IdeaHub tags for each idea.

foundation for an initial set of high-level research themes and example research ideas that were used as the 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 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 30 includes four products: the Narrative Report (this document); Visual Research Roadmap; Research Idea Database; and the Narrated PowerPoint presentation.

The Visual Research Roadmap is included as an appendix to this document, but the interactive version is located on ACRP's website. 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 subtopic. By hovering over each research idea icon on the Visual Roadmap, users can read the research idea title, background information and objective.

The Research Idea Database is a searchable Excel file containing all 40 ideas generated during the project. The database can be filtered by a number of categories, including high-level theme, subtopic, keyword, related research (existing or ongoing research), and by related ACRP Idea Hub tag.

The Narrated PowerPoint presentation provides an overview of the project, the roadmap development process and instructions for how to read the visual roadmap.

2 Literature Review

The research team reviewed existing, ongoing and planned research from a variety of sources. The most prolific source of research relating to the area of airport design and construction is the Airport Cooperative Research Program (ACRP) itself. In addition to projects in ACRP, the research team searched the other TRB cooperative research programs such as the Transit Cooperative Research Program (TCRP) for related research. The second largest source of research the team reviewed was from the International Facilities Management Association (IFMA). The Federal Aviation Administration (FAA) also conducts a significant amount of research relevant to airports, for example through their Technical Center, and university centers of excellence. Many offices 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), published in 2016 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]
- 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 design and construction 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 approximately 90 resources that have some applicability to this issue area, and organized the publications by high-level issue area 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

ACRP had the most information in the areas of airport design and construction. The ACRP Research Fields 7: Design and 8: Construction were a particular focus of the research team, though publications from all other research fields were reviewed as well. ACRP Research Field 7 (Design) contains fifteen research projects that are either published, in progress or planned. There are only two projects completed or anticipated in Research Field 8 (Construction). All ACRP publications (reports, synthesis reports, impacts on practice, etc.), FAA guidance and advisory circulars and other resources related to terminal designs are included in ACRP's Airport Passenger Terminal Design Library.³

³ Developed as part of ACRP Project 07-15, accessed at: <https://crp.trb.org/acrp0715/>

The literature review focused on resources published within the past five years, but did include some older research. Older (pre-2011) research products were reviewed when they covered the same or similar topics as identified during the stakeholder outreach process, to determine if an update is warranted.

The vast majority of ACRP research in the Design and Construction fields focuses on traditional aspects of these areas, including financing mechanisms, project management, and best practices for usage of various materials in the airport environment.

Existing and ongoing ACRP research projects were organized into theme area and subtopics in order to identify overarching trends and knowledge gaps. Overall, the distribution of existing ACRP sources we reviewed include:

- Sustainability related topics – 14 publications
 - Subtopics for publications in this category include: energy infrastructure, energy efficiency and renewable energy, electric vehicle charging stations, construction emissions, water efficiency, resiliency planning, and sustainability rating systems for example.
- Finance / Revenue / Procurement related topics – 10 publications
 - Subtopics include: non-aeronautical revenue, transportation network companies (TNCs), replacement or renewal of assets, airport privatization, project delivery methods and airport capital improvement estimation methodology.
- Integrating Advanced Technologies and IT-related topics – 7 publications
 - Subtopics for publications in this category include: advanced airport operations centers, Internet of Things (IoT) integration, general IT systems guidance and/or implementation tools, building information modeling (BIM), asset management and autonomous vehicles.
- Customer Service topics – 6 publications
 - Subtopics for publications in this category include: wayfinding, customer satisfaction, aging passengers and passengers with disabilities, service animals, and public address systems.
- Terminal related topics – 6 publications
 - Subtopics for publications in this category include: terminal design trends, common use facilities and equipment, accommodating service animals and pets, replacement or renewal of assets, and effective activation practices of airport terminal facilities.
- Planning, Phasing and Coordination of Projects topics – 5 publications
 - Subtopics include: maintaining systems availability to support ongoing operations, apron planning, general aviation facilities, passenger conveyance systems, airport capital planning processes.
- Overarching Design and Construction topics – 3 publications
 - Subtopics in this category include: ramp control facility development, sound insulation program longevity, cell-phone lot considerations, and airport terminal design.

The following high-level topics each had one or two publications: Airside Planning and Design; Climate Change and Severe Weather; Curbside and Roadways; Infrastructure Maintenance; NextGen, Safety and Unmanned Aerial Vehicles.

While there are limited specific research products specifically categorized under ACRP's "Design" or Construction research fields, all of the publications reviewed are applicable to airport design and construction in some manner, even though they are categorized in other fields. For example, there are a number of sustainability related topics within ACRP's body of research, which address various aspects of sustainable design and construction.

Sustainability as a concept promotes collaboration and integration in the design, development and operation of airports.

There has been considerable attention paid to research topics that address airport project financing and revenue development. ACRP has developed projects that provide guidance on the redevelopment of under-used facilities, the generation of non-aeronautical revenue, evaluating repair or replacement of assets, and calculating life-cycle costs for projects. During the outreach process, stakeholders repeatedly expressed an interest in additional guidance on revenue development, and guidance on replacing vs. renewing assets, which indicated a need for continued research into these subjects.

Integrating advanced technologies and reacting to disruptive technologies is a broad topic area, and encompasses a number of subtopics, both in the existing literature as well as the proposed ideas on the roadmap. Existing research in this category includes topics on BIM, integrating IoT considerations into airport design, IT systems at airports, and integrating TNCs into airport infrastructure for example. Because this field is so broad and constantly evolving, a number of research ideas appear on the roadmap to address the varied topics in this theme.

Existing research addressing planning, phasing and coordination of airport design and construction projects provide guidance on planning airport facilities, automated people movers, aprons and general aviation facilities, and collaborative decision making for airport capital improvements. Project delivery and finance mechanisms were two topics that came up repeatedly during the stakeholder outreach process, indicating that this a gap to be address by future research.

2.2 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 programs⁴ 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 R&D spending. This source provided further insight into research currently underway or planned by the FAA.

⁴ FAA National Aviation Research Plan, Report to Congress, 2016

The research team reviewed FAA documentation specifically related to NextGen⁵ as well as their research plan and prioritization regarding the implementation of NextGen technologies.⁶ 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 AIP grant funding over the next five 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. Understanding these development trends was useful for putting potential research ideas into context of overall industry needs. The shift in focus shifts from airfield to terminal projects is coinciding with an increasing interest on customer and passenger experience with respect to terminal and facility design and construction.

Finally, the research team reviewed the National Safe Skies Alliance, Inc.'s "Recommended Security Guidelines for Airport Planning, Design & Construction" document (published in April 2017), the fifth iteration of this guidance. This document, previously published by the Transportation Security Administration (TSA) is now managed by the Safe Skies research program modeled after ACRP, the Program for Applied Research in Airport Security (PARAS). PARAS publishes relevant guidance for airports on design and construction topics as they relate to security. Several research ideas were generated from stakeholders during the outreach phase that were similar to published or ongoing PARAS projects. Therefore ongoing coordination between the two programs would be beneficial.

2.3 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 Consultants 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 design and construction 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, it highlights the need for ensuring continuity of operations during construction projects. This is a topic of interest to both the design and construction but also the airport operations stakeholders. RTCA has also taken the multi-dimensional approach to research tasks requested of them by the FAA. By including

⁵ FAA defines NextGen as "the FAA-led modernization of our nation's air transportation system. Its goal is to increase the safety, efficiency, capacity, predictability, and resiliency of American aviation."

⁶ FAA Technical Center, "Airport Technology Research Program", 2012

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.

2.4 Other Stakeholders

Through the stakeholder outreach process, we were directed to resources developed by San Diego International Airport, including two 'lessons learned' documents they developed in their design and construction process. The first of these documents, *The Green Build Recommended Best Practices*, details various capital improvement topics such as programmatic documents, alternative delivery methods, phased facility occupancy, and executive collaboration efforts. The second, *The Rental Car Center Knowledge Transfer*, features success factors from centralizing rental car facilities, or the Rental Car Center. The success factors include a collaborative and supportive team culture, generating team buy-in and participation, and defining a clear mission.

2.5 Research Gaps

As discussed, the research team categorized the reviewed resources based on high-level themes and subtopics in order to identify trends and knowledge gaps. After conducting the literature review and stakeholder outreach process, the research team identified several research gaps, which were organized into the following seven high-level themes: 1) Customer Service; 2) Integrating Advanced and Disruptive Technologies; 3) Project Management, Delivery and Finance Models; 4) Safety, Security and Terrorism; 5) Sustainability and Resilience of Infrastructure; 6) General Design and Construction, and; 7) Workforce Development.

Enhancing customer service and the passenger experience was an oft-cited priority of airport industry stakeholders interviewed for this project. As described by both ACI-NA in their "Airport Infrastructure Needs" report and the FAA in the 2017 NPIAS Report, there is significant terminal project work anticipated to occur in the industry over the next five years. As terminals are being built or renovated, airports expressed a need for information on how to accommodate passengers of all abilities, measure and improve the passenger experience, and integrating new technologies to improve the passenger experience.

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 significant gap regarding updating and integrated technologies at airports, for example in designing and monitoring smart buildings, integrating new technologies with older IT systems, and preparing for autonomous vehicles. Further, a gap was identified of resources intended to assist airports use available tools for enhancing revenue through the modernization of concessions, adapting to the current demographic of travelers, and gaining a better understanding of the passenger experience and how to influence it.

With the anticipated development over the next five years, another gap identified was guidance and information on project management and alternative project delivery mechanisms. Going beyond the traditional design-bid-build project delivery option is important for maintaining project schedules, improving coordination, staying within budget. More creative approaches also allow for collaborative decision making between the owner, designer, builder, and airport operations and maintenance staff after project handoff. Additionally, research that focuses on improved coordination across divisions and teams, improved staff development, and training with emerging technologies can help improve the overall design, construction and commissioning process.

Safety and security are always important topics for airports and a number of ideas were generated in these areas. The way airport operators, passengers and other stakeholders use space on both the landside and airside has changed significantly since 9/11. Unfortunately, airports are still the target of terrorist attacks and active shooters. Terminals designed and built decades ago were clearly not designed with today's security environment and passenger screening requirements in mind. Improvements are needed in the way that airports are designed and constructed to reflect this reality. Although much security research is undertaken by PARAS, there were several gaps identified during this process which are included on the roadmap.

Sustainability and resiliency are two issues that came up often in the course of the roadmap development. These issues have been addressed by ACRP through the Environment research field. In the near future, ACRP plans to begin development of an updated Environmental Research Roadmap. Thus the research team included only those issues that relate closely to design and construction such as guidance on selecting the most appropriate sustainable design rating system, and designing for net zero energy.

In addition, the stakeholder outreach process illustrated a widely recognized need for guidance on recruiting and retaining quality employees in the airport industry. Although not limited to design and construction, ensuring a consistent pipeline of talent is critical to the development, operation and growth of our nation's airport system.

2.6 Conclusion

Numerous resources and existing research projects were studied to complete the literature review component of the research roadmap development process. The bulk of the relevant resources came from ACRP, as expected. Although many of the topics raised by the research team and stakeholders thus far are covered in some way by prior research, some of the projects are several years old and technological advances may necessitate a second look. Sources and documents from the trade associations and FAA have served as references for ensuring that research ideas generated as part of this project are not duplicative and achieve some alignment with other 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 as additional sources were brought to our attention, they were added to the spreadsheet to accomplish a more robust review of literature and research.

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 design and construction. 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 30 outreach activities (webinars, interviews, meetings, teleconferences and conference presentations) to groups ranging in size from one to over 50 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 (OSPEM) 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 airport industry 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 70 individual research ideas through this process and from a review of existing IdeaHub entries. The research team consolidated this input and refined the high-level topics and specific subtopics. An additional layer

of organization was added in the Idea Matrix database at the highest organizational level as a result of stakeholder outreach. All research ideas are thus further categorized as aligning with one of three overarching industry and FAA goals: 1) customer / passenger travel experience; 2) safe and secure air transportation system; and 3) capacity enhancement and growth.

As previously discussed, the research team is also developing ACRP 11-02/Task 29, “Research Roadmap in the Area of Airport Operations and Maintenance”. Since both projects proceeded on a concurrent schedule, some of the stakeholder outreach was conducted for both projects simultaneously. This resulted in several benefits for the projects. First, in some cases the relevant stakeholders for each roadmap are the same individuals, and it was helpful to discuss both roadmaps at the same time. In particular, for smaller or general aviation airports, staff often are responsible for multiple duties and therefore could provide input on both roadmaps (whereas at larger airports typically have more specialized staff). Second, by holding discussions on both roadmaps simultaneously, the research team was able to identify those topics that are multi-dimensional and can provide benefits to different groups of airport stakeholders.

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 multiple ACRP research 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. Each research idea was given a score of one to four (with one being the least and four being the most) for each prioritization criteria described below (with the exception of the first criteria, where the idea either was or was not duplicative). If the research idea was determined to be duplicative of existing or ongoing research the idea was not included on the roadmap.

The scoring methodology was then applied to each research idea through a survey of Project Panel members. This process was used to determine the relative priority of ideas compared 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. The accompanying idea database provides a rank for each idea (indicated in column B). Ranks are from 1 (indicating the highest rank, or greatest priority) to 40 (lowest priority). Some ideas received the same prioritization score, and were thus assigned the same rank.

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

These criteria are based on what ACRP uses to prioritize submitted problem statements, and refers to whether or not the research idea is understandable and logical, and 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). For example, ACRP cannot make policy recommendations to federal agencies, so research ideas that would result in a recommendation to the FAA to change a regulation would not be implementable.

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 silos. 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 design and construction 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 design and construction 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. 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. In FAA's 2017 NPIAS report, the agency identified \$32.5 billion in AIP-eligible projects across the airport system between 2017 and 2021. ACI-NA forecasts an even larger amount of capital projects over the next five years, estimated to be closer to \$100 billion. After significant investment over the past decade in capacity projects and runway safety areas, the focus in design and construction at airports is shifting. The majority of airport investment over the next five years is forecasted to be for terminal projects (expansion, renovation, and rehabilitation), airfield pavement projects, bringing airports up to current design standards and surface access projects.^{7 8}

Against this backdrop, the seven high-level themes previously described were identified for airport design and construction research ideas, based on a comprehensive review of existing research and stakeholder outreach. Ideas are further categorized into twelve subtopics, including: 1) Passenger Experience; 2) Integrating Technology and Data; 3) Finance and Revenue Development; 4) Alternative Approaches to Project Delivery Mechanisms; 5) Sustainable Design and Construction; 6) Innovative Approaches to Security / TSA Operations; 7) Construction Best Practices / Guidance and Tools; 8) Modernizing and Retrofitting Airport Facilities; 9) Construction Materials; 10) Accommodating Changing Demographics; 11) Curbside, Roadways and Vehicles; 12) Unmanned Aerial Systems. Using both high-level themes and subtopics to organize the ideas reinforces the multi-dimensional nature of the research ideas and the need for collaboration.

Each high-level theme is described below with the list of research ideas categorized within that theme listed beneath. 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 Research Idea Database, Appendix C). Next to each research idea (in parentheses) is the corresponding subtopic.

The Research Idea Database contains more detailed background information about each idea, and allows users to sort and search based on a number of criteria, including: overarching industry and FAA goals; high-level theme; subtopic; keyword; existing and ongoing related research; and ACRP Idea Hub tag.

⁷ FAA National Plan of Integrated Airport Systems (2017-2021), September 2016. Accessed at https://www.faa.gov/airports/planning_capacity/npias/reports/media/NPIAS-Report-2017-2021-Narrative.pdf

⁸ ACI-NA, "Airport Infrastructure Needs: 2017 – 2021", March 2017. Accessed at: <http://aci-na.org/sites/default/files/2017infrastructureneedsstudy-web.pdf>

4.1 Customer Service



As reported by both ACI-NA and the FAA, the airport industry is experiencing an increased emphasis on design and construction of terminals and other occupied spaces. This turn is driving many airports to focus on customer and passenger experience. Many airports and designers described their goals, such as creating an airport environment that meets high passenger expectations, providing efficiencies for the operator and tenants, and maintaining a strict target value that keeps the project within budget. The rise of global industry service indicators, such as the Airport Council International's Airport Service Quality survey (ASQ) and the International Air Transport Association's (IATA) Level of Service (LoS) benchmark concept has resulted in many U.S. airports comparing themselves with foreign airports in a way that is influencing their design goals to improve customer service.

One potential flaw in using international benchmarks for U.S. airports is that international airports have very different funding and regulatory regimes, passenger characteristics and cultures. To that end, research on understanding passenger experience and how U.S. airports can influence it would be beneficial.

Finally, creating a "sense of place" has become a priority for many airports in the U.S., impacting decisions around airport design and budget. This not only impacts passenger experience and satisfaction but also revenue generation. The following is the list of ideas in this category on the roadmap.

- **Designing Airport Facilities for Aging Populations (*Subtopic: Accommodating Changing Demographics*)**– The number of Americans aged 65 and older is expected to double from 46 million today to over 98 million by 2060. As a result the design for aging air passengers continues to be discussed throughout the industry as airports and airlines grapple with the best way to accommodate these passengers, while providing an acceptable level of customer service. The objective of this research idea is to develop airport-specific design guidelines and best practices for serving an aging American demographic as well as understanding the concessions and customer service preferences of this demographic.
- **Restroom and Facility Design to Accommodate Travelers of All Abilities, Ages, Genders and Gender Identity (*Subtopic: Accommodating Changing Demographics*)** – The debate and shifting public opinion regarding issues of inclusivity for all people has resulted in a new way to look at public restroom facilities. Airport designers can take a new approach to designing restrooms that provide a non-discriminatory way for people who may not identify with their outward gender appearances to use facilities of their choosing. The objective of this research is to develop a comprehensive guidebook for airport designers, planners and consultants on best practices for restroom design to accommodate all traveling demographics. The guidebook should include information on how to design restrooms and ancillary facilities (such as changing rooms, showers, etc.) taking into account passengers of various ages, abilities, genders and gender identity, and families.
- **Accommodating Families in Crises – Preparing Passenger and Family Staging Areas (*Subtopic: Passenger Experience*)** – Airports deal with a variety of safety and security events such as accidents, terrorism, active shooter events, etc. They also serve as staging areas for disaster response. ACRP has conducted research on crisis and emergency communication and family assistance programs, but additional research is needed to develop guidelines, best practices and case studies on how to design and implement passenger and family staging areas/spaces in these cases. The objective is to develop design guidelines, best practices and case studies on designing passenger and family staging areas in the event of a safety or security event or disaster.
- **Defining, Measuring and Designing the Passenger Experience (*Subtopic: Passenger Experience*)** – The objective of this research is to determine an objective definition of exceptional passenger experience and

methods for delivering this experience, as well as determining strategies for airports to influence the passenger experience beyond the confines of the airport itself (i.e. before the journey starts, or once the passenger boards the plane). The research will also identify how the aviation industry can standardize and validate planning criteria guidelines for achieving the optimum level of service provided to passengers and customers (e.g. business aviation).

- **Maximizing Concessions and Non-Aeronautical Revenue (*Subtopic: Finance and Revenue Development*)** – Research and case studies on retail design options for maximizing and diversifying revenue as well as campus-wide non-aeronautical revenue generation are needed. These could include a discussion of optimal locations of concessions, optimal co-location of certain types of concessions, aesthetic design components, alternatives to traditional airport concessions (i.e. integrating more experiential offerings instead of just food, beverage and retail), and non-aeronautical redevelopment options. The objective of this research is to develop a guidebook and case studies on retail design options for maximizing and diversifying revenue, as well as campus-wide non-aeronautical revenue generation opportunities.
- **Guidebook for Aviation Symbol System & Guidelines (*Subtopic: Passenger Experience*)** – Research is needed to develop a universal Aviation Symbol and Nomenclature System for the airport/travel sector that is comprehensive, rigorously tested, and industry accepted. The research should produce guidelines for best use of this system in airports with a focus on campus-wide wayfinding. The process should be based on a global approach with U.S. airport application.
- **Designing for Data – The Foundation for Customer Service (*Subtopic: Integrating Technology Data*)** – As evidenced by the literature review and stakeholder interviews, a current focus of the airport industry is on improving customer service, facilitation and passenger experience. In today's highly connected world, the ability to personalize each passenger travel experience through their smart device is technologically feasible. However, research is needed to determine exactly what data is available, what can be used to determine passengers' needs and preferences, and how that data can be employed to improve the way passengers interact with the airport and airline(s). The research objective is to determine data availability for improving and tailoring customer service, facilitation and experience. This research would provide information on how airports can best utilize customer data to improve facility design and interaction between airport, airlines, and customer, while maintaining a high level of security.
- **How Airports Can Influence the Entire "Customer Experience" from Start to Finish (*Subtopic: Passenger Experience*)** – The customer or passenger experience has become a metric in how we look at and design airport terminals in the U.S. today. There are questions as to how to objectively apply this metric, both from terminal to terminal and from airport to airport, however only a small percentage of travelers' journeys take place at the airport. The "passenger experience" is influenced from the time of ticket purchase and continues until the passenger exits the destination airport. The question remains, how much of this experience is the airport able to influence? This research project would provide guidance on how airlines and airports can collaborate to create best in class customer experience, and identify those areas and initiatives where airports can make the greatest difference.
- **Creating a Sense of Place with Local Concessions (*Subtopic: Passenger Experience*)** – The airport industry is finding new ways to increase concessions revenue, including a recent trend towards integrating more local businesses, international products, or designs that direct 100% of passenger foot traffic through a concessions area. In addition, airports are beginning to incorporate concessions that offer experiential offerings (such as spas or gyms) as opposed to just food, beverage and retail offerings. The objective is to enable airports to find new ways to increase concessions revenue by developing and incorporating a "sense of place" into their design. The research should address strategies for airports to assess their ideal

mix of concession and service types, national brands and local flavor in a way that maximizes passenger participation and airport revenue.

4.2 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 design new 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.

Research is needed to help airports understand new and potentially disruptive technologies and services and how to adapt. One example of a disruptive technology that has forced airports to change is the growth of passenger ride sharing services such as Uber and Lyft. These services have changed how passengers choose to arrive and depart from airports in recent years. Ride sharing companies, or TNCs represent both an opportunity and a challenge for airports in ensuring that passengers have access to safe, efficient and convenient ground transportation options, while addressing the impact on parking revenue and curbside operations that these services have. Airports now have to consider the use of ride sharing services as they design (or redesign) passenger loading and unloading areas and parking facilities.

Other technology-focused topics that were frequently mentioned by stakeholders include BIM and the need to consider possibilities created by IoT enabled devices and components during the design phase of projects (for example to create operational and energy efficiency and enhanced security). Research ideas in this theme include:

- **Integrating TNCs into Ground Transportation Infrastructure (*Subtopic: Curbside, Roadways and Vehicles*)** – Transportation network companies, or TNCs have revolutionized ground transportation options for passengers traveling to and from airports. Airports have worked at the local level to integrate these services into the airport environment and ensure some cost and regulatory parity with other ground transportation service providers, such as taxis. However, research is needed to build off of ACRP Synthesis 84 to develop design guidelines and best practices for incorporating TNCs into ground transportation infrastructure, in addition to how airports can develop TNC user agreements and fee structures. The objective is to develop design guidelines and best practices for incorporating TNCs into ground transportation infrastructure, including TNC user agreements and fee structures to properly monetize airport infrastructure.
- **Plug-N-Play: Integrating New Technology into Older Infrastructure and Systems (*Subtopic: Modernizing and Retrofitting Airport Facilities*)** – 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 with aging systems and facilities. Research is needed on how to integrate new technologies into both old facilities and legacy software programs, as well as planning for technology integration into new projects (both new construction and renovation). The research objective is to identify strategies for integrating new technologies into existing facilities and seemingly incompatible software programs through a guidebook and case studies.
- **Smart Buildings: Performance Monitoring Systems and Centralizing Dashboards for Building Health and Resiliency (*Subtopic: Sustainable Design*)** – Research is needed to understand technology solutions for automatizing building systems and integrating with both new and various existing IT systems and software programs at airports. The benefits of building automation is well understood from an energy efficiency

and building comfort standpoint, however airports often find themselves with limited options depending on what hardware is in place. Research to help airports employ open-ended systems that can integrate with non-branded software with hardware for building automation would be helpful. The objective is to identify technology solutions for automatizing building systems and best practices for integrating these solutions into both new and existing IT systems and software programs at airports.

- **Airports and the Internet of Things (IoT): How Will New Technology and Business Models Impact the Revenue and Expense of Airports (*Subtopic: Finance and Revenue Development*)** – Buildings and systems are growing more sophisticated and able to connect to the internet, each other, and feed information to the airport for a number of purposes. The objective of this research is to build off the ongoing ACRP Project (01-33, “Preparing for the Connected Airport and the Internet of Things”) and develop guidance for airports to consider IoT networks and data utility specifically during the design of new or renovated airport facilities. Information on how decisions made on the front end (in design) can also help the airport achieve cost savings in operations and maintenance later, enhance revenue from concessions, and improve communications.
- **Passive to Active Monitoring Space: How to Retrofit for Smarter Buildings and Systems (*Subtopic: Modernizing and Retrofitting Airport Facilities*)** – Building and asset management systems are not new, but new technologies are becoming available to better monitor assets, components, systems, energy use, etc. Research is needed to understand how these new monitoring and sensing technologies can be incorporated into older buildings and systems (such as elevators, escalators, etc.). The objective is to determine how airport facilities/buildings/systems can be retrofitted to integrate monitoring and sensing technologies into existing IT systems, or through building and asset management systems. In addition information on savings that can be associated with building and system retrofits would be useful. This idea could be a stand-alone project or combined with either the “Plug and Play” of “Smart Buildings” research ideas within this theme.
- **Airfield Design Guidelines for Unmanned Aerial Vehicles (*Subtopic: Unmanned Aerial Systems*)** – Current standards for airport design are mainly based on collision and excursion risk models developed for manned aircraft, and it is unclear if Unmanned Aerial Vehicles (UAVs) are following the same rules. Questions remain for the airport industry regarding the standards and needs of aviation facilities designed for UAV use, for example if such facilities should be based on the same acceptable levels of risk for manned aircraft. UAV landing and takeoff requirements may be different than manned aircraft as well. The objective of this research is to develop a guidebook for designing airfield infrastructure and facilities to safely and efficiently meet the unique operational requirements of UAVs of various sizes and configurations.
- **Infrastructure for Autonomous Vehicles (*Subtopic: Curbside, Roadways and Vehicles*)** – As autonomous vehicles arrive at the airport, on both the landside and airside, airports will need to understand their operations, what infrastructure and technology is needed to enhance the effectiveness and ensure the safety of autonomous vehicles, and how to quantify the benefits. The objective is to provide information on the impending use of autonomous vehicles on both the landside and airside at airports, including infrastructure considerations, methods for integrating new technology into existing IT systems, strategies to ensure effective and safe autonomous vehicle systems, and methods for deployment as well as quantifying environmental and customer service benefits.

4.3 Project Management, Delivery and Finance Models



Technological developments are not only impacting airport design decisions, passenger expectations, and revenue generation, but also the options for project delivery. The traditional model for construction contracts has been “design-bid-build”. In this type of scenario, the design is completed by a design professional, contractors bid on the project, and the project owner (i.e. the airport) selects the contractor based on their own criteria (such as cost or other factors).

Airports interviewed for this project expressed interest in alternatives to that traditional formula, for reasons such as funding availability, complex scheduling requirements, an evolution in the way that design and construction firms work together, and a shift towards more collaborative decision making (CDM) across airport functions.

Newer models include the Construction Manager at Risk (CMR or CM@R) or Design-Build delivery mechanisms. These types of delivery mechanisms are gaining in popularity since in theory they compress the time it takes to produce and build projects, while simultaneously maintaining construction cost certainty. Another model is a hybrid approach combining elements of CMR and Design/Build. This hybrid approach gives the client greater access to the design professional during the design phase of the contract while maintaining the efficiency of the early involvement of the builder. In some ways, this is the process typically contained within the “Special Purpose Vehicle” of Public-Private Partnerships (PPPs or P3s).

Yet another project delivery model is termed “Integrated Project Delivery” (IPD), whereby the owner, design professional and the builder all share risk and reward in a contract designed to promote collaboration and reward innovation. Lastly, “Progressive-Design-Build” (PDB) is another alternative, and as the name implies, PDB is a progressive process, and typically uses a qualifications based selection. This is followed by an iterative design and budgeting process and negotiation of contract price. Some states have restrictions on these type of project delivery mechanisms, and the alternative approaches are still relatively new to the airport industry.

These changes are causing design and construction companies to innovate on project delivery mechanisms. They are enabling airport staff and management to engage in a more collaborative manner to achieve efficiencies. As project delivery and financing mechanisms evolve over time, and technology continues to advance at an accelerated rate, project management approaches must keep pace. Developing, maintaining and updating successful airport project management processes are not new challenges, and ACRP has looked at similar topics in the past. However changes in the industry warrant a renewed focus on these topics.

Identified research ideas in the Project Management, Delivery and Financing category include:

- **Best Practice Guidance on Modernizing Existing Aging Facilities with Limited Budgets (Subtopic: *Modernizing and Retrofitting Airport Facilities*)** – In the face of budget constraints and the need for updated facilities, research would seek to develop guidance and best practices to identify the most appropriate updates to aging airport facilities, including guidance on selecting and implementing the least cost - highest impact initiatives for airports. The guidance should be broad and sufficiently flexible to help airports select the most important criteria for their unique facilities.
- **Alternative FAA Funding Mechanisms for Grants: Beyond Design-Bid-Build (Subtopic: *Alternative Approaches to Project Delivery Mechanisms*)** – Some airports have successfully utilized alternative project delivery methods for AIP funded projects beyond the standard design-bid-build delivery model. Research is needed to educate airports, consultants, and regulators about successful alternative delivery models. The objective is to develop a synthesis of case studies in which airports have completed projects funded through FAA AIP grants that successfully utilize alternative delivery methods while meeting regulatory requirements.

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- **Alternative Delivery Methods – Replacing Design, Bid, and Build (Subtopic: Alternative Approaches to Project Delivery Mechanisms)** – Design-bid-build is a traditional project delivery mechanism in use in the airport industry, but interest is growing in project delivery models, such as Design-Build (DB), CMR (CM at risk), and PDB. Some states have restrictions on these type of project delivery mechanisms, and the alternative approaches are still relatively new to the airport industry. Research would provide a primer on these alternative delivery methods, including guidance on strategies for selecting the most appropriate method based on project needs, laying out pros/cons, and presenting successful case studies.
 - **Guidebook on Project Delivery and Construction: How to Successfully Manage Construction Projects (Subtopic: Alternative Approaches to Project Delivery Mechanisms)** – There is significant interest in the airport community regarding new and evolving project delivery methods, but there lacks a guidebook on construction project delivery methods and contracting issues for airport staff, particularly small and GA airports. FAA resources on overall construction management are limited and the joint ACC/FAA best practices guide dates back to 2008. The objective is to develop a guidebook on selecting the most appropriate construction project delivery methods for airports, with a particular focus on small and GA airports. The research should contain educational materials on contract negotiations as well.
 - **Determining the Best Financing Approach for Your Project (Subtopic: Alternative Approaches to Project Delivery Mechanisms)** – In the face of decreasing AIP funding despite increasing costs for airport design and construction projects, and with Congress' failure to raise the Passenger Facility Charge cap, airports have to consider alternative financing options for their capital projects. Public-Private Partnerships have been of great interest to the airport industry for several years, but there has only been one successful airport-wide P3 arrangement to date, in San Juan PR. More frequently, P3 projects at airports are on a facility level, for example a terminal, parking garage, or CONRAC. The objective is to develop guidance for airports whom are considering alternative financing options for their capital projects, including P3s and other options.
 - **Consistent Planning of Complex Construction Projects: Guidance and Best Practices (Subtopic: General Guidance/ Implementation Tools)** – Although the industry is focusing more on greater collaboration between stakeholders in complex construction projects, there is no comprehensive resource for executing these projects in a repeatable way. There is a need to develop comprehensive planning and phasing guidance, to include at a minimum, the definition of necessary participants and their roles in construction planning.
 - **Applying Dynamic Network Analysis to Improve Collaboration on Airport Construction Projects (Subtopic: Integrating Technology, Data)** – Research is needed on existing and emerging technologies that can better foster cross-departmental and organizational communication and collaboration, especially in construction projects during delivery. Research would explore how the airport industry can employ technologies such as social network analysis and artificial intelligence to provide real-time feedback on communication networks and collaboration (who is communicating with whom, about what, how often). The data can be used to determine if the right stakeholders are involved in decision making to meet project/organizational goals, and if not, what corrections are needed. The ultimate objective of employing these technologies is to enhance collaboration to better meet project and organizational goals, timelines, budgets etc. and work more effectively across divisions.

4.4 Safety and Security



The way airport operators, passengers and other stakeholders (such as TSA, airlines, other tenants) use space in and around airports today has changed dramatically over the past 10 years. Terminals designed and built decades ago were clearly not designed to accommodate post 9/11 passenger screening requirements or with rapidly evolving security threats in mind. Many screening areas are not configured to process passengers efficiently. These areas often lack sufficient space to accommodate current volumes of passengers and carry-on luggage, leading to longer security lines and wait times. Long wait times can impact the passenger experience, therefore improvements to airport screening areas represent opportunities for enhancing not only the security of airport facilities but also customer experience.

In addition to creating inefficiencies and delays, the long passenger queues caused by inadequate screening areas present an increased security risk in that they become unintended “soft targets” for potential terrorist attacks (i.e. large groups of people congregating without quick emergency exit routes). When active shooter or other terrorist incidents occur, a common airport response is to secure the entire landside terminal. While this response provides a secure terminal for travelers, it also results in a relocation of the passenger queue to a different area of the airport without eliminating the soft target. Passengers may be forced to self-evacuate, scattering to all areas of the airport, both landside and airside, creating additional safety and security concerns.

Airport stakeholders reported an interest in design and technology solutions to eliminate long queues, such as the implementation of remote baggage check-in, as well as the continued evolution of risk based screening to focus the most energy on the most likely targets.

Ensuring a safe and secure air transportation system is paramount for the FAA and industry stakeholders, and is one of the main overarching themes guiding FAA research, as described in the NARP. While the Program for Applied Research in Airport Security (PARAS) focuses exclusively on security problems faced by airport operators, some research ideas identified during the stakeholder engagement process are appropriate for ACRP funding. These include the following specific ideas, listed from higher to lower priority:

- **Passive Screening as a Pre-Checkpoint Risk Based Screening Tool (Subtopic: Innovative Approaches to Security/ TSA Operations)** – Airports continue to be an enticing target for individuals and organizations intent on doing harm to a large amount of people in a very short time. While airports have secured the airside of the terminal, the landside portion of the terminal continues to provide a target-rich environment for those intending to do harm. The objective of this research is to determine how airports can utilize active and passive security screening systems as a pre-checkpoint tool to identify security risks prior to entering the secured portion of the airport facility in order to protect the general public from harm as a result of terrorism.
- **Data Security for Airport Building Information Management Systems (Subtopic: Integrating Technology, Data)** – In order for facilities and maintenance Building Information Management (BIM) to be valuable, two-way data exchange is necessary so that data can be pushed out to tablets, phones, devices in the field in real time. However, this raises data security challenges since exchanges occur across stakeholder file servers and systems. Cloud Computing provides a common “file server” that allow access for multiple stakeholders, however airports are restricted from using cloud-based applications that do not satisfy GSA data security requirements. Research is needed to address the issue of data security for airport BIM systems and guidance on how to secure data across these applications while satisfying GSA data security requirements.

- **Airport Terminal Design for Protection during Active Shooter Events (Subtopic: Innovative Approaches to Security/ TSA Operations)** – Research is needed to develop terminal design guidelines specifically for protection during an active shooter or other terrorism event. Guidance should include the design and construction of barriers or places where passengers and staff can hide/ protect themselves from the security threat. This would include the pros and cons of such designs, for example consideration of how an active shooter could use such design features for their benefit.
- **Reducing Impediments to Remote Baggage Check-In (Subtopic: Integrating Technology, Data)** – There is an opportunity to provide a higher level customer service if remote baggage check-in options are explored. Research to examine chain of custody issues is needed; if there is a remote check-in and remote screening of bags then theoretically all bags introduced into the system will be secured, so it shouldn't matter who is checking it in. Under the current scenario, baggage check needs to be completed with an ID check. Research would examine the feasibility and security of remote baggage check-in and screening, and if feasible, how airports might begin to implement it. Research is also needed to develop industry understanding of what the future of baggage check-in might look like with the adoption of biometrics.
- **Implementation of Access Control in Cargo Facilities (Subtopic: Innovative Approaches to Security/ TSA Operations)** – Those seeking to create harm and disruption in our nation's air travel system are constantly trying to access critical infrastructure, especially airports. Airport cargo facilities are vulnerable to breaches, as often the facility operator is responsible for securing the premises and standards are not uniformly stringent. Research is needed to examine procedures, technologies, processes and practices for better securing access to airport cargo facilities to only authorized users.
- **Business Case for a Consolidated Distribution Facility: A Centralized Trucking Facility to Streamline Security in Landside and Airside Supply Delivery (Subtopic: Innovative Approaches to Security/ TSA Operations)** – Constructing consolidated distribution facilities at airports provides an opportunity for increased safety, security, environmental, and operational efficiency. Examples include reducing the number of people that need access to secure spaces, removing vehicles from other parts of the airport, and offering a more controlled environment for inspections. Research is needed to develop a compendium of business case studies to determine how to best construct and implement consolidated distribution facilities to allow for streamlined security on both landside and airside supply delivery. The case studies would examine costs and benefits as well as key considerations for airports as they decide whether to develop a centralized distribution facility.

It should be noted that a number of participants in the stakeholder outreach process identified the need for research on design and construction to minimize landside “soft targets”. This research is currently being undertaken by PARAS, and was therefore not included on the roadmap at this time. It is possible that the PARAS report could identify follow-on research topics, or raise new questions that could be addressed with further research from either PARAS or ACRP.

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 design and construction.

Climate change and extreme weather are two challenges within this issue area that airports currently face. For example, airports on both coasts must consider the risks to their infrastructure posed by sea level rise and storm

surges. In addition, airports all over the country have to consider changing precipitation patterns (type, intensity and frequency), greater temperature swings, droughts, flooding and other extreme weather. Infrastructure that was designed to withstand a 100-year storm using historical data may now be exposed a similar level of extreme weather more frequently, and as a result may not be equipped to withstand changing conditions and stressors. 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.

In addition to funding constraints, airports may also be faced with natural resource constraints, or expectations from their community to operate in a less impactful manner, or regulatory requirements to meet certain building standards, such as the U.S. Green Building Council's LEED rating system. In recent years the FAA has provided grant funding for sustainable management and master plans, which has also driven interest in these topics.

Sustainability rating systems continue to evolve as well, for example the Institute for Sustainable Infrastructure's Envision rating system for infrastructure, the USGBC's rating systems such as WELL (a certification system designed for the built environment focusing on occupants health and well-being) and Parksmart (a program of sustainable practices in parking structure management and design).

For airports that have not developed their own sustainability programs or management plans, it can be challenging to know where to start, and what initiatives or programs are right for their facilities. 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, or to understand how far they can go in the realm of sustainable design. Some airports have set ambitious goals to build "net zero" facilities (for example using less energy than they generate, or creating zero waste). While advances in technology are making these previously unattainable goals more realistic, there is still a need to understand what is possible given limited resources.

This issue area 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:

- **Designing Resilient Infrastructure for an Uncertain Future: When a 100 Year Storm Occurs Every Decade (*Subtopic: Sustainable Design*)** – A number of airports have recognized the importance of developing updated design guidelines that account for risks related to climate change, in order to increase infrastructure resiliency. The research could include guidance for airports to justify the expense of designing infrastructure intended to withstand future storms and demonstrate they are not "over-designing" for purposes of obtaining AIP grants. The objective is to provide guidance for developing airport design guidelines that take climate change into account in the face of increased frequency of extreme weather events and changing weather patterns, including strategies for justifying expenses related to resilient infrastructure.
- **Subsurface Drainage System Benefits in Airport Pavement Performance (*Subtopic: Construction materials*)** – Research is needed to evaluate the effectiveness of subsurface drainage configurations by investigating field performance of airport pavements with and without drainage features, including quantifying the cost and benefits of including subsurface drainage by comparing any potential extension in service-life with increased construction and maintenance costs. Research would include recommendations of subsurface material properties and the FAARFIELD implementation. The objective is to synthesize best practices and evaluate the effectiveness and benefits of subsurface drainage systems for airport pavement including cost-benefit analysis.
- **The Costs and Benefits of Designing for Net Zero Energy (*Subtopic: Finance and Revenue Development*)** – Some airports are setting goals for new facilities to be net zero - that is the average annual energy consumption for the building to operate is equal to the amount of energy produced on site (or in some definitions, renewable energy produced offsite but 'owned' by the airport). Research would identify

examples in other industries and facilities that have similar characteristics to airport buildings in order to provide an overview of the level of effort, design techniques, trade-offs, and cost-benefit analysis required to achieve net zero energy.

- **Net Zero Greenfield versus Net Zero Brownfield – Examining Feasible Outcomes (*Subtopic: Sustainable Design*)** – Net Zero energy buildings consume less energy than they create on an average annual basis. Research is needed to better understand and develop guidance for implementation of both technology and materials currently available for achieving net zero applicable for both new and existing airport facilities. This guidance should take into account both state and local regulations and limitations.
- **Selecting and Implementing the Right Certification or Rating System (*Subtopic: Sustainable Design*)** – Existing sustainability rating and certification systems are consistently updated (e.g. LEED for campus / multiple buildings, EPA Energy Star) and newer sustainability rating systems are emerging (e.g. Envision, PEER, WELL). States often have their own guidance and requirements as well. The objective is to produce guidance for selecting and implementing the most applicable sustainability certification or rating system for airport projects / facilities.

4.6 General Design and Construction



While the topics described above sort research ideas into high-level categories and subtopics, several research ideas generated during the roadmap development did not fit neatly into one of these categories. These remaining ideas have merit and practical application in the area of airport design and construction, and were thus included under a separate, general category of research. This general category of research topics includes:

- **Best Practices for Developing Airport Construction "After Action" Reports (*Subtopic: Construction Best Practices, Guidance and Tools*)** – Airport construction projects of all sizes take considerable planning and preparation. Once a project is complete there are varying levels of effort made to capture valuable lessons learned to aide in future project planning. Airports that have developed "after action" reports are able to use them as a resource for improving the processes of future projects and educating new employees. The objective is to develop a synthesis of best practices from both within and beyond the airport industry on developing "after action" reports for construction projects. The research can include information on how to develop these reports, key elements and how they are best utilized.
- **Improving Awareness of Airport Construction Projects: Construction Clearinghouse (*Subtopic: Construction Best Practices, Guidance and Tools*)** – The idea for an airport construction clearinghouse came from RTCA's Tactical Operations Committee Report in 2016, titled "Improving Awareness, Planning and Execution of Airport Construction". According to the report, there is a need for "standardization related to construction planning and notification". The report identified a construction clearinghouse as a solution, providing an online resource accessible to various airport and airline operator stakeholders. The clearinghouse would serve as a database for all planned construction projects that could impact airline operators, and would send an alert out to users when a project is entered so affected stakeholders can engage with the airport to learn more about the project. The objective is to develop an airport construction clearinghouse to allow for standardized construction planning and notification through an online database containing all planned construction projects.
- **Costs and Consequences of Procurement Delays (*Subtopic: Finance and Revenue Development*)** – Delays in contracting and procurement can have significant impact on project budgets and timelines. The full consequences of procurement delays are not well understood and as a result, solutions to the underlying causes of delays have not been systematically identified. Research is needed to show cost impacts and the

range of consequences for contracting and procurement delays, to provide guidance for airports to quantify the impact of the delays in terms of cost, and to deliver strategies for reducing or eliminating delays. The research would have multiple objectives depending on the audience (i.e. airport executives, staff, local government, etc.).

- **Guidebook on the Selection, Application and Tracking of Building Materials for Airport Construction Projects (Subtopic: Construction Materials)** – A comprehensive resource is needed for architects, interior designers, engineers, builders and airport operators to better enable selection of materials for new construction or renovation of existing facilities. The research will also examine and evaluate tracking technologies for materials. The guidebook should also provide information to airport operators and designers on how to evaluate life-cycle cost implications of selecting different building materials.

4.7 Workforce Development



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 the airport industry. In addition to developing a pipeline of new talent to the field, organizations may need to train and develop their existing workforce to adapt to new technologies. While this subject is not limited to design and construction, workforce development is a challenge that came up frequently during stakeholder outreach, and is therefore included on the roadmap despite the existence of an ACRP research field of Human Resources.

- **Guidebook on Professional Development and Retention: How to Retain Great Employees (Subtopic: General Guidance/ Implementation Tools)** – Attrition, workforce development, and growing the next generation of airport leaders is a critical issue for airports of all sizes and all departments within airports. Along with many other industries, 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. Guidance is needed to attract, retain, and train new and existing employees in airport design and construction, including professional development best practices. The research can build off of prior ACRP guidance on this topic.
- **Integrating Advanced Digital Technologies into Staff Development Programs (Subtopic: Integrating Technology, Data)** – With the increased adoption of advanced technologies in the airport environment, from building automation to modeling systems, connected system components, autonomous vehicles, etc., airport personnel need to be trained to effectively use these technologies and understand their capabilities in order to gain the most benefit from investment. Research is needed to produce training materials for airport staff that are not information technology experts in how to use a range of technologies. The objective is to produce training guidance for integrating advanced digital technology training into staff development programs.

5 Conclusion

During the roadmap development process, it was clear that enhancing customer and passenger service, as well as preparing for and integrating new technologies were reoccurring themes raised by stakeholders. Often the two topics are interrelated, such as how to mine data to individualize customer service, or using technology to build more comfortable, efficient and resilient buildings and infrastructure. The rise of connected devices, systems and individual components into integrated building management systems, i.e. the Internet of Things is continuing to expand as well. Airports will need guidance on how to effectively select and integrated these new technologies during the design and construction process, but also with the future use, operation and maintenance of airport facilities in mind. Adapting to new and disruptive technologies will require airport professionals to take a collaborative approach, 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 design and construction for improved project delivery, creating a better passenger experience, enhancing security and safety, and building 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 airport design and construction. However it does represent the industry's understanding of the challenges that exist today, 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.

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
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 visual Design and Construction Research Roadmap is interactive and designed to be viewed on the web. The interactive roadmap is available on ACRP's website. The following page depicts a static version of the visual roadmap.

- The roadmap depicts the 40 research ideas organized by high-level theme (timeline is on the x-axis going from the present on the left-hand side, to 5 years out on the right-hand side).
- Research ideas are placed along the five-year timeline in relative order, based on the idea's overall prioritization score (in other words, the timeline is not meant to be exact. Rather the ideas placed closer to the left represent those with higher prioritization scores).
- Each idea is represented by an icon, which corresponds to one of the seven high-level themes.
- Each idea is also represented by a color, which corresponds to one of the twelve subtopics.
- To read the research idea title, objective and background information, hover the cursor over an icon on the interactive version of the roadmap. A window with this information will appear.
- To display only the research ideas in a particular subtopic, click on the subtopic in the key at the top of the roadmap.
- To display only the research ideas categorized in a particular high-level theme, click on the theme name in the left-hand column.



Appendix C – Research Ideas Database

To find the Research Ideas Database, go to the TRB website (www.trb.org) and search for *ACRP Web-Only Document 40: Airport Design and Construction Narrative Research Roadmap*.